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OGC® WaterML 2 – Part 3: Surface Hydrology Features (HY\_Features) Conceptual Model

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Abstract

The OGC Surface Hydrology Features (HY\_Features) standard defines a common conceptual information model for the identification of surface hydrologic features independently of their geometric representation and scale. The model describes hydrologic features by defining fundamental relationships among major components of the hydrosphere. This includes relationships such as hierarchies of catchments, segmentation of watercourses, and topological connectivity of hydrologic features such as catchments and water bodies based on the flow and conservation of water. The standard also defines normative requirements for HY\_Features implementation schemas and mappings to meet in order to be conformant with the conceptual model.

The HY\_Features model provides for an identified hydrologic feature to have multiple alternate geographic feature realizations and geometric representations in order to support a range of applications. It supports referencing information about a hydro feature across disparate information systems or products, thereby improving data integration within and among organizations. Similarly, the model can be applied to cataloging of observations, model results, or other study information involving hydro features. The ability to represent the same catchment, river, or other hydrologic feature in several ways is critical for aggregation of cross-referenced or related features into integrated datasets and data products on global, regional, or basin scales.

Keywords

The following are keywords to be used by search engines and document catalogs.

ogcdoc, OGC document, hydrology, feature, identification, conceptual model, UML, implementation standard, hydrology model.

Preface

This standard defines the HY\_Features common hydrologic feature model for the identification of hydrologic features. It is intended to be used to document and share information about hydrologic objects of study and reporting for a range of applications. HY\_Features was originally commissioned to link hydrologic information across the scientific and technical programs of the World Meteorological Organization (WMO), and to assist WMO Members in discovering, accessing, and utilizing hydrologic data from different sources.

This standard is also intended to support the need for governance and guidance by national and international authorities. Aspects of the standard that support this goal are 1) canonical form, 2) implementation neutrality, 3) conformity to internationally recognized geographic information standards, and use of semantics inferred from terminology endorsed by the WMO and the UN Educational, Scientific and Cultural Organization (UNESCO).

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Submitting organizations

The following organizations contributed to the initiation or development of this standard and submitted this Document to the Open Geospatial Consortium OGC):

* U.S. Geological Survey (USGS), USA
* Federal Institute of Hydrology (BfG) , Germany
* CSIRO Land and Water, Australia
* Bureau of Meteorology, Australia
* Metalinkage, Australia
* French Geological Survey (BRGM), France
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Changes to the OGC® Abstract Specification

The HY\_Features conceptual model, described in this standard, references concepts defined in the OGC Abstract Specification (OGC AS). Conformance to the OGC AS may be achieved via specialization of the relevant concept. An example of this kind of conformance is a geographic feature specialization that carries specific hydrologic feature attributes and associations. Conformance may also be achieved by asserting a correspondence or analogy between HY\_Features concepts and OGC AS concepts. For example, the river reference system for referencing positions along a nominal flowpath corresponds to linear referencing along any linear feature element.

This standard requires no changes to the current version of the OpenGIS ® Abstract Specification.

# Scope

This OGC Implementation Standard defines a common feature model for the identification and description of surface hydrologic features using established models and patterns in use in the Hydrology domain and endorsed by WMO and UNESCO such as those documented in the "International Glossary of Hydrology".

This standard will form (along with any subsequent implementations) the third part of an intended ‘OGC WaterML 2’ suite of standards that groups water-related OGC standards. Following Part 1: Timeseries, Part 2: Ratings, Gaugings and Sections, this standard is titled Part 3: Surface Hydrology Features Conceptual Model.

This document introduces the HY\_Features conceptual model only. The normative model is a machine-readable UML artifact published by the OGC in conjunction with this document at: **[insert URL here]**. Clause 7 of this document presents requirements classes and requirements for model implementations to meet in order to be considered conformant with the conceptual model. Conformance classes indicating how to demonstrate conformance to requirements are presented in Annex A.

Future standards documents in this series are expected to specify particular implementations of the conceptual model. For example, an OWL/RDF implementation will define machine-processable entities and relationships in the OWL schema language that implement the HY\_Features conceptual model elements. HY\_Features implementations are expected to support documentation and discovery of data as well as aid data transformation efforts. For example, a discovery service such as a catchment catalog might use HY\_Features concepts to index services that provide differing catchment representations as well as related water quality and quantity observations. A catalog client could then use the index for automated analysis and data product generation.

The initial scope has been defined by the WMO Commission for Hydrology (WMO-CHy): to facilitate data sharing within the hydrologic community of the WMO Member countries and to improve the quality of data products based on these data by defining hydrologic features to convey their identification through the data processing chain "from measurement to hydrological information" [8].

To enable semantic interoperability of hydrologic data and services, it is necessary to agree on common concepts and methods. The HY\_Features model was developed in order to formalize concepts and relationships of hydrologic and hydrographic features using the WMO/UNESCO "International Glossary of Hydrology" as a starting point.

This standard is meant to support the widest possible linkage of data products across differing applications and jurisdictions. To enable this, a holistic and generalized concept of catchments is defined but specific surface-water aspects of the concept are modeled as realized features. This allows a particular catchment to be represented in different feature data products for different purposes while still retaining its identity. Another HY\_Features objective is to provide a standard terminology to describe relationships between hydrologic features that can be used to implement data transfer formats for specific feature subsets, particularly catchment hierarchies and river networks.

The HY\_Features model provides a basis for common and stable references to hydrologic features in a wide variety of applications:

* to link hydrologic observations to their feature-of-interest, e.g. link a streamflow observation to the river or catchment being observed,
* to allow aggregation of cross-referenced features into integrated datasets and data products on global, regional, or basin scales,
* to enable information systems to unambiguously link data across distributed systems and domains,
* to enable cross-domain or multi-discipline services to communicate through reference to standard concepts.

This standard defines a conceptual model (normative) containing feature type definitions that conform to the OGC General Feature Model (GFM) (ISO 19101:2002 and ISO 19109:2006), expressed in the Geographic Information Conceptual Schema Language (ISO 19103:2005) using the Unified Modeling Language (UML). The GFM is a meta-model developed as a general framework for features and their properties in the context of geographic information. Feature types specific to an application domain are defined as instances of the general feature metaclass with their own sets of typical characteristics (property types and constraints) such as attributes, associations, or operations.

As shown in Figure 1, the HY\_Features conceptual model defines instances of the general feature metaclass specific to the hydrology domain. A general HY\_HydroFeature type is defined to carry properties such as identifier and name that all hydrologic features should have. Specific feature types are then derived from HY\_HydroFeature to reflect different aspects of hydrology and carry properties specific to each aspect. Figure 1 also illustrates that HY\_Features features can fill the role of features-of-interest or sampling features for hydrologic observation data conforming to the Observation and Measurement (O&M) model (OGC Abstract Specification Topic 20, Observation and Measurement (aka ISO19156:2011) or to hydro-specific O&M profiles such as in the WaterML 2 suite.

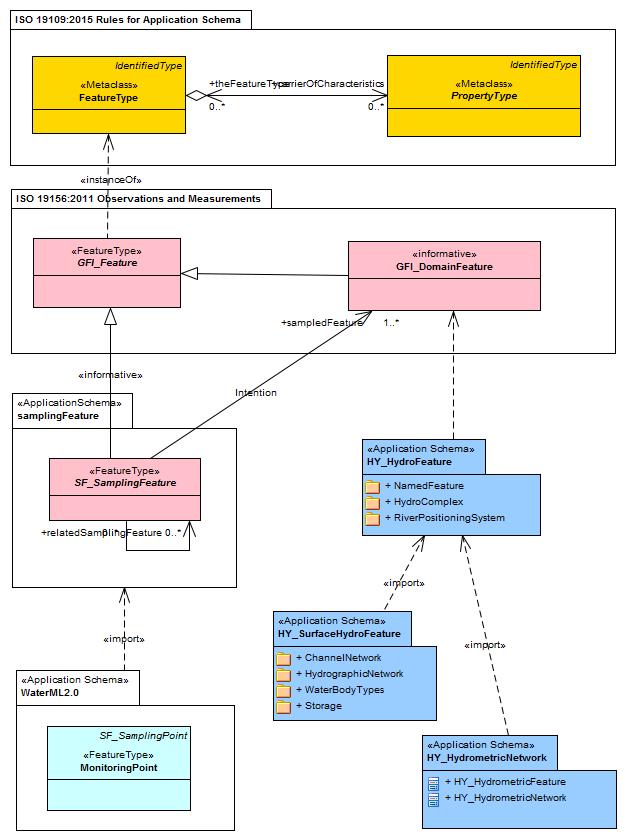


Figure 1: HY\_Features in the context of the OGC Abstract Specification as well as Observations & Measurements

# Conformance

This standard defines a conceptual model for hydrologic features and their fundamental relationships. Requirements for conformance with the conceptual model are defined for two types of implementation targets: a) implementation schemas for representation of hydrologic data or b) implementation mappings between terms or concepts from two or more other existing hydro data schemas based on common intermediary HY\_Features concepts. Any conformant implementations are required to satisfy the requirements defined in Clause 7 of this document for the requirements class(es) with which they assert conformance. This is true whether the implementation is explicit in the case of a schema (such as an OWL/RDF ontology or XML schema) or implicit in the case of common concepts for a schema mapping (such as an XSLT rule). The accuracy or detail with which an external term is mapped to a HY\_Features common concept is beyond the scope of this standard, as is specification of a particular concept mapping methodology.

Annexes C-F of this document provide, nevertheless, informative mappings to and from HY\_Features for the following hydro data models:

* Australian Hydrological Geospatial Fabric (AHGF) [11],
* USGS National Hydrography Dataset Plus (NHD Plus)[10],
* INSPIRE Hydrography theme [2],
* French National Service for Water Data and Reference-dataset Management (SANDRE) [12].

These mappings are intended to provide a general understanding of the correspondence between HY\_Features concepts and existing conceptual / physical models. They are informative with respect to any future mapping implementations.

Conformance of implementation targets with this standard shall be verified using all the relevant tests specified in Annex A (normative) of this document. The framework, concepts, and methodology for testing, and the criteria to be met to claim conformance are specified in the OGC Compliance Testing Policies and Procedures and the OGC Compliance Testing web site[[1]](#footnote-1).

All requirements-classes and conformance-classes described in this document are owned by the HY\_Features standard.

# Normative References

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OGC Abstract Specification Topic 1, Feature Geometry   
(aka ISO 19107:2003, Geographic Information — Spatial schema)

OGC Abstract Specification Topic 2, Spatial referencing by coordinates   
(aka ISO 19111:2007, Geographic Information — Referencing by coordinates)

OGC Abstract Specification Topic 5, Features   
(aka ISO 19101:2002, Geographic Information—Reference Model)

OGC Abstract Specification Topic 11, Metadata (aka ISO 19115-1:2014, Geographic Information — Metadata – Fundamentals)

OGC Abstract Specification Topic 19, Geographic information - Linear referencing (akaISO 19148:2012, Geographic Information — Linear referencing)

OGC Abstract Specification Topic 20, Observations and Measurements (aka ISO 19156:2011, Geographic Information — Observations and Measurements)

ISO/TS 19103:2005, Geographic Information — Conceptual schema language

ISO 19108:2006, Geographic Information — Temporal schema

ISO 19109:2006, Geographic Information — Rules for application schemas

ISO 19133:2005, Geographic Information — Location-based services – Tracking and navigation

# Terms and Definitions

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r8], which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word SHALL (not "must") is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

For the purposes of this document, the following additional terms and definitions apply.



application schema

Conceptual schema for data utilized in one or more applications [ISO 19101].

boundary (line)

Geometric representation of a (catchment) boundary, usually a geometric composite curve

NOTE: This definition references the definition of a *divide* described as summit or boundary line [9].

catchment

A physiographic unit where hydrologic processes take place. This class denotes a physiographic unit, which is defined by a hydrologically determined outlet to which all waters flow. While a catchment exists, it may or may not be clearly identified for repeated study.

NOTE: This approach considers the catchment concept to be the basic unit of study in hydrology, water resources management, and environmental reporting. The approach is meant to be holistic, referring to the continuous interaction of surface and subsurface waters within a catchment, even if a particular representation of the catchment refers to only surface or subsurface aspects of the catchment. Special subtypes such as drainage basin and groundwater basin may be defined with a particular application.

The synonymous use of the terms catchment and catchment area in the WMO/UNESCO International Glossary of Hydrology (which is the key reference for the definitions in the HY\_Features model) does not clearly distinguish between the catchment concept and its geometric representations such as catchment area, nor between catchment and its possible specializations like drainage basin and groundwater basin.

The essential logical separation of concerns between a common concept and its realization as interpretable data is dealt with by defining separate features for the catchment and its realization and may be understood as a refinement of the complex, ambiguous definition given in the glossary. See also clause 5.4 of this standard on the use of WMO terminology.

catchment area

Two-dimensional (areal) topological feature realizing the logical catchment in terms of a face bounded by catchment boundary and flow path edges. The concept of a face bounded by edges is described in detail in the ISO topology model [ISO19107]. The catchment area is usually represented as a geometric surface, and the measure of the catchment area may be denoted as surface area (if required).

catchment boundary

Two-dimensional feature that realizes a logical catchment by representing its boundary either topologically as divide edges bounded by inflow and outflow nodes, or geometrically as a polygon ring.

catchment divide

One-dimensional feature, usually represented by a curve, that separates two adjacent catchments [9] and forms part of the boundary realization of each catchment.

catchment topology

Edge-node topology pattern of a set of catchments connected by their outfalls. The topology pattern may be derived from flowpath and outfall node features, but reflects the inferred hydrologic connectivity between catchments an their outfalls whether or not corroborated by geometric representations.

channel

Natural or artificial waterway, clearly distinguished, which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water [9].

channel network

Connected set of depressions and channels that continuously or periodically contain water.

contour (of a shoreline)

Geometric representation of a water edge or shoreline of a waterbody, e.g. as left and right curves. A *contour-line* on a map represents the locus of points at which a certain property is constant (e.g. elevation, salinity) [9]. A water edge is the locus of points at which water depth is nearly zero. This is equivalent to an elevation contour only if the water is not moving.

cross section (of a stream)

Section of a stream at right angles to the main (average) direction of flow [9].

cross section (of a stream bed)

transversal section of a stream bed in a vertical plane. This definition references the definition of a *bed profile* describing the shape of a stream bed in a vertical plane [9].

data

Documented value of some characteristics of a real-world phenomenon.

data set

Data compiled and arranged into a set.

data product

Data set compiled for a specific purpose, e.g. for global dissemination using Web services.

dendritic catchment

Catchment wherein all waters flow to a single common outlet. A dendritic catchment is permanently connected to others in a dendritic (tree) network, the most common *drainage pattern* of streams ultimately flowing into the ocean after joining together at confluences into larger and larger streams.

depression

Landform lower than the surrounding land and partially or completely closed that is able to but does not necessarily contain water.

domain feature

Feature of a type defined within a particular application domain. [ISO 19156].

endorheic (drainage)

Draining [ultimately] into interior catchments [9].

exorheic (drainage)

Draining [ultimately] into the ocean [9].



feature

Abstraction of real-world phenomena. [ISO 19101]

flow path (also flowpath)

One-dimensional (linear) feature realizing a catchment in terms of a topological edge bounded by inflow and outflow nodes, and associated with left-bank and right-bank sub-catchment faces. A flowpath feature may also form the “main stem” of the stream network flowing to the catchment outflow node from its inlet node(s).

NOTE 1: With respect to the river positioning system described in this standard, the flow path can also form the axis in a linear coordinate system. This corresponds to the linear element ‘that serves as the axis along which linear referencing is performed’ as described in the OGC Abstract Specification Topic 19, Linear referencing [aka ISO 19148].

NOTE 2: Hydrologically, the flow path references the *path line* described by a moving particle of water [9].

flow line (also flowline)

Geometric property of a flowpath, usually a geometric curve.

NOTE: This definition references the definition of a *path-line* [9] through using the synonym *flow line* to express the geometric property of a flow path.

hydrographic network

Aggregate of rivers and other permanent or temporary water bodies, including lakes and reservoirs [9], standing in depressions or moving in channels, that can be mapped on the Earth’s surface but is not necessarily navigable for the purposes of this document.

NOTE: Not to be confused with the network of hydrological stations and observing posts.

hydrologic complex

Collection of distinct hydrologic features forming a hydrologically connected system where the union of one or more catchments and a common outfall is realized by multiple complexes of topological elements. For example, a catchment may be realized simultaneously as a face-edge complex of subcatchment areas, an edge-node network of flowpaths and outfall nodes, and also as a dendritic edge-node network of either waterbodies or containing channels.

hydrologic feature

Feature of a type defined in the hydrology domain, whose identity can be maintained and tracked through a processing chain from measurement to distribution of hydrologic information.

hydrologic realization

Concrete hydrologic feature that realizes a logical concept / feature within the hydrologic domain. For example, catchment boundaries realize logical catchments and outfall nodes realize logical outfalls.

hydrology

Science that deals with the waters above and below the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, their reaction with their environment, including their relation to living beings. [9]

hydrometric feature

Feature of a type which denotes a physical structure intended to observe properties of a hydrologic feature.

