for Information Technology—

Geographic Information Framework – Data Content Standards For Hydrography

American National Standard
for Information Technology

Geographic Information Framework Data Content Standards For Hydrography

(Part XXX)

April 3, 2003

Secretariat
INFORMATION TECHNOLOGY INDUSTRY COUNCIL
Approved
MONTH/YEAR

American National Standards Institute

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Published by:
Information Technology Industry Council
1250 Eye Street NW, Suite 200
Washington, DC 20005
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www.itic.org

Note to Commenters: Although this working draft is presented as a stand-alone standard in ANSI format, it is intended to become part of a single, harmonized NSDI Framework Data Content Standard. In all, five transportation subthemes and seven Framework themes will be harmonized into one standard for presentation to the International Committee on Information Technology Standards, Geographic Information Systems [1]. Structural and formatting changes are likely to occur to this and other working drafts during the harmonization process. While editorial comments are very welcome on this and any working draft, standards' development would benefit most, at this time, from comments on scientific and technical issues. The single, harmonized draft will also be made available for public review and comment. To comment on working drafts, please use the Microsoft Excel spreadsheet located at http://www.geo-one-stop.gov/Standards/index.html. Only comments received in this format will be considered. You can email comments to GeospatialComments@geo-one-stop.gov., or mail them to the following address:

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Foreword

NB: Although this working draft is presented as a stand-alone standard in ANSI format, it is intended to become part of a single, harmonized Geospatial One-Stop data standard. In all, five transportation subthemes and seven Framework themes will be harmonized into one standard for presentation to the InterNational Committee on Information Technology Standards, Geographic Information Systems[1]*. Structural and formatting changes are likely to occur to this and other working drafts during the harmonization process. While editorial comments are very welcome on this and any working draft, Geospatial One-Stop would benefit most, at this time, from comments on scientific and technical issues. The single, harmonized draft will also be made available for public review and comment.*

The primary purpose of this draft is to support the exchange of surface water (hydrography) information. This standard also seeks to establish a common baseline for the semantic content of hydrographic databases for public agencies and private enterprises. It seeks to decrease the costs and simplify the exchange of hydrography data among local, tribal, state, and federal users and producers. That, in turn, discourages duplicative data collection. Benefits of adopting the standard also include the long-term improvement of the geospatial hydrography data through the establishment of Web data services for hydrography data and maps within the community.

This standard has been developed to fulfill one of the objectives of the National Spatial Data Infrastructure (NSDI) – to create common geographic base data for seven critical data themes, known as Framework data, reflecting their critical importance as geographic infrastructure. This standard is intended to support the data standardization needs of both the Geospatial One Stop e-government initiative and various homeland security activities to realize the goals and objectives of the NSDI in information exchange.

This standard proposed is for the exchange of hydrography data. Framework hydrography describes the geographic locations, interconnectedness, and characteristics of features in the surface water system. The hydrography system includes physical and logical components representing the flow and presence of water within the surface water portion of the environment. This Standard, and the model included therein, is a result of contributions from a variety of information and systems models. These include: the National Hydrography Dataset (NHD), the Pacific Northwest Framework (PNW), the ArcHydro data model, and the Geographic Names Information System (GNIS). The development of a shared database would be accomplished through "alliances" of data providers.

The Hydrography Modeling Advisory Team (MAT) had the following contributing individuals and organizations:

Ken Adee, U.S. Forest Service
Erika Boghici, Texas Strategic Mapping Program
Steve Davis, GeoDigial Mapping

[1] See the diagram, "Nested Relationship of Geospatial One-Stop Standard Harmonization" at the end of this document.

Chetan Desai, ProLogic
Cindy McKay, Horizon Systems (for U.S. Environmental Protection Agency)
Doug Nebert, Federal Geographic Data Committee
Barbara Poore, U.S. Geological Survey
Brian Sanborn, U.S. Forest Service
Dan Wickwire, U.S. Bureau of Land Management
Paul Wiese, U.S. Geological Survey

American National Standard for Information Technology
Geographic Information Framework
Data Content Standards
(ANS X.X.X2002)

1 Background

Based on two months of online discussions and its work at its November 2001 meeting, the Hydrography Modeling Advisory Team agreed on the following five problem statements pertaining to the lack of an agreed upon hydro content standard. A summary of discussions about the meaning of each statement follows.

- Duplication of data and application development;
- Complications exchanging hydro Framework data and related information;
- Difficulties integrating data;
- Poor framework/support for analytic activities; and
- Difficulties managing multiple representations of features.

Minimizing Duplication Of Data and Application Development

Duplication of data and application development refers to duplicative efforts required, in the absence of a content standard, to store and manage data and develop applications for their use. Parties sharing data who add, edit, or remove features from base data, for example, can be forced to manage duplicate datasets because no dataset conforms to a standard and because there is no agreed upon protocol for replacing or archiving datasets as they are amended. Similarly, applications can be developed and re-developed to meet the same business needs as data models change.

Simplifying Exchange of Hydro Framework Data And Related Information

The original wording of this objective used the term "share" instead of "exchange." "Share" was thought to refer to the institutional arrangements and attendant administrative issues required for organizations to provide one another with data. This meaning was deemed outside this draft's scope, although perhaps appropriate for an informative annex. "Co-managing" (e.g. managed by more than one party) was similarly considered for discussion in this standard. Because of the significant maintenance arrangements it implies, this topic should be handled as the subject of a separate document. "Exchange" was selected because it was thought to convey the central meanings of giving, taking, and replacing data between individuals *or* systems.

The phrase "related information" was also added to the original wording to cover situations when hydro data users exchange fish data, environmental information, point sampling locations, protected status, etc. along with base hydrography data.

Overcoming Difficulties in Integrating Data

The MAT identified four possible meanings of "integrating" which should be addressed by this draft:

- Overlapping data of similar content;
- Processing adjacent data;
- Handling or arbitrating different scale data; and
- Conflation.

It was agreed that to make the data model extensible, this draft should tie attribution to an identifier. The measure of this objective would be whether or not users can understand and use the resultant data.

Improve Support For Analytic Activities

The MAT clarified the meaning of this objective as supporting critical uses and meeting the business needs of managers for decision making. By contrast to the other objectives, this objective is broader than objectives pertaining to data and datasets, per se.
Participants noted that measuring this objective will be difficult because a standard's capacity to support analytic activities depends on and varies with data and business needs. It is also important to note that users' business and decision making needs are too varied and numerous to be equally supported by this draft. The goal of the Framework standardization activity is to identify the *intersection* of information content for exchange that is universally useful within a community. Based on this approach as opposed to a *union* approach, this draft can reasonably be expected to support certain common business and decision-making needs, but not all possible needs.

Difficulties Managing Multiple Representations Of Features

The MAT discussed requirements of Framework data for managing multiple representations and data lineage. It was agreed that a Framework model should differentiate data states induced by changes over time, scale, or information content. The Standard should not require that all versions be available, but a user should be able to know what version of data they're exchanging.

2 Scope of this Standard

The goal of the Hydrography Framework data content standard is to provide common definitions and syntax to enable collaborative development, use, and exchange of hydrography data. This standard defines the components of networked and non-networked surface water features, one of seven NSDI Framework themes. The primary purpose of the standard is to support the exchange of hydrographic feature and network information. It is the intent of the standard to set a common baseline of information content for exchange within the hydrographic community that will enhance data sharing and applications development when used with standards-based Web services or file transfer.

The major part of this Standard describes an abstract or conceptual model of hydrographic information content, expressed in the Unified Modeling Language (UML). This is not a database model; it describes the common content and structures that could be exchanged between members of the hydrography community. Implementation of the abstract model in specific computing or encoding environments is described in Annexes to this draft. Through these implementation Annexes, syntactic conformance to the standard can be tested.

The determination of "best-available" hydrography data depends on the usage or organizational requirements and is thus not addressed by the Standard. It is anticipated that multiple representations of hydrographic features will exist within the broader community. Policies have been or will be established for describing, maintaining, and exchanging the various representations of Features within specific application communities, such as the NHD. This draft will accommodate the exchange of these multiple representations.

This Standard describes a recognized set of Feature types and their definitions, attributes, and relationships and guidance on appropriate metadata for hydrographic information. The scope of this standard is intended to be applicable at a variety of scales. The use of UML and abstract modeling concepts allows this draft to be technology independent but permits current and future implementation cases that can be derived from the UML model. This draft permits multiple representations of features within the same feature namespace authority.

While collection criteria could be linked to each feature to give some guidance as to quality characteristics, this draft does not specify the criteria by which each feature would be captured (see capture conditions in definitions). Building on the intention to define common community Framework content, this draft defines a data content model for the exchange of agreed-upon thematic data, rather than the endorsement of a particular native database content design. This draft supports the mapping and conversion of native data in any format into a common representation for exchange over the Web or as files.

The audience of this Standard includes hydrography data users, maintainers, and distributors. The content is intended to support the requirements of natural resource managers, environmental and water resources agencies, and hydrography applications designers and developers. Specific guidance on the implementation of this Standard for specific user communities will be made through external guidance or policy documents.

This standard applies to Framework hydrography data produced or disseminated by any organization participating in the National Spatial Data Infrastructure (NSDI). For federal government agencies, Executive Order 12906, [12] states "…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 Federal Geographic Data Committee (FGDC) process." Office of Management and Budget (OMB) Circular A-16 similarly calls for coordination of geographic data activities and assigns lead responsibilities for certain data themes. OMB Circular A-119 requires the participation of federal organizations in open voluntary consensus standards bodies, such as the American National

Standards Institute. Once adopted by the FGDC, ANSI standards must be implemented by federal agencies.

This standard reflects the requirements identified by the Hydrography MAT, whose members are listed in the Foreword.

3 Normative References

The following standards contain provisions, which through reference in this text constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

[1] FGDC-STD-001-1998, *Content Standard for Digital Geospatial Metadata (version 2.0)*.

[2] FGDC-STD-007.1-1998, *Geospatial Positioning Accuracy Standard, Part 1, Reporting Methodology*.

[3] FGDC-STD-007.3-1998, *Geospatial Positioning Accuracy Standard, Part 3, National Standard for Spatial Data Accuracy*.

[4] FGDC-STD-007.4-2002, *Geospatial Positioning Accuracy Standard, Part 4: Architecture, Engineering Construction, and Facilities Management*.

[5] INCITS 353:2001, *Spatial Data Standard for Facilities, Infrastructure, and Environment*.

[6] ISO 19107, *Geographic Information—Spatial Schema*.

[7] ISO 19109, *Geographic Information—Rules for Application Schema*.

[8] ISO 19110, *Geographic Information—Feature Cataloging Methodology*.

[9] ISO 19111, *Geographic Information—Spatial Referencing by Coordinates*.

[10] ISO 19115, *Geographic Information—Metadata.*

[11] ISO 19135, *Geographic Information—Geography Markup Language*

[12] Executive Order 12906, 1994, *Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure*

[13] Geography Markup Language (GML) v1.0, OGC Document Number: 00-029, 12-May-2000

4 Definitions

Definitions applicable to this standard are listed below.

Attribute: A characteristic of a **feature**. Examples: A stream feature may have an attribute of intermittent or perennial and a lake may have a name attribute of 'Walden Pond'.

Area Event: An **event** that is represented as a **polygon.** The representation of the area event may be specified using **polygon** that overlays a portion of an area **feature**. An area event carries an attribute that specifies the **permanent identifier** of the **feature** to which it is associated. Example: An identified "bay" feature within a larger "sea/ocean" feature.

Area Feature: A **feature** that is represented as a **polygon** or series of polygons**.**

Capture Conditions: Conditions a feature must meet in terms of measurement or other characteristics before it is collected and stored in a dataset (e.g. a headwater stream collected for a 1:100,000 scale dataset is at least 1 mile long, a lake collected for a 1:100,000 scale dataset is at least 6 acres, etc.)

Collection Criteria: See Capture Conditions

Composite Feature: A collection of one or more **elemental features** having **attributes**, **relationships** and **events** that are independent of the attributes, relationships and events of the composing features. A composite feature inherits its geometry from the feature(s) that compose it. This is nominally equivalent to the OGC term "Feature Collection." Examples: **reach, watercourse**.

Elemental Feature: A feature instance of a particular **feature type** that has **geometry** and may have **attributes**, **relationships,** and **events.**

Entity: Something that has separate and distinct existence and objective or conceptual reality. This is a UML modeling concept illustrated as a box with a name.

Event: A designation of a part of an **elemental feature** or **composite feature** for which common properties are defined. The location of an event is represented by some portion of the geometry of the feature. See also **Point Event**, **Linear Event**, and **Area Event**.

Feature: Real-world or recognizable object that is implemented as an **elemental** or **composite feature**. In Hydrography, the emphasis is on features that contain water especially features that are components of the surface water network, however other related features such as dams, shorelines, etc. are often also considered hydrographic features. See also **Area Feature**, **Linear Feature**, and **Point Feature**. Modeled as HydroFeature.

Feature Code: A numeric value used that encodes the unique combination of **feature type** and a set of feature **attribute** values. This five-digit code has two parts: the first three digits encode the feature type; the last two digits encode values for a set of **attributes** associated with the feature. See Annex XXX for more information.

Feature Delineation: Criteria or rules for defining where a feature begins and ends and how it will be represented in a dataset (e.g. point, linear, or area feature). For example, stream features are sections of the stream network between confluences or individual, isolated natural water channels.

Feature Type: A classification of features into groups that share the same form or function. Example: streams, lakes, dams, springs, etc. Composite **Feature Type** is a classification for only composite features. Examples: reach, named watercourse. See Annex XXY for more information.

Line String: A geographic location referenced by a connected series of (x,y, optional z) coordinates with two endpoints. Often referred to as a one-dimensional (1D) object.

Linear Event: An **event** that is represented as a **line string.** The representation of the linear event may be specified using the applicable portion of a **linear feature** or as a line within an **area feature**. Alternatively, a linear event may be represented by a range of addresses that have been assigned along the length of a **linear feature**. A linear event carries an attribute that specifies the **permanent identifier** of the **feature** to which it is associated. See also **Linear Referencing System**.

Linear Feature: A **feature** that is represented as a **line string** or sequence of line strings**.**

Linear Referencing System: A system of addresses assigned to a set of **linear features** that permit the referencing of attributes to points along or sections of the features.

Permanent Identifier: Unique code that persists in time and space and is managed by an authority organization to identify the existence of an entity.

Point: A geographic location represented by a single (x,y, optional z) coordinate. Often referred to as a zero-dimensional (0D) object.

Point Event: An **event** that is represented as a **point.** The representation of the point event may be specified using the applicable coordinate position along a **linear feature**, a coordinate position within an **area feature**, or the coordinate position of a **point feature**. Alternatively, a point event may be represented by an address that has been assigned along the length of a **linear feature**. A point event carries an attribute that specifies the **permanent identifier** of the feature to which it is associated. See also **Linear Referencing System**.