NOTE: This definition references the definition of a *hydrometric station* at which data on water in rivers, lakes or reservoirs are obtained on physical and chemical properties of water [9]. A hydrometric feature may be a composite station configured by arranging several monitoring components. Used to sample a hydrologic feature, a hydrometric feature may be considered a *sampling feature* of defined in the ISO Observation model. A sampling feature is described in general in ISO 19156: Observation and Measurement, the special monitoring point of hydrologic observation is described in the OGC WaterML 2.0: Part 1- Timeseries standard [4].

hydrometric network

Aggregate of hydrologically connected monitoring stations situated on and used for hydrologic observation of a feature such as a catchment or hydrographic network. This definition references the definition of a synonymous *hydrological network* consisting of hydrological stations and observing posts situated within a catchment in such a way as to provide the means of studying its hydrological regime [9].

hydrometry

Science of the measurement and analysis of water including methods, techniques and instrumentation used in hydrology [9].

indirect position

Position expressing the location of a feature relative to the known location of another feature. Indirect position requires a logical axis bounded by the feature being placed and the feature being referenced, along which the position can be determined. Common examples in hydrology are mileposts along a river referencing the river source or/and mouth, and the placement of monitoring stations relative to already located stations.

interior catchment

Catchment wherein all waters are collected and drainage is endorheic; an interior catchment does not drain to other catchments. This definition is rooted in the *blind drainage* pattern of water collecting in sinks or lakes not connected to streams [9].

longitudinal section (of a stream)

Vertical section of a stream in longitudinal direction. This definition is rooted in the definition of a *longitudinal section* along a channel at its center line [9], but generalized for all types of vertical section along a line.

longitudinal section (of a stream bed)

Longitudinal section of a stream bed in a vertical plane. This definition references the definition of a *bed profile* describing the shape of a stream bed in a vertical plane [9].

main stem

Main course along which water flows in a catchment, usually also the main stream segments flowing from the catchment headwaters to its mouth, excluding tributaries.

mapping

Establishing a semantic relationship between concepts in different information models using a formalism that specifies how elements from a source information model may be transformed into elements of a target model. Every pair of N models generally require a separate (2-way) mapping for each source concept (a total of N!/[2(N-2)!] mappings). Mappings that in contrast involve transformation by way of a common concept can be more efficiently expanded to more than two models as each additional model only requires mapping once into the set of common concepts (N mappings).

named feature

Feature identified by a name. Hydrologic features may have multiple names depending on the cultural, political or historical context.

nillable

Nillable is meant in this standard to signify that a feature property logically exists but may not be determined in a given implementation.

outfall

Logical outlet of the water contained by a catchment. An outfall represents the logical place where a catchment interacts with another catchment. Every catchment flows to an outfall, conversely every location in a hydrologic system is also an outfall that drains some catchment. If a given logical outfall is un-realized or undetermined, it is termed ‘nillable’ in this standard. For example, a logical outfall exists in the form of flow to the subsurface or atmosphere but may be undetermined within implementations focused on surface water hydrology.

referent

Located feature being referenced to locate another feature on the logical axis that is stretched between the two. The (indirect) position of a new location is expressed as distance along that axis from the known referent towards the feature being placed.

representation

Any processable data, data set, or data product which characterizes a given feature concept.

river positioning system

System applied to place a feature on a (linear) watercourse feature. The feature location is specified as an indirect position expressed as distance along the watercourse on which the feature is to be placed.

NOTE: A (hydrologic) feature of interest which is located along the locating one-dimensional flowpath between inflow and outflow nodes, corresponds in general to the linear referencing described in the OGC Abstract Specification Topic 19, Linear referencing ‘specifying a location relative to a linear element along that element’ [ISO 19148].

river reference system

Catchment-specific reference system in which the one-dimensional topological realization of a catchment forms the logical (linear) axis, and the origin is located at the outfall of the realized catchment.

storage (of water)

Impounding of water in surface or underground reservoirs, for future use. [9]

NOTE: Storage refers to a body of water from the perspective of a usable water resource. The management of a reservoir itself, as a human action with the objective of efficient and sustainable use of the resource, is not in the scope of the conceptual model.

stream

Water, generally flowing in a natural surface channel, or in an open or closed conduit, a jet of water issuing from an orifice, or a body of flowing groundwater [9].

water body

Mass of water distinct from other masses of water [9].

water edge

A one-dimensional (linear) feature that references the *shore-line* of intersection between a water body and the confining land surface [9]. Also a topological edge bounded by inflow and outflow nodes that may form that part of a (stream left or right) catchment boundary verging on a water body.

watercourse

Natural or man-made channel through or along which water may flow [9], including large interstices in the ground, such as cave, cavern or a group of these in karst terrain.

# Conventions

This clause provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

## Identifiers

The normative provisions in this specification are denoted by the URI:

[http://www.opengis.net/spec/{standard}/{m.n}](http://www.opengis.net/spec/%7Bstandard%7D/%7Bm.n%7D)

All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base.

## Symbols (and abbreviated terms)

CHy WMO Commission for Hydrology

GML Geography Markup Language

GRDC Global Runoff Data Centre (GRDC)

GWML2 GroundwaterML 2

HDWG OGC-WMO Hydrology Domain Working Group

ISO International Organization for Standardization

OGC Open Geospatial Consortium

OWL Web Ontology Language

RDF Resource Description Framework

UML Unified Modeling Language

WaterML 2 working title for the intended suite of water-related OGC standards

WIS WMO Information System

WIGOS WMO Integrated Global Observing System

WMO World Meteorological Organization

XML eXtensible Markup Language

## UML notation

Most diagrams that appear in this specification are presented using the Unified Modeling Language (UML) static structure diagram, as described in Sub-clause 5.2 of the OGC Web Services Common Implementation Specification (OGC 04-016r2). UML classes are named in UpperCamelCase and property names in lowerCamelCase.

## WMO Terminology

The HY\_Features model uses—as far as possible—terminology recommended by the WMO Commission for Hydrology for use in the WMO Member countries. The key reference is the "International Glossary of Hydrology" [9] [[2]](#footnote-2), a joint publication of the WMO and the UNESCO (hereinafter referred to as WMO/UNESCO glossary of hydrology). Wherever appropriate, terms from this glossary are applied to the feature concepts in this standard to capture meaning and contextual relationships. The synonym approach widely used in this glossary is interpreted as signifying that synonymous terms are not necessarily synonymous in every respect. Differences in terminology were explored through reconciling the explicit definitions documented in the glossary with usage reflected in various data sets and products. The accepted terms were augmented with the relationships inferred from other terminology in order to define complex terms that do not clearly distinguish between a specific logical concept and its geometric representation or between a general term and its specific conceptual meaning. The definitions used in the conceptual model described in this standard may be understood as a conceptual refining and/or narrowing of the definitions given in the WMO/UNESCO Glossary of Hydrology.

Though rooted in the definitions given in the WMO/UNESCO Glossary of Hydrology, many of the hydrologic features in this standard have been defined more specifically for relevance to the surface water domain. Some requirements defined in this standard refer to the Scoped Name concept of ISO 19103: Conceptual Schema and any such Scoped Name implementations should reflect if possible a name endorsed by the WMO.

## Naming convention

The HY-prefix used in the UML model follows the ISO naming conventions for UML elements. There is no explicit requirement to use this same name in a corresponding implemented term but conformance will require that each such term be clearly connected back to its corresponding conceptual model term.

# Clauses not Containing Normative Material

## Hydrology phenomena and the catchment concept

Processes that continuously deplete and replenish water resources cause or result in a wide range of phenomena that are the subject of monitoring, modeling and reporting in hydrology and related sciences. These distinctly named or otherwise uniquely identified real-world hydrologic phenomena are conceptualized as hydrologic features in this standard.

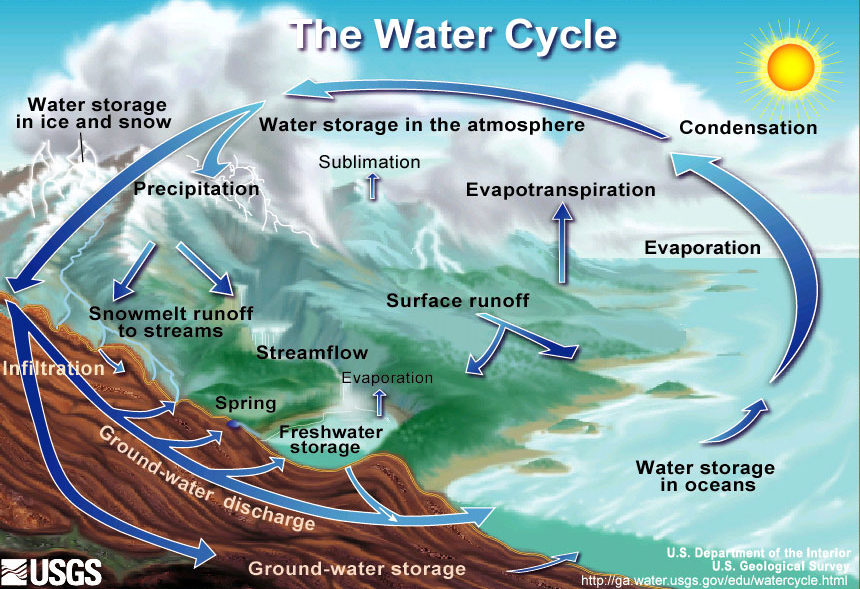


Figure 2: Processes of the Hydrologic Cycle

Water is moving from the atmosphere to the Earth and back to the atmosphere due to the processes forming the Water Cycle (Figure 2). Water from precipitation reaching the land surface is accumulated in water bodies occupying empty space on the land surface or in water bearing formations of soil and rock. Excess water overflows these formations and is driven downhill by gravity. Water flowing over soil or rock causes erosion to occur. This erosion tends to concentrate flowing water into water bodies that flow downhill using a connecting system of channels intersecting other water bodies along their way to a common outlet, conceptualized as a single outfall feature (although potentially complex or ambiguous in realization).

Looking back upstream from the outfall, the corresponding hydrological catchment feature draining to it can be characterized or realized geographically in alternate ways: as a main linear flowpath feature, an area feature, a boundary feature that encompasses the drained area, a network of water body features, a network of channel features, or a network of hydrometric stations. These concepts and terminology form the conceptual and semantic basis for this standard.

The most general conceptualization of hydrology phenomena is the catchment. A catchment is a recognized unit of study where hydrologic processes form physiographic features that are realized in various data products. In this specification, a catchment feature may be just an *identified* means of grouping hydrologic study activities and artifacts, referenced by name or within a set of catchments. A catchment may also be *realized* by catchment features and combinations of other hydrologic features whose geographic characteristics are in turn *represented* by one or more geometric and/or topological properties.

Depending on application and (spatial) scale, the same catchment may be realized in a number of different ways. The following are examples where this multiple realization pattern is important:

1. The most typical example is that scaling a map-visualization up or down leads to multiple more or less detailed representations of the same realized hydrologic feature, both in terms of geometry detail and network complexity.
2. Analyses and reports from different disciplines may reference differing spatial representations of the same conceptual catchment.
3. Some applications require cartographic (visual) representations while others are focused on topological (network connectivity) realizations only.
4. A catchment may be represented geometrically by streamline, drainage area/surface, bounding polygon, or stream network, and realized topologically as a face, or an edge.

Figure 3 illustrates some possible alternative catchment realizations.

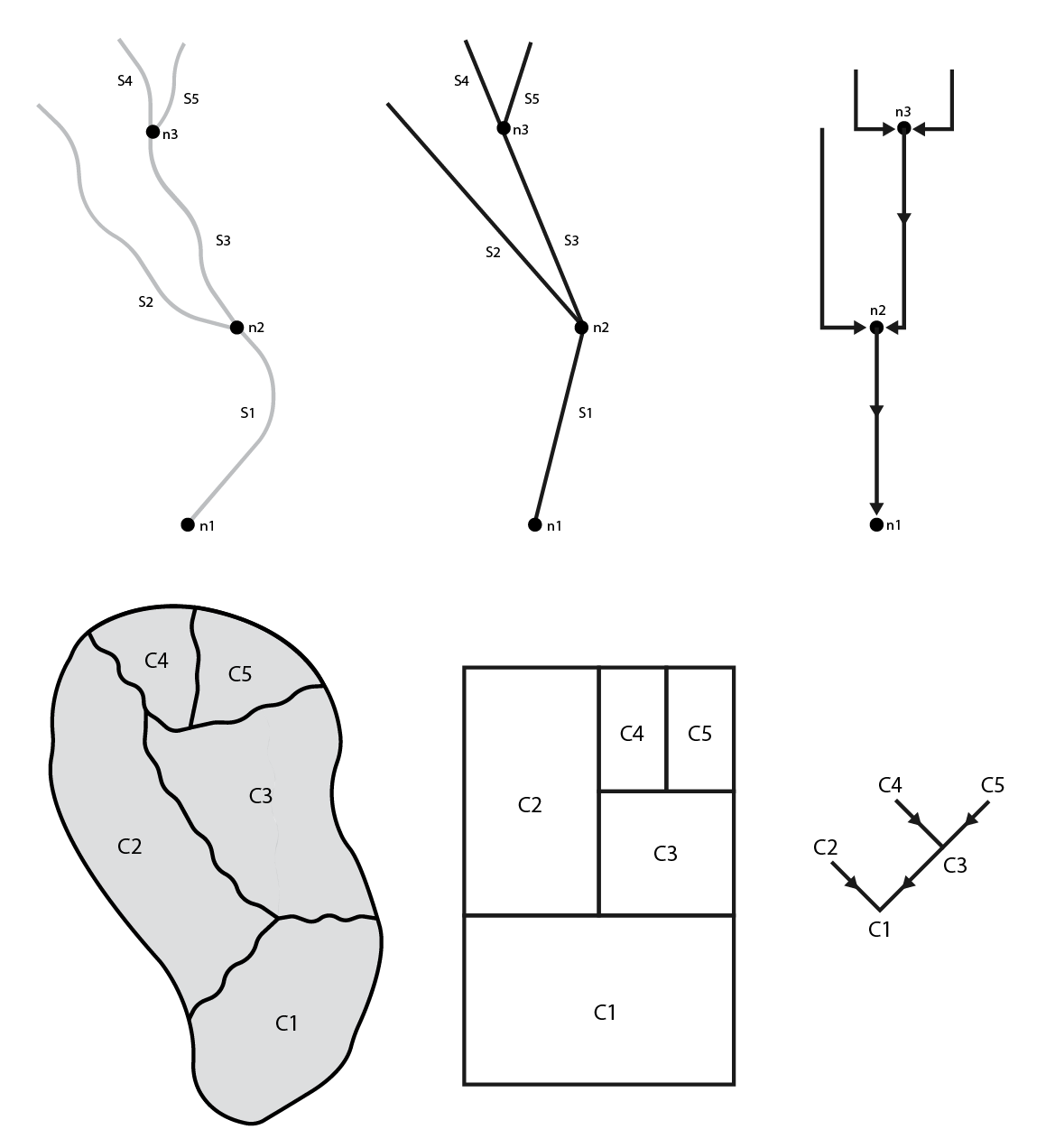


Figure 3: Illustration of multiple representations of a catchment

The catchment concept is still an important one even if it is not realized by another feature. It often serves as a recognized unit of water resources assessment and management across administrative jurisdictions. In multi-stakeholder collaboration and cross-domain research projects, catchments may be recognized as shared monitoring and reporting units. River monitoring stations are typically assigned to a recognized catchment; catchment inflow and outflow outfalls connect information between recognized catchments. Examples of organizational catchments include the "Hydrologic Unit Code" (HUC) catchments defined by the U.S. Geological Survey for research and regulatory data systems to use as a reference [7] and "River Basin Districts" of the European Water Framework Directive [1].

## Catchment realization

The core concept of the HY\_Features model is that studies of hydrology phenomena have a need to reference common conceptual entities of the hydrosphere such as catchment, outfall, water body, channel, or monitoring position, through the use of feature types defined in a specific model (as per ISO 19109 General Feature Model). Depending on the field of study or application, complex hydrology phenomena may be realized in different feature types. Recognizing the catchment as the holistic unit of study allows multiple feature realizations and the information they carry to be connected to the same conceptual entity.

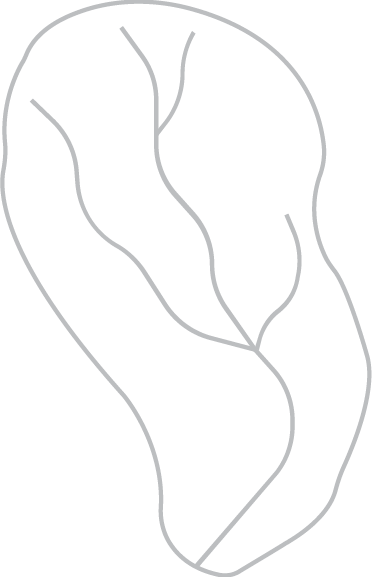


Figure 4: Idealized catchment concept independent of realization or representation.

Fundamental to the catchment concept is that each catchment is defined by and paired hydrologically with an outlet or *outfall* to which all catchment waters drain. Outfalls like catchments are themselves logical (un-realized) features and may be realized by single-point, complex, even diffuse or indistinct geographies. Systems of catchments and outfalls alone can still form a topological complex, however, based on recognition of their hydrologic connectivity, even if the topological elements are not or cannot be derived or demonstrated geometrically. Building on concepts of hydrological catchment topology and multiple catchment realizations, a collection of hydrologic features that realize a larger catchment can be said to form a *hydro complex* that is comprised by the collection of catchment and outfall features and any other feature(s) that realize the larger logical catchment and its outfall. A hydrologic complex may include multiple realized topologies such as flowpath, catchment area, stream or channel networks.