Point Feature: A **feature** that is represented as a **point** or series of points.

Polygon: A geographic location represented by a series of (x,y) pairs of coordinates which form a closed figure. Often referred to as a two-dimensional (2D) object.

Reach: A **composite feature** that is scale-independent and carries a publicly recognized permanent identifier. The real world **feature delineation** of a reach (i.e. the place where it begins and ends) does not change although its underlying **features** may be collected at different scales. A reach inherits its **geometry** from its underlying **features**. Because reaches transcend scale, they are intended to form a stable event-referencing framework for **point events**, **linear events**, and **area events**. When reaches are split or merged, a cross-reference of their **permanent identifiers** is maintained. All linear feature representations of stream/rivers, canal/ditches, pipelines, and all artificial path, connector, shoreline, reservoir, and lake/pond **features** may compose reaches. It may be convenient to create reaches from other **feature types** if they are subject to scale-dependent delineation rules or if there is no other authoritative source for public, permanent identifiers.

Reach Code: A permanent identifier assigned to reaches.

Stream Level: A numeric code that identifies each main path of water flow through a drainage network. It is a stream classification in which lowest level (Level 1) streams terminate in sea/ocean features and tributaries are incremented based on the level into which they terminate. Examples: Mississippi River is a Level 1 stream, the Missouri is a Level 2 stream.

Watercourse: A composite feature, made up of one or more features usually based on a name attribute. A named path or path based on connectivity. Watercourses may be a permanent feature within a hydrography dataset.

5 Symbols and Abbreviations

Symbols and associated abbreviations applicable to this standard are listed below.

ANSI - American National Standards Institute
FGDC - Federal Geographic Data Committee
GML - Geography Markup Language
GNIS - Geographic Names Information System
GUID - Globally Unique Identifiers
IDL - Interface Definition Language
ID/IDs - Identifier/Identifiers
IEC - International Electrotechnical Commission
INCITS/L1 - InterNational Committee on Information Technology Standards, Geographic Information Systems
ISO - International Organization for Standardization
MAT - Modeling Advisory Team
NHD - National Hydrography Dataset

OCL - Object Constraint Language
OCG - OpenGIS Consortium
OMB - Office of Management and Budget
PNW - Pacific Northwest Framework
SRS - Spatial Reference System
UML - Unified Modeling Language
UUID - Universally Unique Identifiers
XML - Extensible Markup Language

6 Hydrography Modeling Approach

6.1 Design Concepts

Several key design concepts are defined in the hydrography standard, as defined by requirements of water resource applications:

- Core component of standard and model is the feature
- All features have geometry, either directly or through association
- Features are classified by type and further qualified by attributes
- Features may have relationships to other features
- Common definition of features is required for data sharing
- Permanent identifiers on features and on associated data are managed by an authority
- Linear referencing is supported through permanent features, identifiers, and measurement references
- Multiple representations of a feature exist and must be managed in a community

6.2 Design Requirements

Common uses of hydrography data have data and information needs associated with them. Below is a table of examples of such requirements.

USES	DATA AND INFORMATION NEEDED
Trace pollution upstream and downstream	Permanent features with IDs, information on flow of water through surface water network, feature classification, measurements on the surface water network, water discharge and velocity
Assist recovery of threatened and endangered species	Permanent features with IDs, linear referencing system, surface water flow relationships, measurements on the surface water network
Identify withdrawn areas for timber Harvesting based on riparian and stream characteristics	Shoreline, surface water flow relationships, linear referencing system, measurements on the surface water network, feature classification

USES	DATA AND INFORMATION NEEDED
Make maps as a reference layer with other data	Feature names, feature classification, attributes for generalizing or symbolization
Landscape analysis: influence of hydrography on landscape and vice versa	Flow relationships, history of features, positional accuracy, quality information, feature classification
Emergency management system for displaying impact areas and model flooding	Permanent features with identifiers (identifies), watersheds
Display and identify the identities/names of water features at a location	Features, IDs, names, geometries
Update local data with most up-to-date hydrography	Permanent feature IDs, representation IDs, metadata

Based on these requirements, this draft and model support the concepts described in the data and information needs.

6.3 OGC Feature Model

This Standard employs the OpenGIS Consortium (OGC) Feature model for the abstract representation of phenomena in the real world. An OGC Feature is a class or instance of a phenomenon that has attributes of an identifier/identity, geometry, and other properties. Feature Type definitions, attributes, and values are described in this Standard for hydrography data. Feature instances may have relationships to one another that are worthy of transfer, and thus these relationships are also captured in the model.

The OGC [13] notes:

> *[A] digital representation of the real world can be thought of as a set of features. The state of a feature is defined by a set of properties, where each property can be thought of as a {name, type, value} triple. The number of properties a feature may have, together with their names and types, are determined by its feature type. Geographic features are those with properties whose values may be a geometry. A feature collection is a collection of features that can itself be regarded as a feature. Consequently a feature collection has a feature type and thus may have properties of its own, in addition to the features it contains.*
>
> *[T]he traditional 0, 1 and 2-dimensional geometries defined in a two-dimensional spatial reference system (SRS) are represented by points, line strings and polygons. In addition the geometry model for simple features also allows geometries that are collections of other geometries (either homogeneous, multi point, multi line string and multi polygon, or heterogeneous, geometry collection).*

These concepts are further illustrated in Figure 1.

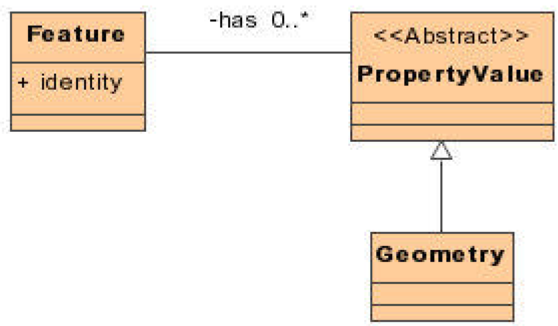

Figure 1 – Basic OGC Feature Model

The OGC Feature Model is a very simple and extensible object model that allows phenomena to be described with zero or more property values, and geometry is a type (subclass) of reserved property values. By this model, features may have no properties, although they typically have many; multiple geometries as property types can be associated with a feature instance.

Wherever possible, this Standard references abstract UML object types from the ISO 19100 series of standards and OGC specifications. Examples of inherited object types include standards for object geometry and topology [6], Feature organization per the Geography Markup Language [11], and the cataloguing methodology for Features [8]. Specialization of these classes of objects allows each theme to inherit properties and behaviors and ensure their propagation when transformed into encoding such as Extensible Markup Language (XML).

6.4 Hydrography Feature Model

Features are central to the hydrography model. Other data objects exist in the model through association to the features. An elemental feature is a geographic entity that can be classified by consistent type over its extent. A composite feature is an aggregation of elemental features. This draft contains specific feature classifications so that all exchange datasets that conform to it are consistent in terms of form or function, and in terms of minimum attributes of those features. For example, if one creates an exchange dataset according to this draft and if that exchange dataset contains features classified as 'stream,' then those features would meet the standard's definition of a 'stream.' This draft contains feature type enumerations and associated specific definitions that represent a set of harmonized types from major stakeholder systems.

Additional classification qualifiers are captured as attributes, also with specific definitions and, where appropriate, with enumerations. This enumeration should not be considered as bounded – more like an open-ended list – but that these types are the currently recognized ones for information exchange. Different provider-consumer arrangements might require validation against this list, or permit exchange of extended and non-standard feature types. The ISO 19115 metadata standard includes elements of a Feature Catalog (using a similar structure to the ISO 19110 layout, above) so that providers could define and extend their list of feature types – hopefully re-using the recognized ones and then adding new types. Characteristics that are less fixed to a permanent location on the ground should not "break" features, but be linked to the core data so as to remain accessible. For example, an application of name is concrete and can be tied explicitly to the feature. However, a classification of hydrographic category (e.g. intermittent vis perennial) is less fixed and may be better represented though a time series or a statistical measure, but not by explicit points that "break" the underlying feature.

As a Framework data content standard, the hydrography model emphasizes permanent features with unique permanent IDs to support the community's uses of hydrography data. Permanent identifiers allow sharing of data in a distributed environment. Permanent identifiers are required to support maintaining entities over time (e.g. exchange of updates); to support maintaining entities across multiple representations (e.g. scale and/or dimension); to support maintaining associations to linked data; and to describe associations among local and external data entities. such as water quality or ecological surveys.

Any permanent identifier scheme requires an authority to manage the included features[2]. The model also allows assignment of local identifiers to server as temporary identifiers or as cross-walks to permanent identifiers. If a permanent identifier does not exist, the model requires at least a unique temporary identifier be assigned for the purpose of the exchange. All feature identifiers must be unique in the context of the transfer and within an authority's coding system. The responsibilities of an authority include: recognition as a maintenance authority within the community, ability to assign, update, manage and publish identifiers, and to assure that identifiers are discoverable by users within a reasonable timeframe of their registration.

This Standard supports the management of multiple representations of features. A feature instance may have multiple representations reflecting different geometries and attributes due to changes over time, changes in scale, or differing generalization criteria applied in support of user needs. This draft does not define a "best available" spatial representation since these differ depending on the application of the data. Data authorities may establish specific data capture requirements to data under their authority. Some feature types, such as reaches and watercourses, do not have direct spatial representation, but instead derive their geographic extent through association to other feature types that do have spatial representation. A feature extent is defined by stable characteristics that allow for distinct bounds (e.g. start, end, location, extent) of the feature instance.

The combination of a specific instance of a Feature – all its attributes including a specific geometry – can be identified with a unique representation identifier. Thus a representation identifier denotes a unique, identifiable packaging of a feature, its attributes, and its geometry. This representation identifier provides a unique code to identify the state of the described feature. For example, a change in attribution or geometry preserves the same permanent feature identifier for purposes of linking to references or tracking changes, but would be tagged with a new representation identifier to indicate a change in the representation. When there are multiple persistent representations of a feature, such as those based on scale, then each representation would have its own identifier. Representation identifiers should be derived algorithmically,

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[2] *Recognized authorities include the National Hydrography Dataset co-administered by the U.S. Geological Survey and the U.S. Environmental Protection Agency, and the U.S. Geographic Names Information System in which official place names are stored. Both authorities support unique and persistent identifiers for features under their maintenance.*

applying methods like a checksum from attributes and geometry or assignment of truly universally unique identifiers (UUID) or globally unique identifiers (GUID). Features may have relationships to other features to describe connectivity or association. Relationship types include flow behavior, vertical offsets, and composition. The feature members of the relationship are referenced through their identifiers. The flow connectivity described in these relationships supports development of a linear flow network for flow navigation without the use of geometry. An attribute should be specified to note whether flow direction is one-way, bi-directional, or unknown. The endpoints of segments (nodes, junctions) will not be managed as first order features in this model.

Hydrography features are classified as either “elemental” or “composite.” Elemental features, as enumerated in the Annex on HydroFeatureTypes, are of a particular feature type that has geometry and may have attributes, relationships, and events. Composite features exist only as aggregations of elemental features and do not have their own explicit geometry. Examples of composite features are “reach” and named “watercourse.” Elemental features may not be composed of other elemental features. Composite features may be composed of only one set of elemental features; for simplicity, the composition relationship is not recursive.

This draft supports a continuous linear representation of the surface water network, although it permits the management and exchange of non-networked features. The network is composed of features that are represented as line strings whose connectivity relationship is known. The logical network is composed of linear representations of hydrography features and centerlines (artificially derived flow paths) within area representations such as reservoirs, rivers, and lakes. A “flows-through” relationship exists between centerlines and the area feature representations through which they flow.

The hydrography standard contains a reference system that supports both linear and non-linear links to the hydrography data. The reference system is described by a single type of composite features (e.g. reaches or watercourses). The reference system features have an attribute that can be used as the reference key. The reference key attribute contains unique values. External information that is linked to the reference system does so by referring to the reference key. The reference systems features may have any configuration of geometry: point, line or area. The reference system's linear features may support a linear reference system. The features that make up the linear reference system have an attribute that identifies the features as being part of a linear reference system. Addresses or measures are assigned along the linear features to support linking external information to just a portion of a linear feature. The addresses or measures begin with zero (0) at one end of the feature and terminate with one-hundred (100) at the other end of the feature. Measures are applied to linear features in proportion to their length. The reference system is defined on composite features, therefore the measures are designated based on the composite feature's consolidated geometry which it inherits from its elemental features. The measures are stored on the geometry of the elemental features as a measure (i.e. 'm') value for each geometry coordinate. The coordinates of linear features in the reference system are ordered from upstream to downstream if the direction of flow is known. Measurements increase in the opposite direction of the coordinate order. Therefore, by definition, where direction of flow is known, measure values increase from downstream to upstream. Both linear and non-linear references support an event model whereby the events are associated to the feature through its reference key and, optionally, to locations along the feature defined by the feature's measures. Measurements along shorelines should have a well-known starting location, such as the point of major outflow or other reference point.

Management of feature names is a core requirement for the standard, including the ability to manage multiple names of the same feature in an exchange. Names are provided in the context of a naming authority, such as the GNIS. To differentiate among different named features that are identically named – e.g. all the 'Mill Creeks' – a unique identifier is assigned by an authority to each named feature instance.

Metadata can be managed for the entire data exchange collection (feature collection), for a feature, or for an event. Although either FGDC or ISO 19115 metadata can be associated with these hydrography data, ISO 19115 is especially suited to describing characteristics on collections, data sets, and features. The standard should require data history/lineage to be reported in metadata so users understand the context for data exchanged. This draft does not impose constraints on metadata; it should only specify that metadata be reported using FGDC or ISO 19115 schemes as part of the data transfer

7 The Hydrography Information Model

7.5 Introduction

This data dictionary describes the characteristics of the hydrography classes defined in the UML diagrams. The dictionary is specified in a hierarchy to establish relationships and an organization for the information. The dictionary is categorized into sections by UML model package diagram name. Each UML model class equates to a data dictionary entity. Each UML model class attribute equates to a data dictionary element. The shaded rows define entities. The entities and elements within the data dictionary are defined by four attributes (those attributes are listed below and are based on those specified in ISO/IEC 11179-3 for the description of data element concepts, i.e. data elements without representation). The term "dataset" when used as part of a definition is synonymous with all types of geographic data resources (aggregations of datasets, individual geographic features and the various classes that compose a feature).

7.5.1 Name/role name

A label assigned to a entity or to a element. Entity names start with an upper case letter. Spaces do not appear in an entity name. Instead, multiple words are concatenated, with each new subword starting with a capital letter (example: XnnnYmmm). Entity names are unique within the data dictionary of this document. Element names are unique within an entity, not the entire data dictionary of this document. Element names are made unique, within an application, by the combination of the entity and element names (example: MD_Metadata.characterSet). Role names are used to identify abstract model associations and are preceded by "Role name:" to distinguish them from other elements. Names and role names may be in a language other than that used in this document.