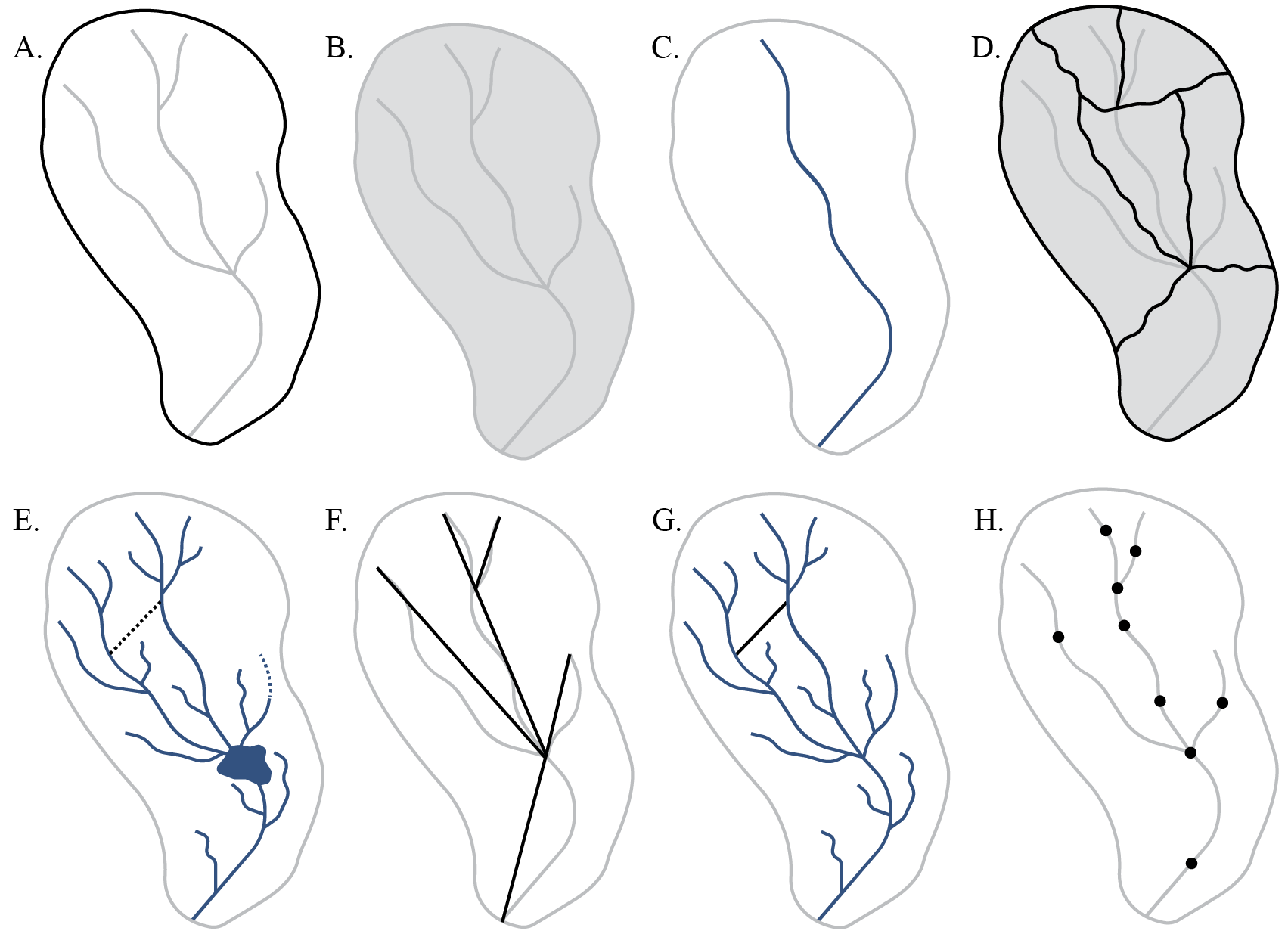


Figure 5: Multiple catchment realizations (top left to bottom right): a) catchment boundary, b) catchment area, c) catchment flowpath d) subcatchment network, e) hydrographic network, f) geo-schematic network, g) flow network, h) hydrometric network of monitoring stations.

Catchment boundary, catchment area, and linear flowpath are the most common topological realizations of a logical catchment, and are widely used to create cartographic representations of a catchment. Map layers that separately visualize the hydrographic network of water bodies (typically as blue lines for small rivers and blue polygons for larger rivers and lakes) or of channels (typically lines displaying a drainage pattern indicating the path that flow may follow), or a network of hydrometric monitoring stations, are usually combined to represent the catchment as a whole. Hydrographic maps are typically based on cartographic data products that portray one or more of these feature realizations. Figure 5 adds to the idealized catchment of Figure 4 graphical representations of such realizations.

Each of these realizations forms a different perspective of the catchment and its interactions with other catchments that emphasize different characteristics of the catchment. This may not be evident from the feature types alone. For example, a map of catchment polygons may portray a coverage of sub-catchments, or a collection of overlapping catchment polygons corresponding to monitoring stations. More detailed information is needed about each catchment’s type and role in an overall application, such as relationships and potential constraints between higher-order catchments and those nested therein, as well as their upstream-downstream outfall flow relationships. Topological networks of logical catchments without geometries are useful even by themselves, for example in data systems supporting hydrologic modeling. Geospatial data may be used to parameterize models that then run only using logical catchment relationships. The topological representation may not even correspond to geometric representations. For example, an outfall may take on the topological role of a node even as it is realized by a polygon geometry indicating a diffuse area of drainage.

Specific feature types defined in the HY\_Features model include HY\_HydroFeature (in clause 7.3.1), HY\_Catchment, HY\_Outfall, HY\_CatchmentRealization, HY\_OutfallRealization, HY\_CatchmentArea, HY\_CatchmentBoundary, HY\_Flowpath, HY\_WaterEdge, HY\_HydroNetwork and HY\_CartographicRealization (section 7.3.2).

## Catchment topology and hierarchy

An unlimited number of catchments can potentially be defined in any region since every point in that region corresponds to some catchment that drains to it. The most useful catchments, though, are generally those that are connected in drainage networks recognizing significant features of the terrain such as divides and confluences. Catchment networks provide continuity between catchments, the ability to aggregate catchments, and to trace flow up- or down-stream.

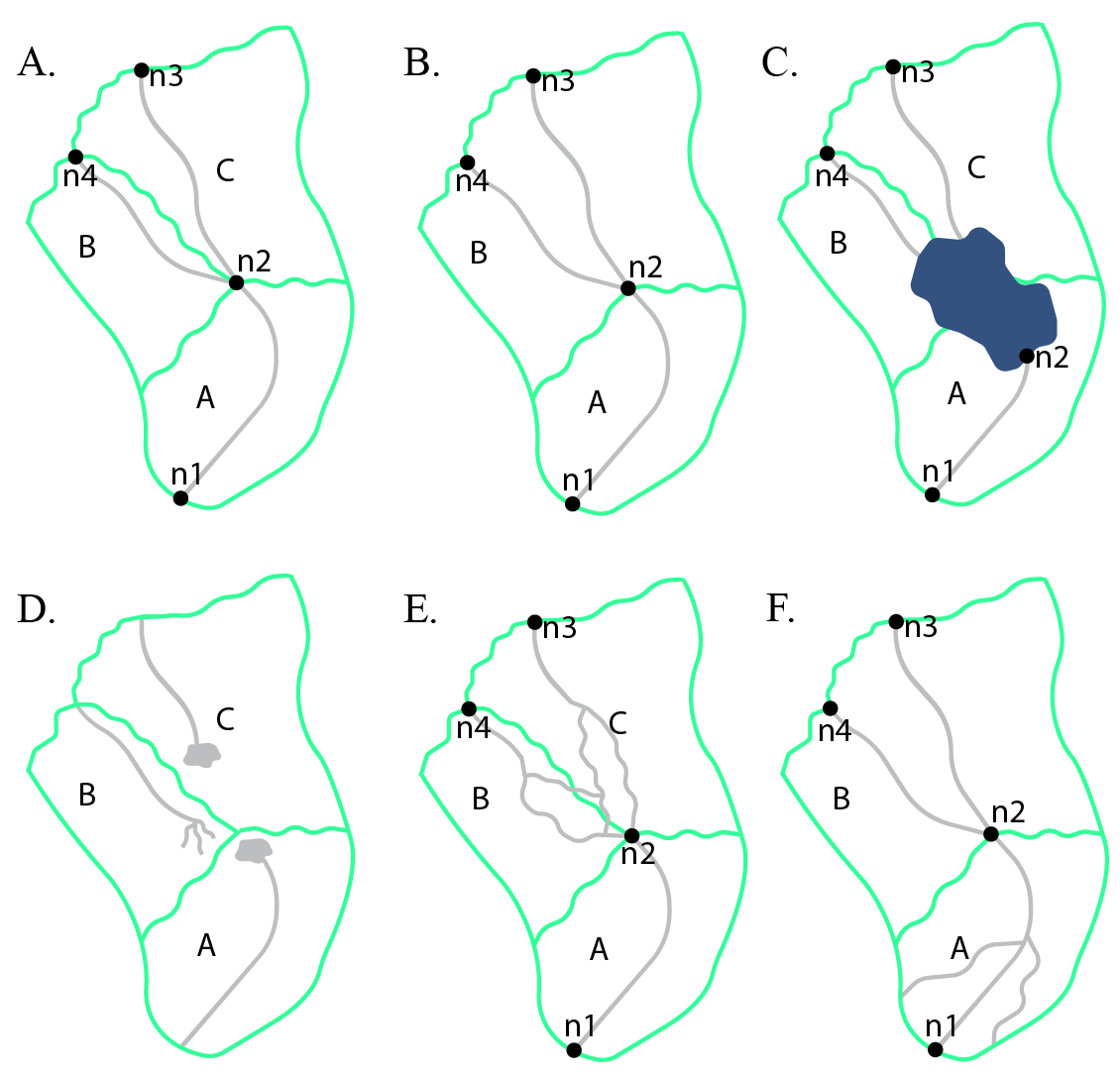


Figure 6: Catchment aggregation (top left to bottom right): a) Simple catchments with one inflow and one outflow each; b) Joined (conjoint) catchments flowing into a single downstream catchment; c) catchments joining in a water body or wetland with no clear network; d) catchments joining through intermittent or subsurface flows; e) catchments that join through areas of complex or braided channels; f, catchments with outfalls made up by many channels such as in a delta.

In a network of catchments, morphological detail may be specified in many ways. Inflows are generally conceptual in headwaters, and outflows are often complex where water flows out of a network. As shown in Figure 6 catchments may connect through simple confluences (Figure 6a), water bodies or wetlands (Figure 6c), intermittent or subsurface flows (Figure 6d), or complex braided streams (Figure 6e), or distributary systems like deltas (Figure 6f). In some situations, diffuse (multiple) inflows can be conceptually joined in a ‘conjoint’ catchment (Figure 6b) and spread (multiple) outflows may be joined in a catchment flowing out at a single, logical outflow (Figure 6e). Although these cases require different geographic representations, they can be realized using the same pattern of the catchment and its common outlet. Since all these cases can be specified referencing a simple edge-node catchment topology, no special treatment is required to handle the variation of flow processes.

Any catchment may also be nested in a larger containing catchment or split into multiple sub units to define catchment hierarchies. Two types of catchment hierarchical relations are supported in HY\_Features: basic nesting and dendritic aggregation. Basic nesting allows any catchment to reference a containing catchment (Figure 7) without defining any particular interconnections between the two. Dendritic aggregations (Figure 8) consist of specialized dendritic catchments that contribute exorheic flow to an outlet and support simple topological relationships that allow determination of flow from upstream to downstream catchments. Specialized interior catchments add support for endorheic flow or interior drainage within dendritic aggregations.

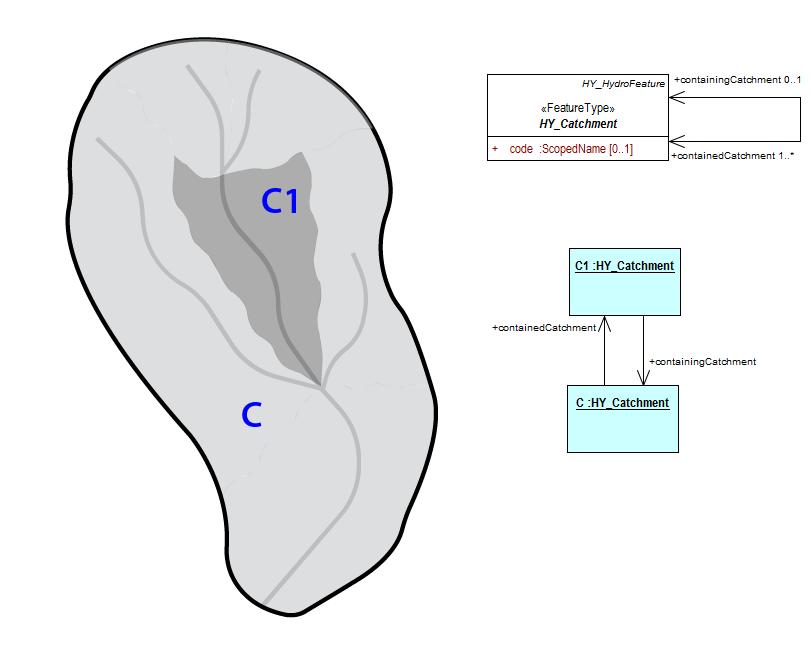


Figure 7: Catchment hierarchy, with one catchment (dark grey) nested within another catchment (light grey)

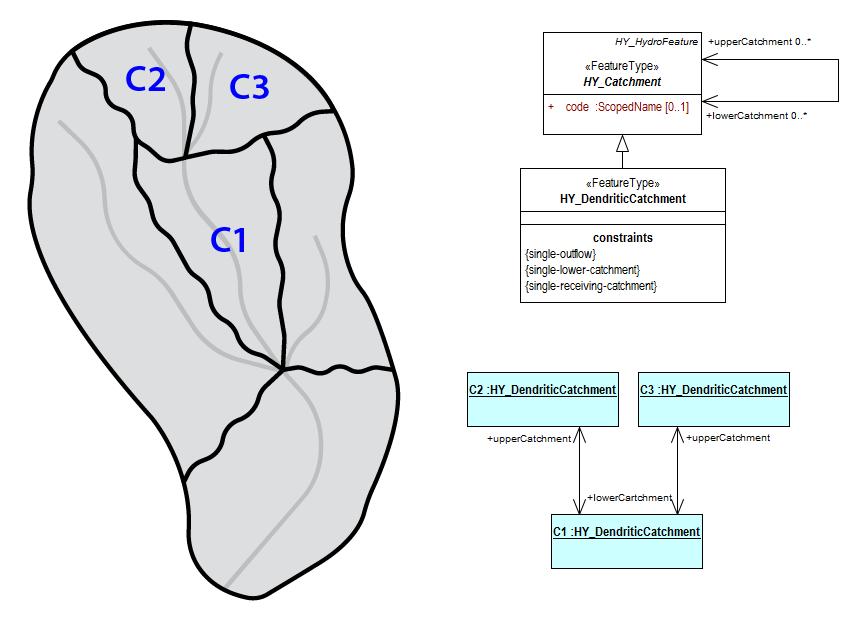


Figure 8: Catchment hierarchy with smaller catchments (C1, C2, C3) part of a dendritic catchment network, which is also a catchment

## Catchment network realization

Catchments can be realized by a number of feature types. Networks of catchments interacting at outfalls can be realized as networks of specific catchment realizations. For example, a network of catchments, each realized as a flowpath, can also be realized as the network of linear flowpaths connected by outfall nodes. Figure 9 illustrates how a single catchment C1 (dark grey boundary line, light grey catchment area), is also realized by the flowpath connecting its outlet N1 (Figure 10) and inlet N2 (Figure 11). The flowpath geometry trace the main flow stem in the catchment or it could be a purely schematic straight-line representation of a topological edge.

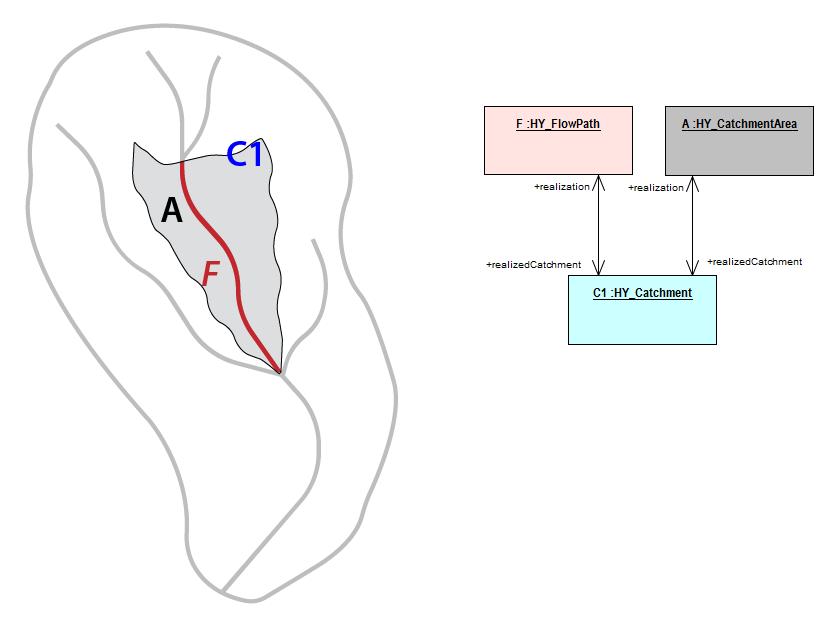


Figure 9: Catchment area (grey) and flowpath realizations that connect catchment inflow to outflow (red) and define a hydrologically significant unit.