7.5.2 Definition

The entity/element description.

7.5.3 Cardinality

Specifies the maximum or range number of instances the entity or the element may have. Single occurrences are shown by “1”; repeating occurrences are represented by “N”; optional occurrences are prefixed by “0..”. Fixed number occurrences other than one are allowed, and will be represented by the corresponding number (i.e. “2”, “3”…etc).

7.5.4 Data type

Specifies a set of distinct values for representing the elements; for example, integer, real, string, and Boolean. The data type attribute is also used to define entities, and associations.

7.5.5 Domain

The domain specifies the values allowed or the use of free text. “Free text” indicates that no restrictions are placed on the content of the field. Integer-based codes shall be used to represent values for domains containing codelists.

8 Conceptual Model for Hydrography

Subsections are presented below for each UML Object in the model. Each section includes a narrative for context and understanding and a table to define the contents. Code lists are included in Annex B.

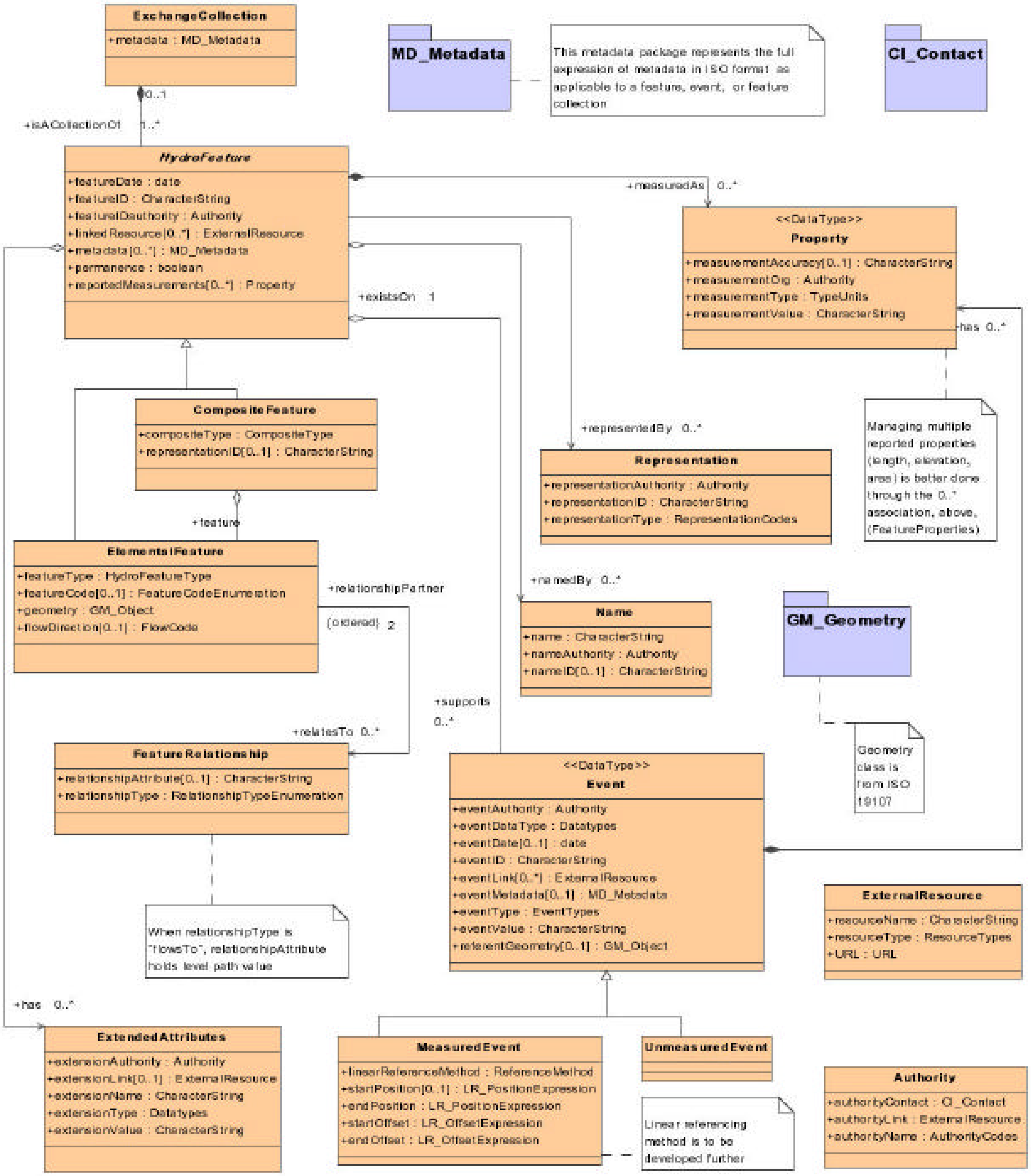


Figure 2 - Primary UML Classes for hydrography

8.1 ExchangeCollection

8.1.1

ExchangeCollection is the container for the features packaged in an exchange.

	Name	Definition	Cardinality	Data type	Domain
1.	ExchangeCollection	ExchangeCollection is the container object for the data in the exchange.	1	Class	
2.	metadata	A set of properties that pertain to the exchange	1	Package	MD_Metadata

8.1.2

8.2 HydroFeature

8.2.1

HydroFeature is an abstract class that captures the characteristics of the hydrographic feature. As the core component of the model, HydroFeature has several significant associations to other classes. HydroFeature has ElementalFeature and CompositeFeature subclasses.

8.2.2

	Name	Definition	Cardinality	Data type	Domain
	featureID	unique identifier of feature	1	char	
	featureIDAuthority	authority that manages the feature identifier assignment	0..1	Package	Authority
	linkedResource	Information related to this feature by URL reference	0..*	Class	ExternalResource
	metadata	A package of descriptive information associated with this feature instance	0..*	Package	MD_Metadata
	featureDate	date of last modification	1	date	
	permanence	status as a permanent identifier assignment	0..1	boolean	
	reportedMeasurements	reported value based on criteria other than spatial representation included in the exchange	0..1	Class	Properties

8.2.3

8.3 ElementalFeature

8.3.1

Basic features with explicit geometry.

	Name	Definition	Cardinality	Data type	Domain
	featureType	description of feature type	1	char	HydroFeatureType
	featureCode	unique combinations of attributes and values for a FeatureType	1	integer	FeatureCode
	flowDirection	direction of flow, where applicable, relative to coordinate ordering	0..1	integer	FlowCode
	geometry	Coordinate representation of the Feature	1	Package	GM_Geometry

8.4 CompositeFeature

8.4.1

CompositeFeature is an aggregate of ElementalFeatures. The CompositeFeature may impose property requirements onto the associated ElementalFeatures. For example, a CompositeFeature of Reach requires measure values based on the extent of the Reach, not of the ElementalFeatures that make up the Reach. As an aggregate representation, a CompositeFeature is retired if the ElementalFeatures that make up the CompositeFeature are retired. The reverse situation does not apply.

	Name	Definition	Cardinality	Data type	Domain
	compositeType	description of CompositeFeature type	1	char	CompositeType
	representationID	Unique identifier of the specific packaging of an identified Feature	0..1	Char	Valid IDs

8.5 FeatureRelationship

FeatureRelationship describes binary relationships between feature instances. The order of the roles in the relationship may be significant and is described in the association in the UML model. The RelationshipAttribute qualifier will have relevance to a specific RelationshipType.

8.5.1

	Name	Definition	Cardinality	Data type	Domain
	relationshipType	description of relationship	1	char	RelatonshipTypeEnnumeration
	relationshipAttribute	qualifier of RelationshipType	0..1	char	free text

8.6 ExtendedAttributes

8.6.1

The ExtendedAttribute object provides the ability to link additional attributes to HydroFeature instances, both Elemental and Composite. The ExtendedAttribute must have an authority which is documented with an Authority object instance. The ExtendedAttribute may be documented through an extensionLink to an ExternalResource object instance.

	Name	Definition	Cardinality	Data type	Domain
1.	extensionAuthority	Authority that manages the extended attribute	1	Association	Authority
2.	extensionLink	Information about the extended attribute	0..1	Association	ExternalResource
3.	extensionName	Field name of extended attribute	1	Char	
4.	extensionType	Data type of the value for the extended attribute	1	Class	DataType
5.	extensionValue	Value of extended attribute	1	char	

8.7 Event

8.7.1

An Event object supports the linking of external attribute information to a portion of a HydroFeature, either Elemental or Composite. Events can be of two types: measuredEvent or unmeasuredEvent. MeasuredEvents are those that reference portions of features that participate in the linear reference method. UnmeasuredEvents are those that reference portions of features that do not participate in the linear referencing method.

	Name	Definition	Cardinality	Data type	Domain
1.	eventAuthority	Authority that manages the event and its identifier	1	Association	Authority
2.	eventDate	An ISO date that provides a version for event	0..1	ISO8601date	ISO8601date
3.	eventID	Unique identifier for event	1	Char	
4.	eventLink	Link to an external resource such as a Web page or database containing additional information about the event	0..*	Association	ExternalResource
5.	eventType	Type of event	1	Class	Scheme Enumeration
6.	eventDataType	The data type for the information stored eventValue	1	Class	Scheme Enumeration
7.	eventValue	Attribute value being associated with the referenced feature	1	Char	
8.	eventMetadata	ISO Metadata describing the event	0..1	Association	MD_Metadata
9.	referentGeometry	Geometric representation for the Event. This representation may be geometric coordinates measured for the event or geometry derived from the referenced feature.	0..1	Association	GM_Geometry

8.8 MeasuredEvent

8.8.1

A measuredEvent represents a point or span along a linear feature. In order to have measuredEvents, a linear feature must participate in the linear reference method. A measuredEvent always has a startMeasure and, if it represents a span along a feature, it also has an endMeasure. The measures specifies the exact location of the event relative to the addresses/measures along the referenced feature. A measuredEvent may also have a geometric representation (referentGeometry) which provides an independent location for the event.

	Name	Definition	Cardinality	Data type	Domain
1.	endMeasure	Measure along linear reference feature at which measured event ends	0..1	Real	>= 0
2.	endOffset	Distance from linear reference feature where measured event's ending point occurs. Positive offsets are to the right of the feature looking upstream. Negative offsets are to the left of the feature looking upstream.	0..1	Real	-∞ - +∞
3.	linearReferenceMethod	Method used to locate event within the hydrologic framework	1	Class	Scheme Enumeration
4.	startMeasure	Measure along linear reference feature at which measured event begins	1	Real	>= 0
5.	startOffset	Distance from linear reference feature where measured event's starting point occurs. Positive offsets are to the right of the feature looking upstream. Negative offsets are to the left of the feature looking upstream.	0..1	Real	-∞ - +∞

8.9 UnmeasuredEvent

8.9.1

The unmeasuredEvent may be linked to any feature that does not participate in the linear reference method. The referenced feature may be a zero-dimensional, one-dimensional, or two-dimensional feature and may be either an Elemental or Composite feature. UnmeasuredEvents must have referentGeometry that specifies the location of the event relative to the geometry of the referenced feature. The geometry may be of any ISO geometry type, including, for example, point, line or area.

8.10 Name

8.10.1

The Name object holds 'official' feature names that are managed by an authority. The authority may be a recognized authority such as the Board of Geographic Names or an un-recognized authority such as a local hydrography maintainer. An ExchangeCollection may contain names from different authorities. Feature names are linked to HydroFeatures, both elemental and composite, in a many-to-many relationship. This permits a given feature to have names from different authorities. It also permits a single name to be linked to HydroFeature instances that represent parts of a named feature.

	Name	Definition	Cardinality	Data type	Domain
1.	nameID	Unique identifier for named feature	0..1	Char	
2.	name	Feature name text	1	Char	
3.	nameAuthority	Authority that manages the name, its application to real world objects, and its identifier	1	Association	Authority

8.11 Representation

8.11.1

Features, both elemental and composite, will have more than one representation in the hydro community. A representation is one instance combination of feature attributes and geometry – variation in one characteristics constitutes a new representation. Each HydroFeature instance within a given ExchangeCollection will have a single representation and the Representation object describes which representation is being exchanged. If the ExchangeCollection contains more than one representation for a given HydroFeature, there will be a feature instance (with unique identifier) for each representation in the ExchangeCollection.

	Name	Definition	Cardinality	Data type	Domain
1.	representationAuthority	Authority that manages the representation and its identifier	1	Association	Authority
2.	representationID	Unique identifier for the representation	1	Char	
3.	representationType	Type of representation	1	Class	Scheme Enumeration

8.12 Property

8.12.1

Properties are used to report empirical measurements of features such as real-world reported elevation, length, area, and depth. Both elemental features and composite features may have one or more Properties.

	Name / Role name	Definition	Cardinality	Data type	Domain
3.	measurementAccuracy	Description of the accuracy of the reported measurement	0..1	Char	
4.	measurementOrg	Authority reporting measurement	1	Association	Authority
5.	measurementType	Phenomena being measured and the units of measurement	1	Class	Scheme Enumeration
6.	measurementValue	Value of reported measurement	1	Char	

8.13 Authority

8.13.1

All authorities that maintain and distribute various hydrography objects and their identifiers, are documented in an Authority object. These include authorities for identifiers for features, both Elemental and Composite, names, representations, and events. Also, authorities that provide Property information are documented in an Authority object.

	Name / Role name	Definition	Cardinality	Data type	Domain
1.	authorityContact	Contact information for Authority	1	CI_Contact	
2.	authorityLink	Information about the Authority	1	Association	ExternalResource
3.	authorityName	Name of Authority	1	Class	Authority Codes

8.14 ExternalResource

8.14.1

The ExternalResource object provides the ability to link Internet URLs to HydroFeatures, both Elemental and Composite, to Events, to Authorities, and to ExtendedAttributes. There are a number of different types of ExternalResources as enumerated in the ResourceType codelist.