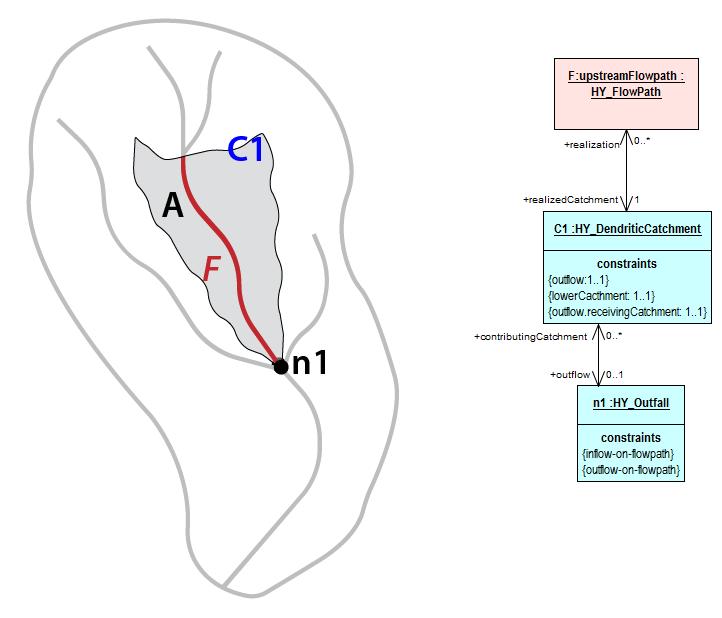


Figure 10: Multiple catchments contributing to a common outflow node.

In a network of such dendritic catchments, one or more catchments may contribute to a given outflow but an outflow contributes to only one receiving catchment. This topological relationship is maintained regardless of the geometric representation of a given outfall. The association role names *inflow* and *outflow* are used to unambiguously describe the flow direction of an outfall (or realization) with respect to a catchment (or realization).

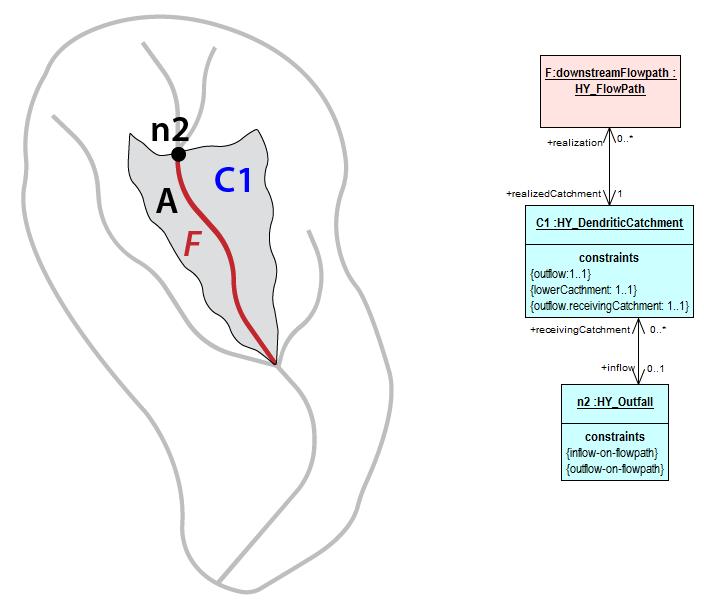


Figure 11: Catchment receiving inflow via an identified but not necessarily realized node (Outfall).

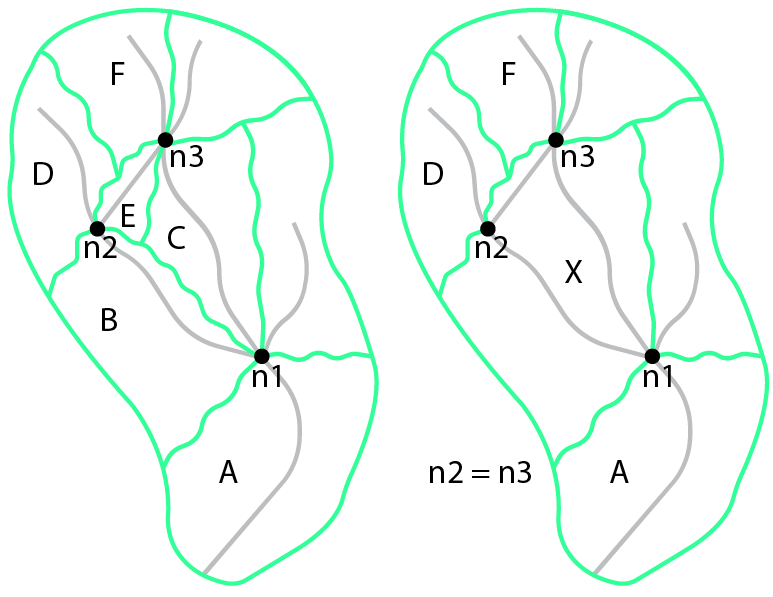


Figure 12: Non-dendritic stream network complexity: a) ambiguous detailed flow: b) unambiguous aggregated flow.

Catchment networks that appear non-dendritic, such as broad river bottoms with complex braided channels and two or more primary inflows, can still be modeled as dendritic networks by introducing conjoint catchments that encapsulate the non-dendritic parts. Figure 12 shows an example of a non-dendritic stream network, where it is not possible to determine to what extent flow from catchment F contributes to catchments E, B or C (Figure 12a). Aggregating the catchments E, B, and C (Figure 12b) and collapsing the nodes n2 and n3 into a single virtual inflow node, accumulates all the flow from catchments D and F in the resulting catchment X contributing inflow into catchment A via the node n1. Using this encapsulation approach, catchments can be represented using a simple tree structure with clear upstream-downstream relations.

The topological pattern of a hydrologically connected catchment network is reflected in the topological patterns of all of its realizations, although the topological “level” of a realization may be different. A catchment may be topologically realized as a solid bounded by inflow/outflow faces, a face bounded by inflow/outflow edges, or an edge bounded by inflow/outflow nodes. A single catchment may also be realized as a topo complex consisting of all of the stream or channel edges and outfall nodes forming the surface drainage of that catchment. The topological role that each feature realization plays may or may not correspond directly to its geometric representation. For example, a pond feature plays the role of an edge between its inlet and outlet, but may be represented geometrically as a polygon.

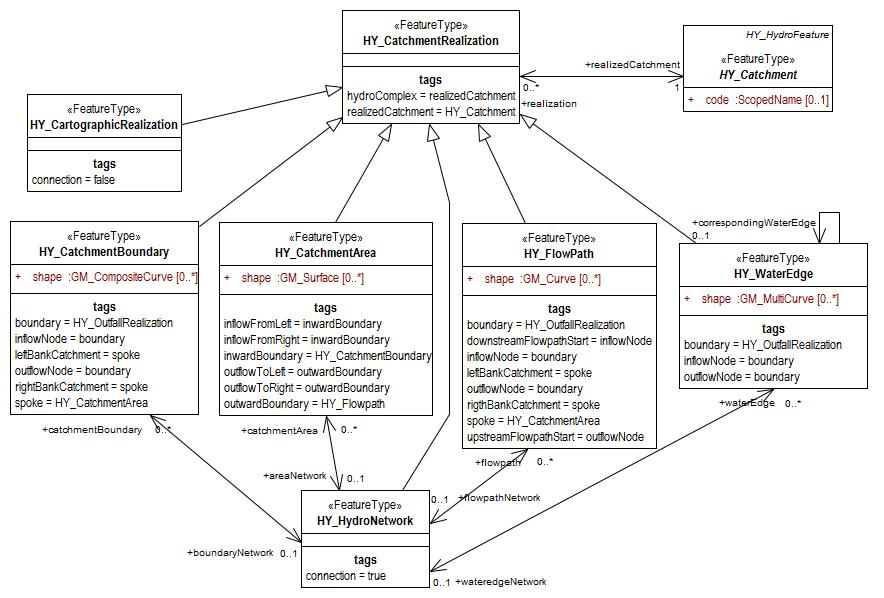


Figure 13: Catchment realization feature types with tagged values indicating possible catchment topological relations

Figure 13 illustrates this by means of ‘tagged values’ that describe some of the topological roles and connectivity relations that realized features may support with respect to other features. For example, the flowpath that realizes a catchment as topological edge has inflow and outflow outfall nodes as boundaries, and may simultaneously form the outflow-edge boundary of a left- or right-bank catchment area, which realizes the catchment as a topological face.

## Surface water networks

Maps displaying a representation of a catchment are very common in hydrology research and engineering. Depending on the scientific concern and application, as well as the spatial scale of interest, different aspects and details of hydrology phenomena may be represented using application-specific map symbols. HY\_Features accommodates this diversity with multiple alternate realizations of the catchment and outfall concepts which in turn may be represented alternately as geometric points, lines, polygons, or surfaces, or as aggregates of these geometric types. This standard is based on a hydrologically determined topology model of directed outfalls acting as inflow or outflow nodes for catchments which in turn connect them. The topological catchment network pattern can be realized in a variety of context-specific feature networks, especially hydrographic networks of water bodies or channels that may contain water bodies; These features may in turn have a variety of scale- and application-specific geometric representations. For example, a fixed landmark point on a water body, or a cross-section line separating a watercourse can each represent realized outfall nodes.

### Hydrographic and channel network

Surface water flows in networks, and so hydrographic data is commonly organized into those same networks. Surface water networks are also self-similar. The patterns of rivers and deltas visible at a continental scale resolve continuously into similar but more detailed nested networks of streams, lakes, confluences, and other features as the spatial scale of mapping and inquiry increases. The HY\_Features model of catchment hierarchies and nested network realizations is intended to address the scale discontinuities of existing models and connect hydrologic phenomena and observations across a range of the scales.

The basic elements of surface water networks at any scale are *waterbodies* and the *channels* through which they flow and in which they are contained. Following the definitions in the UNESCO-WMO "International Glossary of Hydrology" [9] a water body is understood as the mass of liquid water accumulated on or below the land surface as a body of flowing water, which in some parts may have stagnant water that is not moving or flowing. The water body concept formalized in this specification is consistent with this definition, but focuses on surface-water bodies only. A conceptual model capturing the specifics of bodies of groundwater as well as aquifers containing groundwater are provided by the WaterML2 Part 4 - GroundwaterML2 specification [6]. A future WaterML2 specification part is expected to complete the sub-atmospheric hydrologic cycle by addressing features such as recharge zones and springs that connect groundwater with surface water phenomena.

A watercourse is commonly understood as a type of natural or man-made channel through or along which water may or may not flow [9]. A waterbody is generally a flowing body of water contained in a natural watercourse, but could also be in a man-made open or closed conduit [9]. A network (or drainage pattern) of watercourse channels exists independent of whether it contains water at a particular time (but not independent of the existence of water). The HY\_Features conceptual model accommodates both targets of hydrologic study by defining separately and then linking together waterbody features and containing land surface features. **Note that flow-through or standing lakes and similar features are considered to be types of waterbodies whose container is a depression.**

Connected waterbodies with their associated water courses make up in aggregate the hydrographic and channel networks that realize the catchment that the networks drain. Individual waterbodies themselves can also be characterized in more detail along vertical cross- or longitudinal sections as well as within horizontal strata as to their distinct thermal, salinity, oxygen, and nutrient characteristics, etc. Waterbodies or their strata may be also be recognized as storage reservoir features for future water use, regulation, or control. Strata in turn correspond to water edge features that indicate the extent of channel filling at different water levels or flows.

In order to form hydrographic or channel networks, waterbodies or channels representing topological edges need to be connected by way of topological nodes. Although an entire network realizes the catchment that it drains to a single outfall, each node connecting waterbodies or channels is also an outfall that drains the sub-catchment that feeds that waterbody. The HY\_Features model therefore associates the connections between waterbodies with outfall realizations or nodes; catchment relationships defined in the model can be used for both the larger catchment realized by the whole hydrographic network and the catchment(s) whose outfalls are used to connect waterbodies within the hydrographic network.

It is common practice to realize a catchment as a single main-stem flowpath (Figure 5c) as well as a complete hydrographic or channel network. There is some choice in which catchments to delineate and realize in this way. Some elevation-derived hydrographic datasets define one or more associated drainage catchments for each stream segment connecting two confluences. Others identify main-stem rivers that flow from their headwaters to a common outlet. In either case, the corresponding catchment typically carries the name of the main river and its outlet is considered the mouth of the river. The main stem flowpath serves as both a component of the stream network realizing a catchment and as a standalone realization linking the inlets and outlet of that catchment. Networks of flowpaths and outfall nodes can in turn realize larger catchment networks. At small scales, complex networks of watercourses can have one main-stem flowpath made up of many smaller scale reaches. At large scales a network made up of one reach also serves as the single main flowpath.

Specific HY\_Features classes supporting surface water networks include: HY\_ChannelNetwork, HY\_Channel, HY\_Depression (in clause 7.4.1), HY\_HydrographicNetwork, HY\_WaterBody, HY\_WaterBodyStratum, HY\_CrossSection, HY\_LongitudinalSection, HY\_Water\_LiquidPhase, and HY\_Water\_SolidPhase (in clause 7.4.2).

### Hydrometric network

Water bodies are observed using monitoring stations which are typically physical locations with a well-established cross section they monitor. It is common practice to locate a monitoring station in relation to local landmarks and permanent reference points along a stream or in relation to the outlet of the monitored water body. The river reference system, described in clause 7.3.3, gives a mechanism to locate such points in relation to establish catchment outfall locations such as confluences. When aggregated into a network, monitoring stations within a catchment can be said to make up a logically connected hydrometric network which monitors a catchment.

For the purpose of linking identified monitoring stations, (thought to be the sampling feature in terms of the observations and measurements standard) and a river or other hydrologic feature (thought to be the domain or sampled feature in terms of observations and measurements) a specific hydrometric feature participating in a hydrometric network is defined. The monitoring feature role of hydrometric features is unique in contrast to all other outfall realizations in HY\_Features, which would be used as observed domain features in observations and measurements.

Specific HY\_Features classes supporting hydrometric networks include: HY\_HydrometricNetwork and HY\_HydrometricFeature described in clause 7.5 of this standard.

## Indirect Position and river reference system

It is common practice in hydrology to add new features (typically observation stations, but also designated reaches, or flood plain zones) to an existing network of such features, and to reference such features along a watercourse. Recognizing any identified location on a network as the outflow of a contributing catchment, or the inflow of a receiving catchment, an arbitrary new location can be placed on the network based on catchment topology alone through reference to an existing outfall upstream or downstream. Understanding such a reference as a positioning ’along a river’, the one-dimensional flowpath realization of a catchment can be used for linear referencing. This concept of indirect position requires a ‘referencing along a river’ providing a specific linear coordinate system, and a local datum which defines its origin and direction in relation to the linear feature, on which the feature is to be placed.

The HY\_Features conceptual model defines a river reference system which has three components: 1) an origin at an outfall, either inflow or outflow of a catchment; 2) a linear shape defined by the flowpath of a catchment that starts at the origin; and 3) a linear distance or relative (percentage) measure. Each catchment has its own reference system which can be combined as necessary using catchment topology; each river reference system must have one outfall (origin) and one representing flowpath (shape).

### River reference system

This standard defines a simple linear river reference system using the one-dimensional topological realization of a catchment as its linear element and the outfall of the realized catchment as its origin. Recognizing the feature of interest as outfall of a corresponding catchment, the unknown position of this outfall can be determined relative to an already existing outfall used as reference location.

Each outfall is potentially the origin of a river reference system owned by the realized catchment. The orientation of the flowpath axis is always from that origin towards the known reference location, and always declared in relation to the catchment realized by the flowpath. This given, the river reference system defined by a contributing catchment has its origin at outflow node and a flowpath axis directed towards a known inflow node, vice versa a receiving catchment sets up an origin at inflow node from where the flowpath axis is directed to a known outflow node. A flowpath realizes only one single catchment, either a contributing catchment whose outflow can be located through referencing an upstream located inflow, or a receiving catchment having an inflow located through referencing a downstream located outflow. In Figure 14 the downstream flowpath is shown that starts at the inflow node and is directed towards a downstream outflow node.

It is important to note, that the flowpath reflects the topological pattern of a catchment ‘bounded’ by inflow and outflow, and does not necessarily reflect the direction of the natural flow. Forming the logical axis connecting the outfall to be placed with the outfall being referenced, a flowpath ending at an outflow node downstream of its start, is termed as ‘downstream flowpath’ with a known ‘downstream end’, and a flowpath having an known ‘upstream end’ at an inflow node is called an ‘upstream flowpath’. For example, Figure 15 shows an outfall (being placed) along an upstream flowpath referencing an upstream inflow node, or along a downstream flowpath referencing a downstream outflow node.