	Name / Role name	Definition	Cardinality	Data type	Domain
1.	resourceName	Descriptive name of resource	1	Char	
2.	resourceType	Type of resource	1	Class	Scheme Enumeration
3.	URL	INTERNET Uniform Resource Locator address	1	URL	

8.15 External Packages

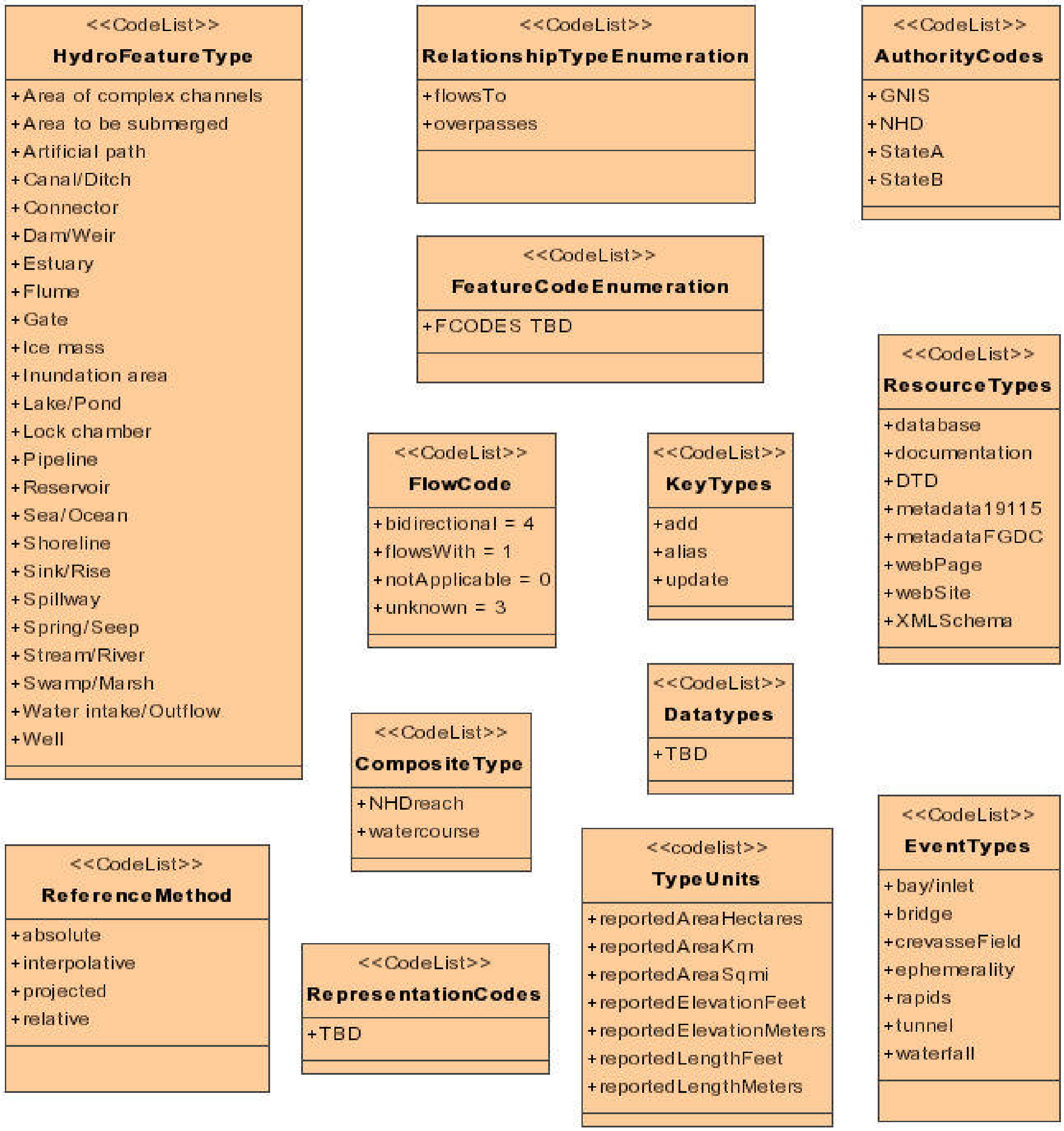
Several packages of structured information are used or referenced from ISO and OGC sources in this Standard. These include geometry, metadata, and contact information (a subset of metadata). The inclusion of these packages of information complements the model. The geometry and contact packages are summarized in Annex C; the metadata package from ISO 19115 is too verbose for inclusion in this Standard.

8.16 Code lists or enumerations

The code lists presented in Figure 3 represent known enumerations of values that are encouraged to promote interoperability. Most of these code lists are not intended to be exhaustive and, in fact, are likely to be placed online and would support controlled update by the community. In implementation, strict validation may include tests for the presence of these codes, whereas lax validation may permit these and additional code values.

8.17

8.17.1



8.17.1.1

Figure 3 – UML Classes representing code lists for hydrography

9 Conformance Testing

The intention of the abstract portion of this standard is to declare all relevant information structures that should be stored in (or converted to or from) systems containing hydrography data. Strict conformance to such an abstract model is difficult if not impossible to test by automated means. The implementation annex(es) of this Standard provide specific implementation-specific guidance for structuring and encoding hydrography information.

Therefore, tests of conformance are to be executed using a specific implementation annex to this standard – to validate conformant packages of hydrographic information.

o - UML Principles

A.1 UML notation

The diagrams that appear in this document are presented using the Unified Modeling Language static structure diagram with the ISO Interface Definition Language (IDL) basic type definitions and the UML Object Constraint Language (OCL) as the conceptual schema language. The UML notations used in this International Standard are described in the Figure 1.

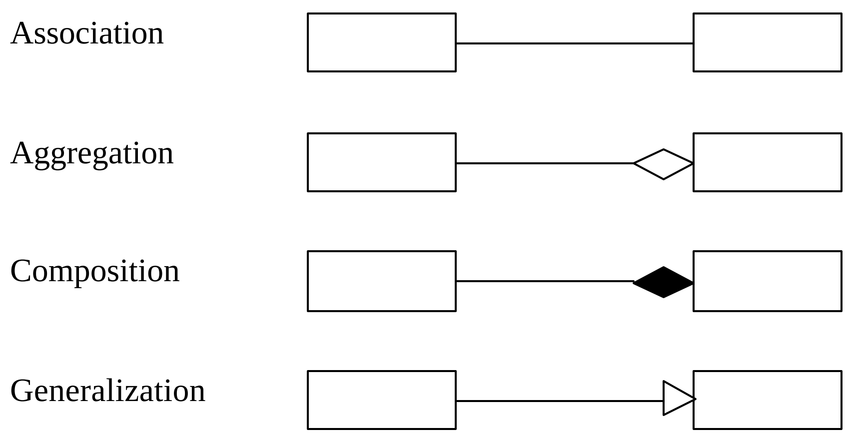


Figure A.1 — UML notation

A.2 UML model relationships

A.2.1 Associations

An association is used to describe a relationship between two or more classes. UML defines three different types of relationships, called association, aggregation and composition. The three types have different semantics. An ordinary association shall be used to represent a general relationship between two classes. The aggregation and composition associations shall be used to create part-whole relationships between two classes. The direction of an association must be specified. If the direction is not specified, it is assumed to be a two-way association. If one-way associations are intended, the direction of the association can be marked by an arrow at the end of the line.

An aggregation association is a relationship between two classes in which one of the classes plays the role of container and the other plays the role of a containee.

A composition association is a strong aggregation. In a composition association, if a container object is deleted, then all of its contained objects are deleted as well. The composition association shall be used when the objects representing the parts of a container object cannot exist without the container object.

A.2.2 Generalization

A generalization is a relationship between a superclass and the subclasses that may be substituted for it. The super-class is the generalized class, while the subclasses are specified classes.

A.2.3 Roles

If an association is navigable in a particular direction, the model shall supply a “role name” that is appropriate for the role of the target object in relation to the source object. Thus in a two-way association, two role names will be supplied.