The position is provided as the distance from the known, downstream or upstream, flowpath end, or as percentage of the entire distance. In order to use an interpolative (percentage along a flowpath) linear referencing method, the flowpath used as the linear element must be bounded by an inflow and outflow node, whereby one of these must be the origin.

### Indirect position

Provided that the network of catchments is realized as network of its topological realizations, and that each catchment is realized as a one-dimensional flowpath, a feature of interest can be located in the network along such a ‘linear’ realization. This is possible considering that any location on the land surface can be an outfall of a logical catchment. In this case, the new location is placed as (outfall) node bounding the flowpath at one side and references an already established (outfall) node bounding the same flowpath at the other side. The new location is expressed as distance along that flowpath ‘measured’ from the known flowpath end as shown in Figure 14 for a downstream flowpath along which the position of the inflow node is expressed as distance from the known outflow node.

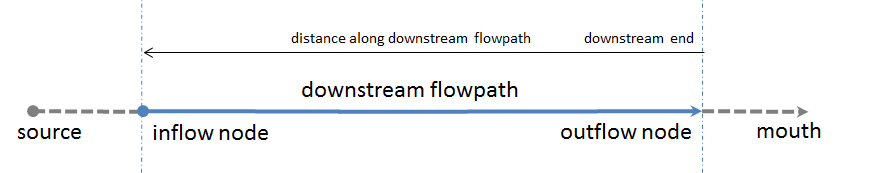


Figure 14: Inflow node referenced along a downstream flowpath

#### Location of features realizing a catchment outfall

In case that the location to be placed is declared to be a new outfall inside an existing network, the already existing catchment will be split into catchments upstream and downstream of the ‘new’ outfall, each realized as one-dimensional flowpath. The upstream catchment is realized as a flowpath starting at the location to be placed referencing the already located inflow of the now split catchment; the downstream catchment by a flowpath starting also at the new location, but referencing the located outflow of the split catchment. The unknown position of the outfall being placed is provided as the distance from the referenced location at the flowpath end. In this way a position may be assigned to any outfall. Figure 15 shows a newly introduced outfall (either as inflow or outflow node) referenced along the upstream and downstream flowpath realizing the split catchment. The indirect position is given as distance either from the upstream or the downstream flowpath end.

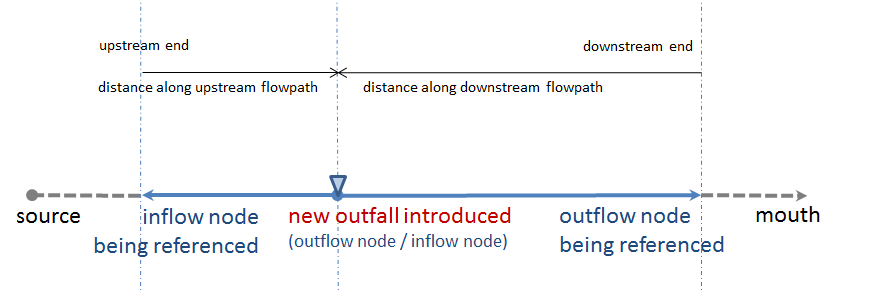


Figure 15: Newly introduced outfall referenced along an upstream and downstream flowpath

#### Location of features not realizing a catchment outfall

In case that the location being placed not realizes a catchment outfall as inflow or outflow node, the catchment realized as the flowpath will not be split, and referencing is along that single flowpath. The indirect position is expressed as part of the known distance between the inflow node and the outflow node, measured from the flowpath end. Figure 16 shows a new feature being located along a downstream flowpath, expressed as part distance measured from the downstream outflow node. Similarly, the new location may be determined along an upstream flowpath referencing the inflow node.

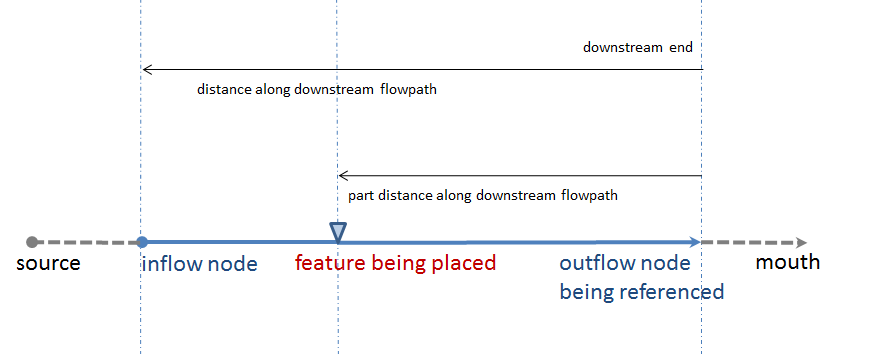


Figure 16: New location referenced along a downstream flowpath, expressed as part of the known distance from outflow node

#### Location of features referencing feature not realizing an outfall

In case that the location being referenced not realizes a catchment outfall as inflow or outflow node, the indirect position is expressed as part of the distance along the flowpath, measured from such an already referenced location (located referent) towards the feature being placed. Figure 17 shows a new feature located along a downstream flowpath referencing a downstream referent that is located along the same flowpath through referencing the outflow node. Similarly, the new location may be determined along an upstream flowpath referencing an upstream referent.

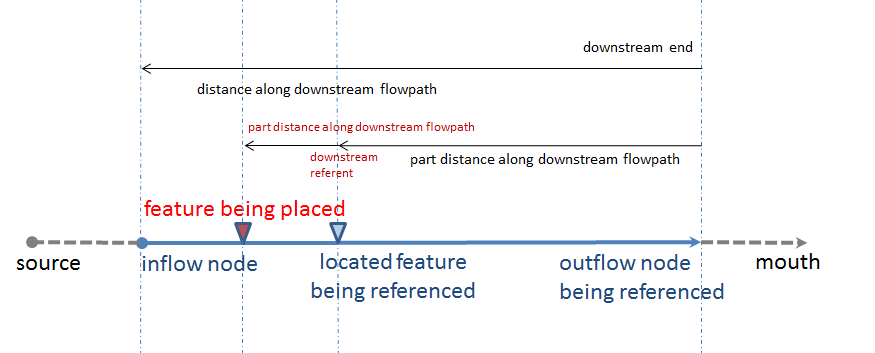


Figure 17: New location referenced along a downstream flowpath, expressed as part of the known distance from outflow node

#### Location of features in a flowpath network

In the flowpath network realizing a logical network of catchments a feature of interest can be located somewhere along a particular network flowpath, either as new inflow or outflow node bounding the flowpath at one end referencing the other end, or between both flowpath ends referencing these or an already referenced location on that flowpath. Figure 18, illustrates how a newly introduced network location can be located along an upstream flowpath, as an outflow node ‘n1’ referencing a known inflow node ‘r2’. Figure 19 shows the location along a downstream flowpath referencing a known outflow node ‘r1’.

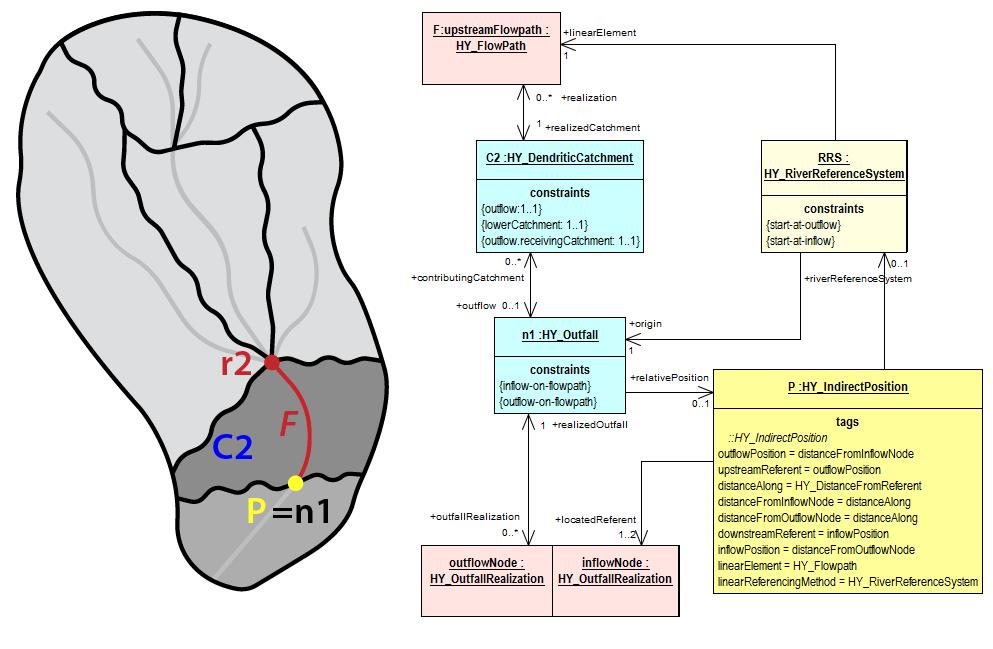


Figure 18: Position (yellow dot) of an outflow node referencing an inflow node, expressed as a measured distance from a upstream referent (red dot).

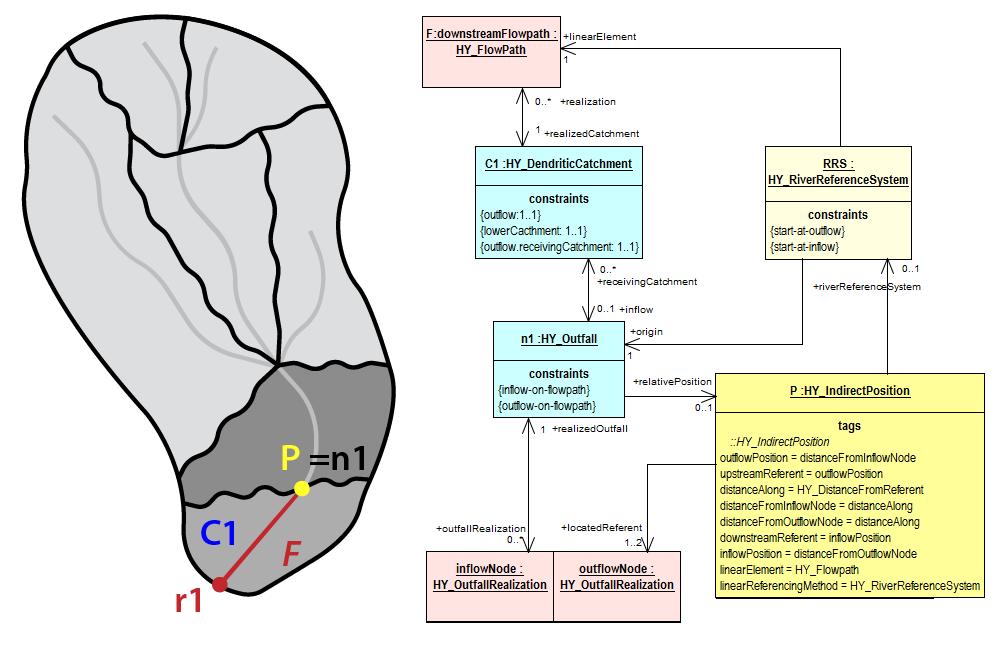


Figure 19: Position (yellow dot) of an inflow node relative to an outflow node, determined along a downstream flowpath, expressed as a measured distance from a downstream referent (red dot).

Figure 20 illustrates how the position of a new location can be determined as part the known distance between inflow and outflow nodes bounding a flowpath in upstream and downstream direction, whereby the origin where the flowpath starts is set at one of these, and directed to the other outfall upstream or downstream of this. This approach may be used in the case that the new location itself is not declared to be an inflow or outflow of a catchment.

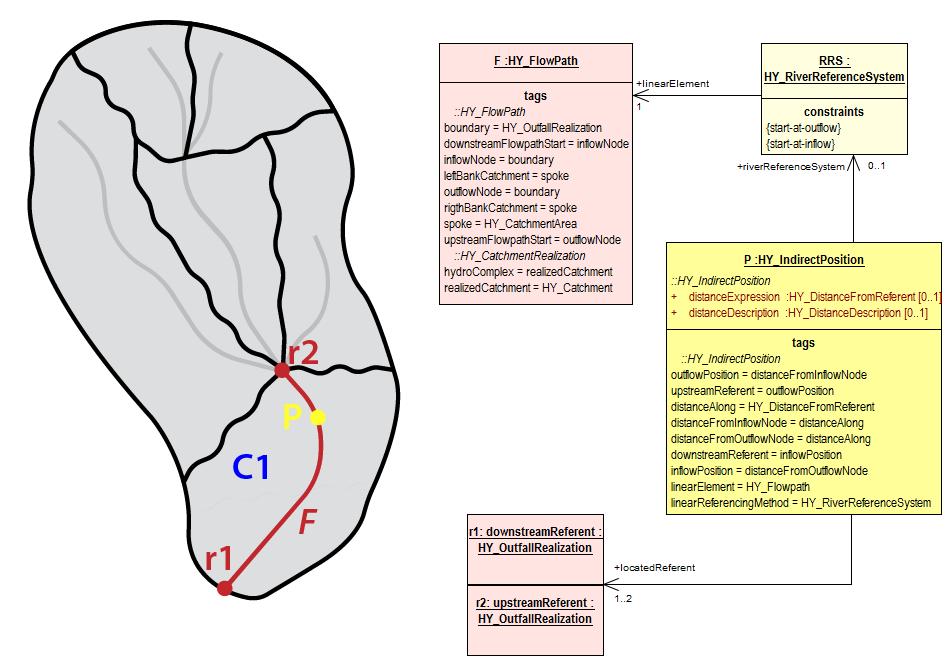


Figure 20: Intermediate Position (yellow dot) between known inflow and outflow nodes, expressed as distance from a located upstream or downstream referent (red dots).

The UML diagrams shown in Figure 18-20 illustrate by means of ‘tagged values’ that the river positioning system defined in this standard generally corresponds with the OGC standard model for Linear Referencing which is considered as the general framework to assign a position to a feature of interest along a hydrologic feature. The ‘tags’ in the UML specify fundamental properties of a linear referencing along a flowpath to express the referenced location as distance from a located referent which may be the known inflow or outflow node but also another referenced location. For example, an ‘inflow-position’ (P=n1 in Figure 19) may be expressed as the ‘distance-from-outflow-node’ (r1) specifying a ‘distance-along’ flowpath. Combining this use case with that displayed in Figure 20, a linearly referenced ‘inflow-position’ (P=n1) may form the already located ‘downstream-referent’ referenced by the new position (P).

Specific HY\_Features classes supporting the referencing ‘along a river’ include HY\_RiverReferenceSystem, HY\_IndirectPosition, HY\_DistanceFromReferent and HY\_DistanceDescription described in clause 7.3.3 of this standard

Table 1 provides a descriptive ‘mapping’ intended to provide a basic understanding of how the HY\_Features river positioning system may specify the OGC standard Linear referencing model. The river positioning system is described in detail in clause 7.3.3 of this standard, the OGC linear referencing model within the OGC Abstract Specification Topic 19, Linear referencing (aka ISO/FDIS19148:2011).