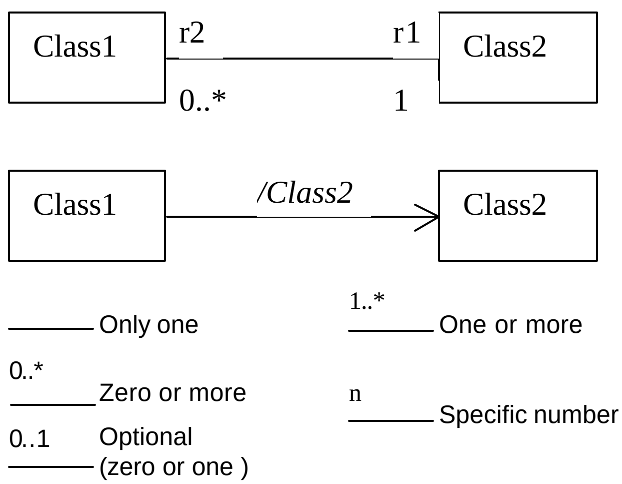


Figure A.2 — UML roles

Figure 2 represents how role names and cardinalities are expressed in UML diagrams. The role name “r1”’ is Class1’s relationship to Class2. The role name “r2” is Class2’s relationship to Class1. The cardinalities show that “zero or many” Class1s are related to “exactly one” Class2. Figure 2 also shows how derived classes will be expressed. The diagram indicates that Class1 is a derived class of Class2. Any attributes and aggregates of Class1 are also derived from Class2.

o – Enumerations

The following table represents a consolidated enumeration of 27 recognized feature types for water features. In general, landmark or non-water features were omitted from this list. Where possible, potential or identified alternate names (aliases) are presented. Some consolidation occurred where what used to be a feature type was recognized to be, in fact, a modifier or property on some other feature type. In these cases, the column of “characteristics” reflects possible modifiers.

Table B.1 – Enumeration of Elemental Feature Types for Hydrography

cat	featureName	definition	co	characteri	aliases	definitionsou
1	Area of complex channels	An area where a stream or river flows in an intricate network of interlacing channels.				NHD, 1999
1	Area to be submerged	The known extent of the intended lake that will be created behind a dam under construction.				NHD, 1999
1	Artificial path	An abstraction to facilitate hydrologic modeling through open water bodies and along coastal and Great Lakes shorelines and to act as a surrogate for lakes and other water bodies.				NHD, 1999
1	Canal/Ditch	An artificial open waterway constructed to transport water, to irrigate or drain land, to connect two or more bodies of water, or to serve as a waterway for watercraft.		tunnel	aqueduct	NHD, 1999
1	Connector	A known, but nonspecific, connection between two nonadjacent network segments.				NHD, 1999
1	Dam/Weir	A barrier constructed to control the flow or raise the level of water.			levee	NHD, 1999
1	Estuary	The lower end of a river, or a semienclosed coastal body of water with access to the open ocean, which is affected by the tides and where fresh and salt water mix. Should be hydrologically based.			bay	NHD, 1999

1	Flume	An open, inclined, artificial channel constructed of wood, metal, or concrete; generally elevated.				NHD, 1999
1	Gate	A structure that may be swung, drawn, or lowered to block an entrance or passageway.				NHD, 1999
1	Ice mass	A field of ice, formed in regions of perennial frost.		crevasse field	glacier, snowfield	NHD, 1999
1	Inundation Area	An area of land subject to flooding.				NHD, 1999
1	Lake/Pond	A standing body of water with a predominantly natural shoreline surrounded by land. (Need a more hydrologically sound definition)		gravel pit/quarry, playa		NHD, 1999
1	Lock chamber	An enclosure on a waterway used to raise and lower vessels as they pass from one level to another.				NHD, 1999
1	Pipeline	A closed conduit, with pumps, valves and control devices, for conveying fluids, gases, or finely divided solids.		aqueduct (if closed), siphon, tunnel		NHD, 1999
1	Reservoir	A constructed basin formed to contain water or other liquids. (Need a more hydrologically sound definition)				NHD, 1999
1	Sea/Ocean	The great body of salt water that covers much of the earth.			gulf	NHD, 1999
1	Shoreline	The contact line between an land and a waterbody		coastal, island, reservoir, non-earthen,		PNW

1	Sink/Rise	The place at which a stream disappears underground or reappears at the surface in a karst area.				NHD, 1999
1	Spillway	A constructed passage for surplus water to run over or around a dam.			masonry spillway	NHD, 1999
1	Spring/Seep	A place where water issues from the ground naturally.		mudpot, fumarole, geyser		NHD, 1999
1	Stream/River	A body of flowing water.		wash	ephemeral drain	NHD, 1999
1	Swamp/Marsh	A [generally] noncultivated, vegetated area that is inundated or saturated for a significant part of the year. The vegetation is adapted for life in saturated soil conditions.			bog, wetland	NHD, 1999
1	Water intake/Outflow	A structure through which water enters or exits a conduit.		intake, outflow		NHD, 1999
1	Well	A pit or hole dug or bored into the earth for the extraction of water.				NHD, 1999

B.2 –Potential Composite Feature Types

cat	featureName	definition	co	characteri	aliases	definitionsou
1	Reach	A composite feature that is scale-independent and carries a publicly recognized permanent identifier.				NHD, 1999
1	Watercourse	A composite feature, made up of one or more features usually based on a name attribute.				NHD, 1999

EventTypes

Notes on Event types: In the NHD, coastal (or Great Lakes) shorelines are artificial paths but could be derived as a new Shoreline type feature. Most shorelines could be derived for the purpose of exchange from existing bounded water area features. The provision of shoreline features (or any other feature type) is not mandatory, but supported by the standard.

- Bridges and tunnels are properties of canal/ditches and pipelines
- Crevasse field is an attribute of an ice mass
- Foreshores are the area between high and low water but are problematic. Should really be defined by NOAA coastal shorelines – it is derivable.
- Hazard zone is a property of general water features, not a first order feature.
- Islands are not water features but may be landmark features. Out of scope in this draft but may be supported in some exchanges.
- A Reach is not a first-order feature but rather is a characteristic (Reach identity) used to group kindred feature instances. We are still struggling for a replacement term for "reach."
- Sand and gravel bar is more like an island and is excluded.
- Sounding datum line (tidal datum) is like edge of foreshore. It seems out of context.
- Special use zone and special use zone limit are really properties of any area water feature. These are not shown in the current feature type table, above, but may be revealed in the FCODE enumeration.

Table B.2 – Characteristics managed as events on Elemental Feature Types

cat	featureName	definition	Reference Feature	definitionSo
1	Bay/Inlet	A water area that is an opening of the sea/ocean into the land, or of an estuary, lake, or river into its shore. (Implemented as a landmark feature)	estuary, lake/pond, sea/ocean, stream/river	NHD, 1999
1	Bridge	Structure spanning and providing passage over a waterway, railroad or other obstacle. For example, a characteristic of a canal/ditch or pipeline with passage over a stream	canal/ditch, pipeline	NHD, 1999

1	Crevasse field	Area of deep fissures in the surface of an ice mass caused by breaking or parting	Ice mass	NHD, 1999
1	Ephemerality	The perennial or intermittent nature of a flowing water feature	Stream/river, lake/pond	
1	Rapids	An area of swift current in a stream or river, characterized by standing waves or by boulders and rocks.	Stream/river	NHD, 1999
1	Tunnel	An underground or underwater passage.	Pipeline, canal/ditch	NHD, 1999
1	Waterfall	A vertical or near vertical descent of water over a step or ledge in the bed of a river.	Stream/river	NHD, 1999

o – External UML Packages

GM_Geometry

MD_Metadata

CI_Contact

Datatypes

Nested Relationship of Geospatial One-Stop Standard Harmonization