Table 1: HY\_Features river positioning concepts comparable with the OGC Linear referencing model

|  |  |  |
| --- | --- | --- |
| **HY\_Features concept**  (internal HYF reference) | **Description** | **OGC LR concept**  (internal LR reference) |
| **River Positioning System** (leaf package), describing the system applied to place a feature on a (linear) watercourse feature . The feature location is specified as an indirect position expressed as distance along the watercourse on which the feature is to be placed. | A (hydrologic) feature of interest which is located along the locating one-dimensional flowpath referencing inflow and outflow nodes bounding that flowpath, corresponds in general to the linear referencing along a linear element described in the OGC standard model for Linear referencing. | **Linear Referencing model** (leaf package),  specification of a location relative to a linear element as a measurement along that element. This model describes allocation as position expressed as distance along a linear element. |
| **Indirect Position** (7.3.3.1), position expressing the location of a feature relative to the known location of another feature along a logical axis,  associates the *distance expression* and *distance description*, and associates a *located referent* and the *river reference system* which defines the linear element, | Feature that specifies a location referenced along a ‘linear’ hydrologic feature using a catchment-specific reference system.  Indirect position is expressed as distance from a located referent upstream or downstream of the feature of interest, or as a term describing this distance. | **Position Expression** (6.2.2.1) specifies a linearly referenced location. Fundamental properties are ‘linear element’, ‘LRM’ [linear referencing method] and ‘distance expression’. |
| **River Reference System** (7.3.3.2 ) catchment-specific reference system in which the one-dimensional topological realization of a catchment forms the logical (linear) axis, and the origin is located at the outfall of the realized catchment,  associates the *origin* and the *linear element* | Feature that defines the one-dimensional flowpath as the linear element along which the feature can be located, and the outfall as the origin where the flowpath starts.  The river reference system may be understood as a hydrology-specific linear referencing method applied to specify a location along a linear hydrologic feature. | **Linear Referencing Method** (6.1.1.3) specifies how a linear element is measured. by ‘name’, ‘type’, ‘units’ and optional ‘constraints’. |
| **Flowpath** (7.3.2.6), one-dimensional feature that realizes a logical catchment in terms of a topological edge bounded by inflow and outflow nodes realizing the corresponding outfall,  associates the *realized catchment* | one-dimensional topological realization of a catchment forming the linear element along which an indirect position is determined. | **Linear Element** (6.1.1.2) describes a feature that can be measured in a linear, one-dimensional, sense, incl. linear topological features such instances of directed edges. |
| **Outfall** (7.3.2.5), logical outlet of the water contained by a catchment,  the logical place where a catchment interacts with another catchment,  associates a *relative position* | Feature being located, i.e. whose indirect position is specified by referencing a known, referenced location along the one-dimensional flowpath.  The outfall may be understood as a linearly located ‘feature event’, that ‘occurs’ somewhere in the logical network of catchments which is realized as a network of its linear realizations. | Linearly located **Feature** (6.1.1.5) that is located along an associated locating feature using a linear referencing system. A feature linearly located specifies where along the locating feature the located feature occurs (feature event) |
| **Outfall Realization** (7.3.2.7), hydrologic feature that realizes the logical outlet,  the topological (0-dimensional) realization as inflow or outflow node forms the boundary of the flowpath realizing the corresponding catchment,  associates the *realized outfall* | Feature being referenced that is already located on the flowpath along which an indirect position is determined.  The feature being referenced can be the inflow or outflow node located at one end of the flowpath, but also any other referenced location on the flowpath between the inflow node and the outflow node. | **Referent** (6.1.1.4.2) specifies a known, already referenced location on the linear element, which is not its start, ‘from’ where a distance along can be measured. |
| **Distance From Referent** (7.3.3.3), distance from a located referent as an absolute or interpolative value. | Data type, expressing an indirect position value as distance along the flowpath ‘measured’ from a referent located at its upstream or downstream end, or elsewhere on the flowpath. | **Distance Expression** (6.1.1.4) specifies the measured value from the start, or another known location, on the linear element along that element. |
| **Distance Description** (Table B.2), describes the spatial relation between two locations | Terms common in hydrology to describe the distance between a location being placed and a location being referenced. These terms may be used to express an offset the distance expression may have. | **Offset** (6.1.1.4.3) qualifies the distance expression with respect to locations not directly located on the linear element. |

### Network navigation

Thinking about catchments realized as topological edges bounded by outfall nodes, a dendritic network of catchments may be traced upstream from the sea or a sink to the inflow/outflow nodes of (multiple) upper catchments. From there, one can navigate further ‘upstream’ eventually arriving at the outflow node of the headwater catchments. Starting at a spring, the catchment network can be traced in the ‘downstream’ direction, first to the single outflow node to which the catchment contributes then further downstream eventually arriving at the inflow node of a branching (non-dendritic), estuary or delta. In a given realization, a sequence of linear flowpaths, each realizing a catchment connected in the catchment network, may be drawn as streams or watercourses, which may or may not be geometrically connected in the representation. For example, water bodies and channel parts of a particular network may be displayed using different geometric shapes, and may look connected on a map even if they are not.

The network navigation approach described here corresponds generally to the standard network (navigation) model defined within ISO 19133: Location-based services – Tracking and navigation – which is considered as a general framework to trace a dendritic network of catchments. Provided that a catchment is topologically realized comparable with the ISO topology model as directed edge (flowpath) and the outfall as directed (inflow/outflow) node, the catchment network (as well as its hydrographic, geomorphologic or hydrometric realizations) can be navigated comparable with the concepts of the ISO network (navigation) model. With reference to catchment topology, this allows to navigate from realized outfall to realized outfall along the flowpath, from fixed landmark to fixed landmark along a water body, from section to section along a channel, or from station to station along a virtual line.

In terms of network navigation, the hydrographic, channel or station network can be thought of as a set of junctions and links that connect these junctions. The realization of an inflow/outflow node is comparable with the 0-dimensional junction associating ‘incoming and outgoing links’, and the flowpath is comparable with 1-dimensional link associated with a ‘start’ and an ‘end’ set by the inflow or outflow node.

Table 2 provides a descriptive ‘mapping’ intended to provide a basic understanding of how the HY\_Features network navigation may specify the Tracking and navigation model.

Table 2: HY\_Features concepts comparable with the OGC Network navigation model

|  |  |  |
| --- | --- | --- |
| **HY\_Features concept**  (internal HYF reference) | **Description** | **ISO 19133 concept**  (internal NT reference) |
| Catchment network realization (6.4), aggregate of hydrologic features realizing a logical catchment | The logical network of catchments interacting at outfalls can be realized as networks of specific catchment realizations. The network of one-dimensional flowpaths connected by 0-dimensional inflow/outflow nodes can be understood as navigation network. | Network (4.17), abstract structure consisting of a set of 0-dimensional objects called junctions, and a set of 1-dimensional objects called links that connect the junctions, each link being associated with a start (origin, source) junction and end (destination, sink) junction |
| Flowpath (7.3.2.6), one-dimensional feature that realizes a logical catchment, associates the *realized catchment* | The topological realization an directed edge bounded by inflow and outflow nodes can be understood as a connecting link between junctions. | Link (4.8),  directed topological connection between two junctions consisting of an edge and a direction |
| Outfall Realization (7.3.2.5), hydrologic feature that realizes the logical outlet, associates the *realized outfall* | The topological (0-dimensional) realization as inflow or outflow node forming the boundary of the flowpath realizing the corresponding catchment, can be understood as junction. | Junction (4.6),  single topological node in a network with its associated collection of turns, incoming and outgoing links |

# Clause containing normative material

## The HY\_Features conceptual model

This standard defines the HY\_Features conceptual model as a standard for the identification and description of hydrologic features reflecting both hydrologic significance and topological connectivity of hydrologic features. HY\_Features formalizes the fundamental relationships between components of the hydrosphere describing the hydrosphere as a hierarchical network of hydrologically connected catchments, the various realizations a catchment may have and the organization in networks of catchments, waterbodies or channels.

Core concepts of HY\_Features are: 1) an abstract idea of 'catchment' which has many possible geometric and/or topological feature realizations, 2) catchments realized as networks of watercourse and stream features, and 3) linear referencing of river positions using a nominal main flow path. The single concept that governs HY\_Features is the hydrologically determined union of a catchment and its outfall: any place on the land surface can be considered the outfall of a corresponding catchment. Catchments and outfalls together form the basis of networks of connected, usually named, hydrologic features.

The conceptual model elements are grouped into three modules. A model implementation may include any or all feature concepts included in any module, include or exclude feature properties, and allow changing cardinality of one or more associations to ‘nillable’, expressing that these logically exist but are not realized in a particular implementation. Table 3 lists the modules, the leaf packages included in each, and the concepts reflected therein.

Table 3: HY\_Features modules, concepts reflected, and leaf packages included

|  |  |  |
| --- | --- | --- |
| **Application schema** | **Concepts reflected** | **Leaf packages included** |
| HY\_HydroFeature | fundamental properties and relationships between features governed by the physical laws of Hydrology, naming of hydrologic features, location of hydrologic feature along a linear flowpath | Named Feature  Hydro Complex  River Positioning System |
| HY\_SurfaceHydroFeature | hydrologic features on the Earth’s land surface without the complexity and detail of hydrologic and hydraulic models | Channel Network  Hydrographic Network  Water Body Types  Storage |
| HY\_HydrometricNetwork | hydrometric network of logically connected hydrometric features located on or along a hydrologic feature | --- |

The conceptual model is expressed in the Geographic Information Conceptual Schema Language (ISO 19103:2005) based on the Unified Modeling Language (UML). The organization of the HY\_Features hydrology model classes into modules, packages, and dependencies is shown in Figure 21.

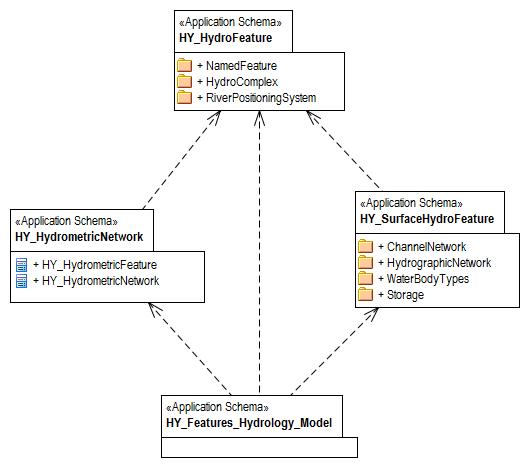


Figure 21: HY\_Features modules and packages

## HY\_Features conceptual model conformance

|  |  |
| --- | --- |
| **Requirements Class** | /req/hy\_features\_conceptual\_model |
| Target types | 1) Implementation Schema  2) Implementation Schema Mapping |
| Name | HY\_Features Conceptual Conformance |
| Dependency | /iso/19103/ |
| Dependency | /doc/AS/Topic1 |
| Dependency | /doc/AS/Topic2 |
| Dependency | /doc/AS/Topic19 |
| Dependency | [/iso/19109/](https://inspire-twg.jrc.it/svn/iso) |
| Requirement | /req/hy\_features\_conceptual\_model/mapping  An implementation schema conforming to HY\_Features SHALL implement one or more feature types defined by the HY\_Features UML model in this standard, including all mandatory properties, associations, and default values.  A mapping implementation conforming to HY\_Features SHALL implement mappings between existing feature types and one or more HY\_Features feature types as defined in the HY\_Features UML model in this standard, including all mandatory properties, associations, and default values. |
| Requirement | //req/hy\_features\_conceptual\_model/GF\_Feature  Each implemented HY\_Features feature type SHALL be an instance of the GF\_FeatureType (aka FeatureType) «metaclass» |

The HY\_Features model specified in this standard is a 'conceptual model', and not intended to be directly implementable for data exchange or persistence. The conformance target of the HY\_Features model is therefore either an implementation schema that implements concepts defined in the HY\_Features model, or a schema mapping that maps between disparate existing feature types by means of common HY\_Features concepts.

The feature types in the HY\_Features conceptual model are defined below according to the modules and leaf packages described above into which their UML classes have been grouped.

## HydroFeature module

The HydroFeature module (Figure 22) provides the core concepts of a named hydrologic feature (shown in Yellow), of a hydrologic complex wherein the union of catchment and its common outlet (conceptualized as outfall) is multiply realized through a collection of hydrologic features (shown in Blue), and of a river positioning system which allows to place an arbitrary feature ‘along a river’ using a linear referencing (shown in Green) along a topological, flowpath realization.

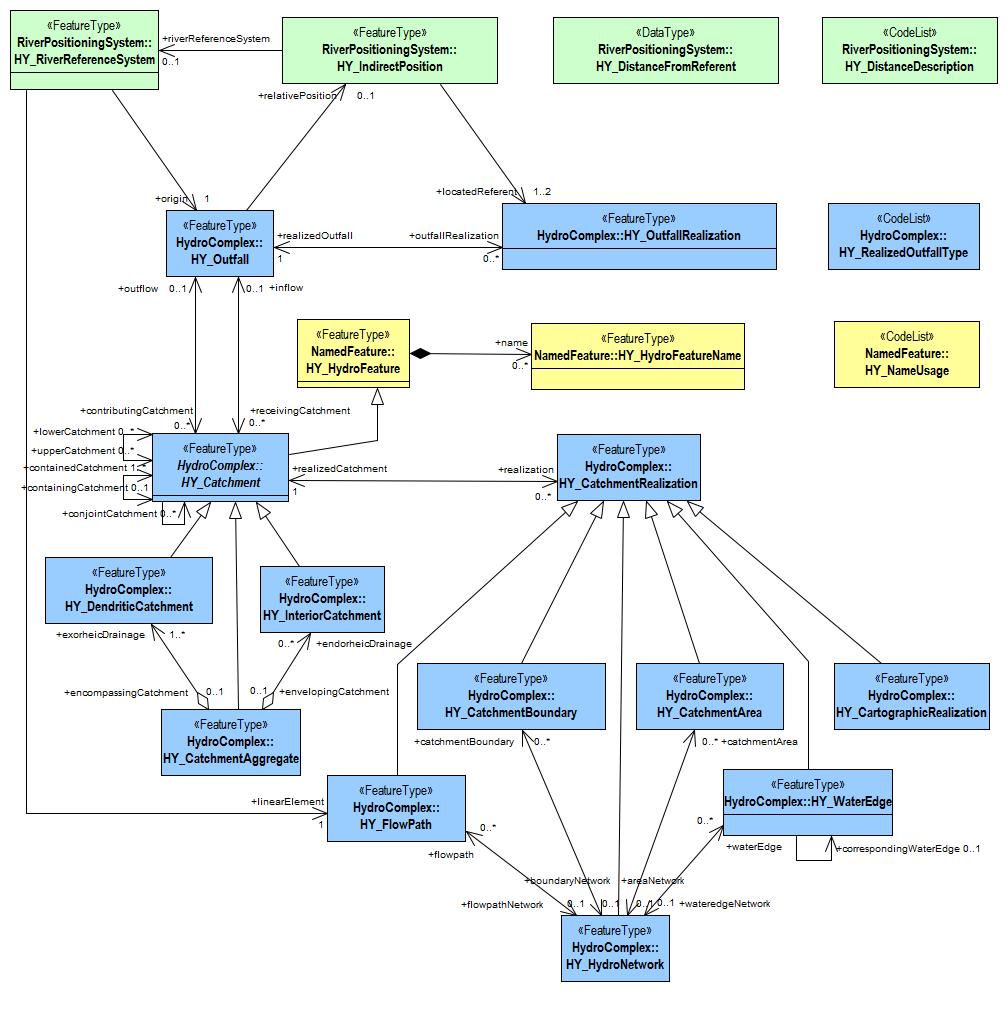


Figure 22: Hydro Feature requirements Class Diagram

If required, an implementation should use terms from the code lists in Annex B of this standard, defined specifically to conform to a terminology common in the hydrology domain. Note that alternative code lists may be used but should be related to the terms in a specific codelist using an appropriate mechanism. The external dependencies are shown in Figure 23.

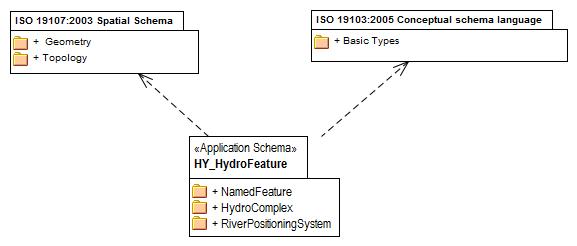


Figure 23: Hydro Feature – external dependencies

The HY\_HydroFeature feature type is defined as hydrology-specific instance of the General Feature metaclass (as defined in the OGC General Feature Model, GFM), whose identity needs to be maintained and tracked through a processing chain from measurement to distribution of hydrologic information.

Being an intended instance of the General Feature metaclass any feature type is identified by a unique identifier and typical properties. Typically, a hydrologic feature is additionally identified through names in common usage and through hydrologically significant characteristics.

The HY\_HydroFeature feature type is then specialized into more specific feature types, which specify additional properties and represent particular hydrologic phenomena (Figure 24).

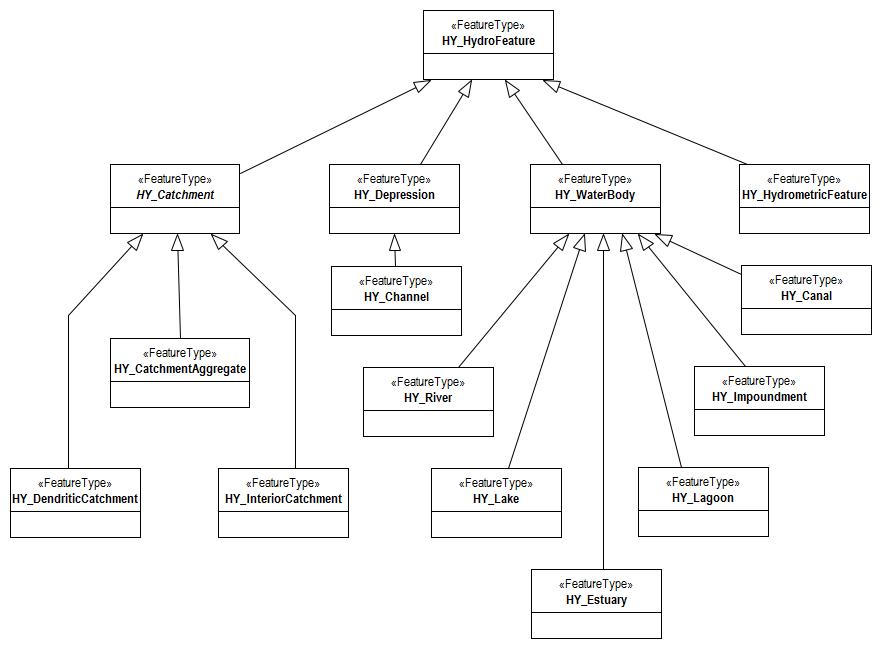


Figure 24: Hydrologic features describing separate aspects of hydrology phenomena

The definitions of HydroFeature feature types are rooted in the definitions documented in the WMO/UNESCO Glossary of Hydrology. They are applied regardless of their application context in respect to the Earth's surface. For the purpose of testing the applicability of the HY\_Features conceptual model in the context of surface water hydrology, the definitions in this standard refer to surface water hydrology. A conceptual model capturing the specifics of features associated with the groundwater domain is developed with reference to the OGC WaterML 2: Part 4 – GroundwaterML2 standard [6]**.**

Providing a standard terminology for the typical relationships between hydrologic features allows the hydrosphere to be expressed in a consistent way across multiple data products, regardless of various spatial or temporal representations.

### Named Feature Package

The Named Feature package (Figure 25) defines the HY\_HydroFeature type as basic feature to reflect the overall properties hydrologic features have, such as names in cross-jurisdictional and multi-lingual contexts. The HY\_HydroFeature type has one association: name.

Table 4: HY\_HydroFeature

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| name | name given to the hydrologic feature in cultural, political or historical context | Association |

**This** links a HY\_HydroFeature object to zero or more HY\_HydroFeatureName objects.

The HY\_HydroFeatureName type provides an pattern to handle cultural, political and historical variability of names. This supports the assignment of a referenceable name for all or parts of a hydrologic feature without necessarily having a formal model for the naming.

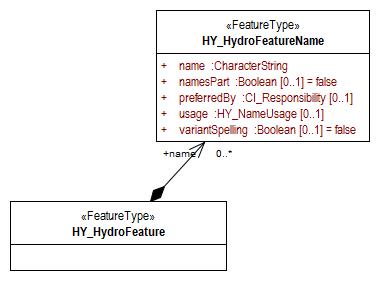


Figure 25: Named Feature (UML class diagram)

HY\_HydroFeatureName carries five attributes: *name*, *namesPart*, *preferredBy*, *usage* and *variantSpelling*.

Table 5: HY\_HydroFeatureName

|  |  |  |  |
| --- | --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** | **Type** |
| name | the individual name used in a country or region under the conditions of nation and language | Attribute | CharacterString |
| namesPart | indicates whether the name applies to a part of feature only or not, using the Boolean value type | Attribute | CharacterString |
| preferredBy | specifies that the name is the preferred name according to the named entity. The CI\_Responsibility type may be used to further structure the information about the responsible party and their role | Attribute | CharacterString |
| usage | expresses the kind of name usage in a specific community, using a term from the HY\_NameUsage code list, or a controlled vocabulary. Alternative code lists may be used but should be related to the terms in Annex B.4 using an appropriate formalism | Attribute | CharacterString |
| variantSpelling | indicates whether the name is a variant spelling or not using the Boolean value type | Attribute | CharacterString |

### The HydroComplex package

The Hydro Complex package is a collection of hydrologic features that form a hydrologically closed system. This includes the catchment, its inflow and outflow (conceptualized as outfalls) as well as various realizations of catchment and outfall by typical hydrologic features. In this complex, the union of catchment and its common outlet determines the topological closure of the logical catchment and its outfall. The catchment topology pattern, expressed for example as a flowpath bounded by inflow and outflow nodes, is then applied to realize the connectivity in hydrographic, channel networks, or hydrometric networks.

The Hydro Complex model also allows for catchments to be recognized through reference to an outfall even if stream networks, catchment areas or catchment boundary are not available. It is intended that hydrological reporting applications may use this model without the full complexity and detail of scientific catchment models.

#### Catchment

The Catchment model conceptualizes the hydrologic determination of a catchment through an 'outfall' feature with the role of getting flow from a contributing catchment, or providing inflow to a receiving catchment (Figure 26 and Figure 27). Conceptually, each catchment has an outfall, and any outfall has a corresponding catchment, even if catchment and/or outfall may not be present in a particular application. A catchment interacts with upper and lower catchments via associated outfalls, and ultimately contributes flow to the outfall of a containing catchment. The catchment should be understood as the logical link between two outfalls.

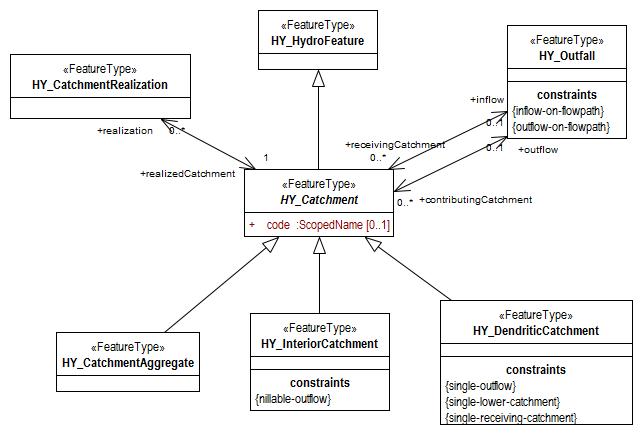


Figure 26: Catchment model (UML class diagram)

The HY\_Catchment feature type captures the union of catchment and outfall, and the multiple realization of the logical catchment. These realizations include both topological realizations, as well as their geometric representation. HY\_Catchment is an abstract class and needs further specialization with respect to catchment interaction.

The **HY\_Catchment** feature type (Figure 27) specializes the general HY\_HydroFeature type. Through generalization, HY\_Catchment inherits the name property. It carries a code attribute and the associations: outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, realization.

Table 6: HY\_Catchment

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| code | unique identifier to the catchment in given context. The code attribute should be implemented using a controlled classification or coding system. Example: WMO Basin Codes. | Attribute |
| outflow and inflow | outfall in terms of an outflow of the contributing catchment, or inflow to the receiving catchment. For a dendritic network of catchments, the outflow of a contributing catchment coincides with the inflow to a receiving catchment. This supports description of upstream-downstream relationships between catchments. | Association |
| *containingCatchment and containedCatchment* | nesting of catchments in a simple “is-in” containment hierarchy as typically used for high-order organization of management and reporting units. | Association |
| ***conjointCatchment*** | catchment interacting with another catchment across an internal boundary, and contributing together with these to a single, common outfall. This internal boundary may be a divide separating adjacent catchments, or a diffuse divide between non-delineated sub-catchments within an encompassing catchment, or a fictive boundary between distant catchments. A dendritic network of catchments provided, where each catchment is determined by its single outflow, this association can be used to summarize diffuse inflow into a catchment, as typical for headwater catchments, or spread outflow occurring for example in estuary catchments. | Association |
| *upperCatchment and lowerCatchment* | neighboring catchment immediately above or below of the catchment. This allows to trace the catchment network in an upstream direction from mouth to source, or downstream from source to mouth. | Association |
| *realization* | topological or geographic feature which realizes the logical catchment. | Association |

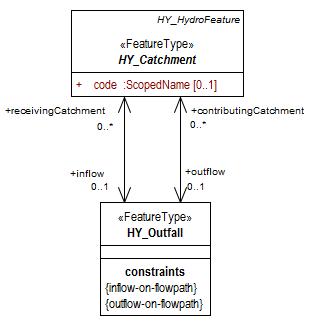


Figure 27: Catchment and outfall (UML class diagram)

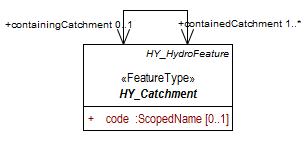


Figure 28: Containing / contained catchment (UML class diagram)

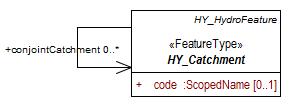


Figure 29: Conjoint catchment (UML class diagram)

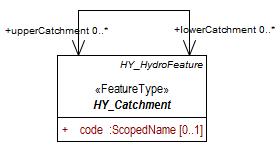


Figure 30: Upper / lower catchment (UML class diagram)

#### Catchment Aggregate

The HY\_CatchmentAggregate feature type (Figure 31) specializes the HY\_Catchment type as a set of non-overlapping dendritic and interior catchments arranged in an encompassing catchment. This can be used to describe multiple inflows into a catchment aggregate through several hydrologically discrete sub-catchments each with a single inflow, and contributing to a joined outflow of the catchment aggregate, including the 'nillable' outflow of interior catchments. Nillable is meant here to signify that the outfall logically exists in the form of flow to the subsurface or atmosphere but is unknown in a given implementation.

Being a special type of the HY\_Catchment, the catchment aggregate may be part of a containing catchment at the next higher level of hierarchy, which consists of similar-scale neighboring catchments. The catchment aggregate does not necessarily imply a series of nested containing catchments. It primarily allows navigation to the 'highest' level system (total drainage basin) as typically used for reporting purposes.

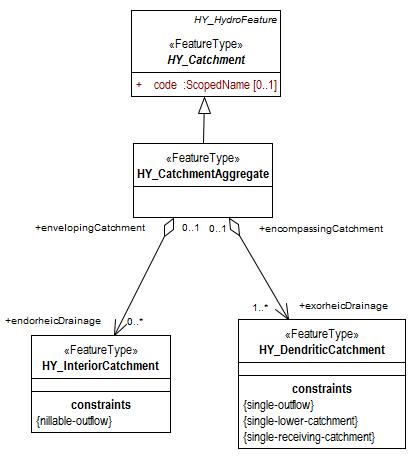


Figure 31: Catchment aggregate (UML class diagram)

HY\_CatchmentAggregate inherits through generalization the outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, and realization properties, and associates an exorheicDrainage and endorheicDrainage.

Table 7: HY\_CatchmentAggregate

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***exorheicDrainage*** | should be used to identify an exorheic drained catchment which is not, but may be temporarily connected to enveloping catchments. | Association |
| ***endorheicDrainage*** | should be used to identify an endorheic drained catchments, which is permanently connected to the enveloping aggregate. | Association |

#### Dendritic Catchment

The HY\_DendriticCatchment feature type (Figure 32) specializes the general HY\_Catchment class as a catchment which is determined by a single common downstream catchment. It represents the catchment as the topological link between an inflow and an outflow. This allows catchments to be connected in a dendritic network by upstream-downstream relationships without knowing the complex hydrology between inflow and outflow. This concept requires a stable identifier purposefully assigned to the catchment and that catchments are delineated as a simple tree hierarchy.

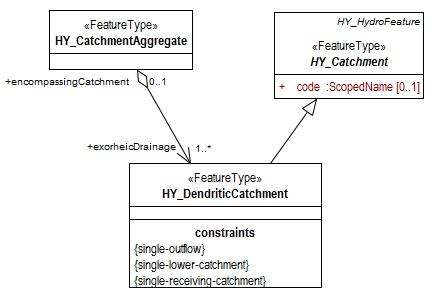


Figure 32: Dendritic catchment (UML class diagram)

HY\_DendriticCatchment inherits from generalization the code, outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, and realization properties, and associates with the encompassingCatchment. The dendritic nature of this feature is enforced through *singleOutflow, receivingCatchment* and  *lower catchment* constraints.

Table 8: HY\_DendriticCatchment

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***encompassingCatchment*** | identifies the catchment encompassing one or more dendritic catchments contributing together flow to the common outlet. | Association |
| *single-Outflow* | defines a cardinality of ‘1’ indicating that the dendritic catchment contributes to one and only one single outflow. A single outflow can be unknown (nillable) in a particular application, for example in case of a delta to which a virtual outflow is assigned. An implementation SHOULD unambiguously specify whether the logical outflow exists, or is nillable. | Constraint |
| *single-Receiving-Catchment* | defines a cardinality of ‘1’ indicating that one and only one single catchment receives flow via the outflow of the catchment. A receiving catchment can be unknown (nillable) in a particular application, for example in case of the latest catchment contributing flow to the ocean or an internal sink. An implementation SHOULD unambiguously specify whether the logical receiving catchment exists, or is nillable. | Constraint |
| *single-Lower-Catchment* | defines a cardinality of ‘1’ indicating that one and only one lower catchment exists neighboring the catchment. A lower catchment can be unknown (nillable) in a particular application, for example in case of the latest catchment contributing flow to the ocean or an internal sink. An implementation SHOULD unambiguously specify whether the logical lower catchment exists, or is nillable. | Constraint |

#### Interior Catchment

The HY\_InteriorCatchment feature type (Figure 33) specializes the general HY\_Catchment class as a catchment which is generally not connected to other catchments. This class describes the interior catchment as a catchment enveloped by other catchments to which it may temporarily contribute. While the interior catchment concept precludes flow to neighboring surface catchments, holistically it is a candidate for establishing connections to groundwater or atmospheric systems.

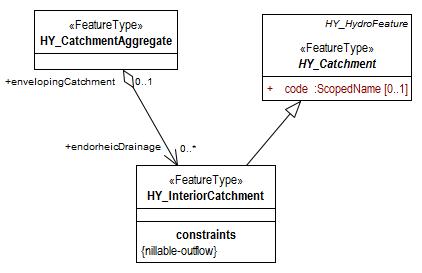


Figure 33: Interior catchment (UML class diagram)

HY\_InteriorCatchment inherits from generalization the code, outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, and realization properties, and associates the envelopingCatchment. A *nillable-outflow* constraint emphasizes the non-existing outflow.

Table 9: HY\_ InteriorCatchment

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***envelopingCatchment*** | identifies a catchment surrounding the interior catchment. | Association |
| ***nillable*-*outflow*** | defines a cardinality of ‘0’ indicating the not existing outflow. | Constraint |

#### Outfall

The HY\_Outfall feature type (Figure 34) conceptualizes the hydrologically determined outfall of a corresponding catchment (Figure 27). The outfall represents the logical place where a catchment interacts with another catchment, i.e. where the outflow of a contributing catchment becomes inflow into a receiving catchment. A catchment may receive flow from several upstream catchments or contribute flow to several downstream catchments through a single logical outfall. Through unique identity, each outfall feature may associate different outfall realizations within an hydrologic complex given that each realization has the same hydrologic determination. This includes the topological realization as a node on the one-dimensional flowpath (edge) in terms of a topological 'boundary'.

Logically placed in reference to a catchment which links inflow and outflow, an outfall has a position relative to another outfall that is 'fixed' by the catchment. Referencing the union of catchment and outfall, the topological realization can be used to define a linear river reference system with the inflow/outflow node as origin and the flowpath realizing the catchment as linear element along which a position can be determined.

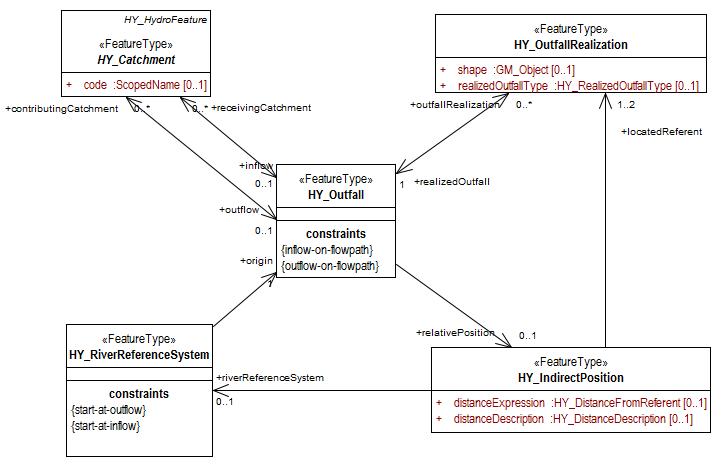


Figure 34: Outfall (UML class diagram)

HY\_Outfall carries the associations: contributingCatchment, receivingCatchment, relativePosition and outfallRealization. The linear referencing along a flowpath is enforced by outflow-on-flowpath and an *inflow-on-flowpath* constraints.

Table 10: HY\_Outfall

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***contributingCatchment*** | identifies the catchment that contributes flow to this outfall. This allows to connect a catchment's outflow to an identified inflow and to determine its position through referencing the inflow. | Association |
| ***receivingCatchment*** | identifies the catchment that receives flow from this outfall. This allows to connect a catchment's inflow to an identified outflow and to determine its position through referencing the outflow. | Association |
| ***relativePosition*** | assigns a position to the outfall relative to a reference location fixed in the logical network of catchments, i.e. to another, already existing (realized) outfall. Commonly, this is used to locate an outfall such as at a hydrometric station, to a reference outfall such as a confluence but it can be used to locate any outfall relative to another. | Association |
| ***outfallRealization*** | identifies a hydrologic feature which realizes the logical outfall. In case of a topological realization, the realization of the outfall is of lower dimension than the realization of the corresponding catchment. Example: an outflow node realizing the outfall is of lower dimension than the flowpath realizing the contributing catchment. | Association |
| ***inflow-on-flowpath*** | defines that whenever a relative position is assigned to an inflow using the river reference system, the receiving catchment is realized as linear flowpath. | Constraint |
| ***outflow-on-flowpath*** | defines that whenever a relative position is assigned to an outflow using the river reference system, the contributing catchment is realized as linear flowpath. | Constraint |

#### Catchment Realization

The HY\_CatchmentRealization feature type (Figure 35) conceptualizes the multiple realization of an 'un-realized', logical catchment, by typical features used to describe a catchment as a unit of study shared across sub-domains and studies.

The catchment realization concept implies a hydrologic complex in that, if a catchment realization exists, this exists in the same hydrologic complex as the catchment it realizes. In this way, any feature realization of a logical catchment references the hydrologic determination of the realized catchment. If the realized catchment is connected with other catchments via its outfall, possible feature realizations are also connected. A topological realization of the logical catchment is always of higher topological dimension than the realization of the corresponding outfall in terms of a topological boundary. For example, a linear flowpath realizing a catchment may be understood as an edge between inflow and outflow nodes; the areal realization of a catchment as a face bounded by linear inflow and outflow.

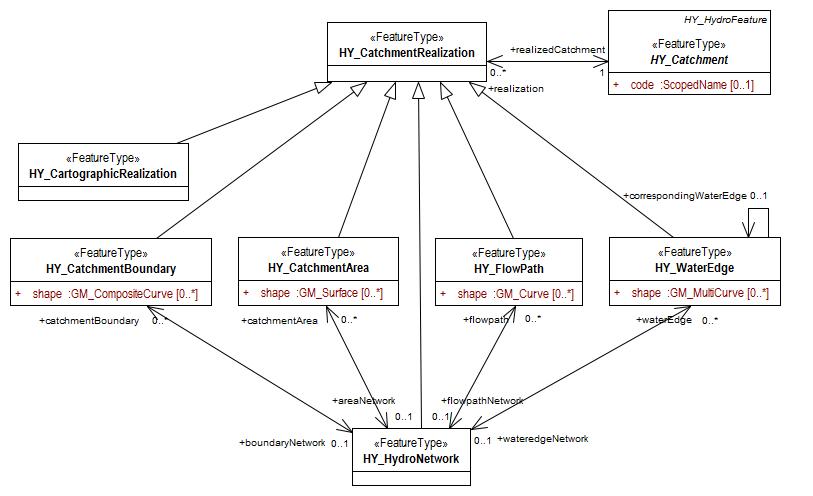


Figure 35: Catchment realization and its specialization (UML class diagram)

The catchment realization features defined in this standard refer to objects on the land surface for the purpose of surface water hydrology. In other contexts, other types of catchment realization may exist. Catchment realizations that do not conform to those defined in this standard, for instance realizations in 3- or 4-dimensional perspectives, may be implemented using the general HY\_CatchmentRealization type. HY\_CatchmentRealization carries the realizedCatchment association.

Table 11: HY\_CatchmentRealization

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***realizedCatchment*** | identifies the one and only one catchment that is realized by a particular feature. Referencing the hydrologic complex containing the catchment and all of its realizations, supports a catchment's existence to be recognized and linked to multiple realizations without the complexity and full detail of a scientific model. By referencing the catchment topology, topological relationships can be established and common identifiers assigned. | Association |

The **HY\_Flowpath** feature type realizes an 'un-realized' catchment specifically as a path connecting the inflow and outflow of the logical catchment it realizes. HY\_Flowpath specializes HY\_CatchmentRealization with respect to an implied linear geometric representation including a straight or curved line. Topologically, the flowpath connects the inflow and outflow of the logical catchment, and is understood as an edge bounded by an inflow node and an outflow node, and corresponding to left-bank and right-bank catchment faces. Hydrologically, the flowpath is a line describing a moving particle of water. Through generalization, HY\_Flowpath inherits the realizedCatchment association. It carries the properties: shape, and flowpathNetwork.

Table 12: HY\_Flowpath

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***shape*** | linear geometric representation of the one-dimensional flowpath, usually as a curve. | Attribute |
| ***flowpathNetwork*** | sequence of flowpaths forming a connected network, which realizes as a whole the catchment that contains the catchment realized by the single flowpath. This concept requires a non-branching 'main-stem' of watercourses, and a single linear representation of each of these. | Association |

The **HY\_WaterEdge** feature type realizes an 'un-realized' catchment specifically as path connecting the inflow and outflow of the logical catchment it realizes. HY\_WaterEdge feature type specializes HY\_CatchmentRealization with respect to an implied linear geometric representation, including a closed line. Topologically, the water edge realizes the catchment as an edge connecting inflow and outflow realized as nodes fixed at the inflow node and outflow node of the corresponding flowpath. Hydrologically, the water edge follows the line of intersection between a water body stratum and the confining depression, or channel. Through generalization, HY\_WaterEdge inherits the realizedCatchment association, and carries the properties: shape, *correspondingWaterEdge*, and waterEdgeNetwork.

Table 13: HY\_WaterEdge

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***shape*** | linear geometric representation of the one-dimensional water edge, usually an aggregate of curves. | Attribute |
| *corresponding water edge* | water edge fixed at the inflow node and the outflow node of the water edge. By 'snapping' the inflow nodes into one node on and outflow nodes into one node, the representing curves may be closed. | Association |
| ***waterEdgeNetwork*** | aggregate of water edges forming a connected network, which realizes as a whole the catchment that contains the catchment realized by the single water edge. This concept requires an aggregate of non-overlaying water edges, and a single linear representation of each of these. | Association |

The **HY\_CatchmentBoundary** feature type realizes an 'un-realized' catchment specifically as catchment boundary connecting the inflow and outflow of the logical catchment it realizes, whereby inflow and outflow may overlay. Implying a linear geometric representation, a catchment boundary is topologically understood as an edge bounded by inflow node and outflow nodes, and corresponding to left-bank and right-bank catchment faces inside of the boundary. Hydrologically, the boundary refers to the summit line separating adjacent catchments. HY\_CatchmentBoundary inherits from generalization the realizedCatchment association, and carries the properties: shape, and boundaryNetwork.

Table 14: HY\_CatchmentBoundary

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***shape*** | linear geometric representation of the one-dimensional catchment boundary, as an composition of succeeding curves or a polygon ring. | Attribute |
| ***boundaryNetwork*** | mesh of boundary lines forming a connected network, which realizes as a whole the catchment that contains the catchment realized by a single boundary. This concept requires a mesh of non-overlapping boundary lines, and a single linear representation of each of these. | Association |

The **HY\_CatchmentArea** feature type realizes an 'un-realized' catchment specifically as a catchment area connecting the inflow and outflow of the logical catchment it realizes, including a plane surface. HY\_CatchmentArea specializes HY\_CatchmentRealization with respect to an implied areal geometric representation Topologically, the catchment area connecting the inflow and outflow of the logical catchment is a face bounded inwards by an inflow edge and outwards by an outflow edge. Hydrologically, catchment area refers to the area having a common outlet for its runoff, HY\_CatchmentArea inherits from generalization the realizedCatchment, and carries the properties: shape, and areaNetwork.

Table 15: HY\_CatchmentArea

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***shape*** | areal geometric representation of the two-dimensional catchment area, usually as a surface. | Attribute |
| ***areaNetwork*** | aggregate of catchment areas forming a connected network, which realizes as a whole the catchment that contains the catchment realized by the single catchment area. This concept requires an aggregate of non-overlapping catchment areas, and a single areal representation of each of these. | Association |

The **HY\_HydroNetwork** feature type realizes an 'un-realized' catchment as a network of connected hydrologic features. Such a network realizes in the hierarchical network of logically connected catchments contained in a higher-order catchment. It may be a sequence of flowpaths, an aggregate of water edges, an aggregate of catchment areas or a mesh of catchment boundaries. HY\_HydroNetwork feature type specializes HY\_CatchmentRealization. Through generalization it inherits the realizedCatchment association, and carries the associations flowpath, waterEdge, catchmentBoundary and catchmentArea.

Table 16: HY\_HydroNetwork

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| *flowpath* | flowpath that participates in the network. | Association |
| *waterEdge* | water edge that participates in the network. | Association |
| *catchmentBoundary* | catchment boundary that participates in the network. | Association |
| *catchmentArea* | catchment area that participates in the network. | Association |

The HY\_CartographicRealization feature type realizes a catchment as set of separate cartographic layers or maps, displaying a network of hydrologic features which may be connected at the representation level, or not. Specializing HY\_CatchmentRealization, it inherits from generalization the realizedCatchment association including hydroComplex.

#### Outfall Realization

The HY\_OutfallRealization feature type (Figure 36) conceptualizes the idea that an outfall can be realized by practically any feature of interest. Using the outfall to define and reference the hydrologic determination of a catchment, hydrologic features may be associated to a corresponding catchment through reference to the feature that realizes its outfall. Any feature that can be identified as (said to be) the outfall of a catchment may realize the logical outfall. Typically this will be a permanent, stable location that is fixed and/or referenced by coordinates.

Landmarks such as confluences, points corresponding to vertical sections, or the position of a monitoring station on a river are typical outfall realizations. In other than surface water contexts other types may realize a catchment's logical outfall. Other kinds of outfall realizations that don't carry normal surface water characteristics as defined in this standard, e.g. a spring where groundwater enters the surface, an arbitrary point projected onto the surface, or an outfall that collects many disjoint locations may use or specialize the general HY\_OutfallRealization type.

Topologically, the HY\_OutfallRealization should be understood to be the boundary of the corresponding catchment, and always of lower topological dimension than the catchment. With respect to the typical topological realization of a catchment as an edge, a 'spoke' property of type HY\_Flowpath is described by means of a 'tagged value' and used to associate an outfall realization with its upstream and downstream flowpaths. Even though the topological realization of an outfall is typically a node between catchment edges, an outfall realization may also have any geometric representation, including a single point.

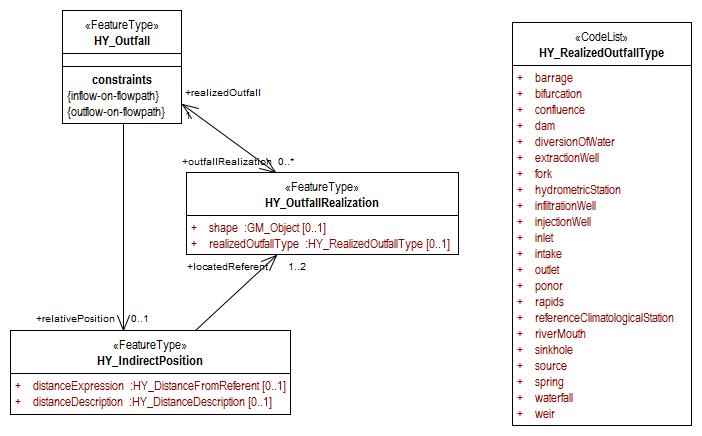


Figure 36: Outfall Realization (UML class diagram)

HY\_OutfallRealization carries the realizedOutfall association implying the hydroComplex feature collection, and carries two attributes: shape and realizedOutfallType.

Table 17: HY\_OutfallRealization

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***shape*** | geometric representation of the realized outfall. | Attribute |
| ***realizedOutfallType*** | expresses the type of the realized outfall, using a term from the HY\_ RealizedOutfallType code list, or a controlled vocabulary. Alternative code lists may be used but should be related to the terms in Annex B.1 using an appropriate formalism. | Attribute |
| ***realizedOutfall*** | identifies the one and only one outfall that is realized by a particular feature. Referencing the hydrologic complex containing the outfall and all of its realizations, supports an arbitrary feature of interest to be recognized as outfall of a catchment, and to be placed using the river positioning system defined in this standard. | Association |

### The River Positioning System

The River Positioning System (Figure 37) provides a simple model to place a feature of interest 'on a river'. It introduces the concept of indirect position where a position is determined relative to an already established reference location. This concept uses a linear river reference system whose origin is set at the outfall of a catchment, and whose linear shape is given by a flowpath realizing the catchment between its outfall and another known outfall. It is important to note, that each logical catchment has its own reference system, and must have one outfall (origin) and one linear flowpath realization (shape).

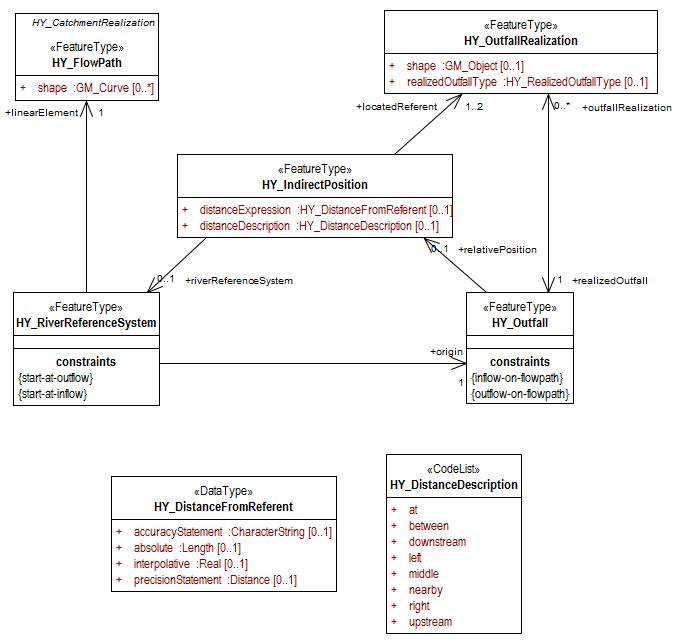


Figure 37: River Positioning System (UML class diagram)

The River Positioning System references the one-dimensional topological realization of catchment and outfall within the implied hydrologic complex in such that the origin and the already located referent are nodes on the boundary of the same flowpath. Given that a flowpath realizes a logical catchment between inflow and outflow nodes, the feature of interest is either the inflow or the outflow node located at flowpath start, while the location being referenced is located at the upstream or downstream end of the flowpath. Using located referents in both directions allows placement of a feature of interest interpolative between inflow and outflow nodes on a flowpath even if the realized catchment is not explicitly delineated.

#### Indirect Position

The HY\_IndirectPosition feature type defines the location referenced along a logical axis, without the necessity of a geometric realization which it however may have. Indirect position uses a catchment-specific reference system which defines the flowpath as the required linear element along which the position is determined, and the location where the flowpath starts as the origin. The indirect position then is expressed as the distance from the upstream or/and downstream end of the flowpath, or from a referent that is already located on that flowpath.

The (indirect) position of an outflow node referenced along an upstream oriented flowpath (Figure 18) can be expressed as distance from an upstream inflow node located on that flowpath, while the (indirect) position of an inflow node referenced along a downstream oriented flowpath (Figure 19) can be expressed as distance from a downstream outflow node located on the flowpath. An ‘intermediate’ position referencing known inflow and outflow nodes bounding a flowpath at both ends (Figure 20) can be expressed as part of the distance along the entire flowpath, measured from the upstream end of an upstream flowpath, or/and from the downstream end of a downstream flowpath. A position referencing an already referenced location on the flowpath can be expressed as part of the distance along the entire flowpath, measured from the ‘located referent’.

HY\_IndirectPosition carries the distanceExpression, and distanceDescription attributes, and associates the locatedReferent and a riverReferenceSystem.

Table 18: HY\_IndirectPosition

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***distanceExpression*** | absolute or interpolative value of the distance from the feature being referenced, including an indication of accuracy and precision of the absolute value. An implementation may use the HY\_DistanceFromReferent (data type) referencing basic types. Alternatively, the types described in ISO 19103: Conceptual Schema may be used. | Attribute |
| *distanceDescription* | term describing the distance from the feature being referenced An implementation may use the HY\_DistanceDescription code list. Alternatively, the types described in ISO 19103: Conceptual Schema may be used. Alternative code lists may be used but should be related to the terms in Annex B.2 using an appropriate formalism. | Attribute |
| ***locatedReferent*** | identifies an existing ‘realized’ outfall used as the permanent reference location relative to which a position is assigned to an outfall, or the feature of interest recognized as outfall. | Association |
| ***riverReferenceSystem*** | catchment-specific linear reference system defining the outfall of catchment as origin, and the one-dimensional flowpath as linear element forming the axis. | Association |

#### River Reference System

The HY\_RiverReferenceSystem feature defines the catchment-specific linear reference system where the flowpath which realizes the catchment is the linear element forming the axis and the outfall of a catchment forms the origin where the flowpath starts.

HY\_RiverReferenceSystem associates the linearElement and the origin. Constraints *start-at-*outflow and *start-at-*inflow are defined enforcing the start of the flowpath at the inflow or outflow of the realized catchment.

Table 19: HY\_RiverReferenceSystem

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***linearElement*** | one-dimensional catchment realization, flowpath, used as the linear element along which a position is determined. To describe the linear axis in detail, including the unit of measure, an implementation may use the types described in ISO 19103: Conceptual Schema. | Association |
| ***origin*** | inflow or outflow of the catchment, where the flowpath realizing that catchment starts. | Association |
| ***start-at-outflow*** | defines that whenever the flowpath (linear element) realizes a contributing catchment, this flowpath starts at the outflow (origin) of the realized catchment, and is directed towards the upstream inflow. | Constraint |
| ***start-at-inflow*** | defines that whenever the flowpath (linear element) realizes a receiving catchment, this flowpath starts at the inflow (origin) of the realized catchment, and is directed towards the downstream outflow. | Constraint |

#### Distance From Referent

The HY\_DistanceFromReferent data type provides the distance from a located referent as an absolute or interpolative value, including simple statements on accuracy and precision of the measured position.

Table 20: HY\_DistanceFromReferent

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***absolute*** | geometric expression of the distance from a located referent. An implementation may use the types described in ISO 19103: Conceptual Schema. | Attribute |
| ***interpolative*** | interpolative expression (percentage) of the distance from a located referent. An implementation may use the types described in ISO 19103: Conceptual Schema. | Attribute |
| ***accuracyStatement*** | simple statement whether the distance value agrees with the value accepted as being true. This statement assumes that all known corrections have been applied. An implementation may use the types described in ISO 19103: Conceptual Schema. | Attribute |
| ***precisionStatement*** | simple statement on the smallest unit of division on the scale of measurement. An implementation may use the types described in ISO 19103: Conceptual Schema. | Attribute |

## The Surface Hydro Feature model

The Surface Hydro Feature application schema (Figure 38) provides common concepts of hydrologic features occurring on the land surface and specifies the core concepts defined in the abstract Hydro Feature application schema. This will enable contextually linked information models to build relationships between multiple realizations of the same catchments. Typical realizations of the catchment concept and logical outfalls can be described in a consistent way using standard terminology for the relationships between surface water features defined in this application schema.

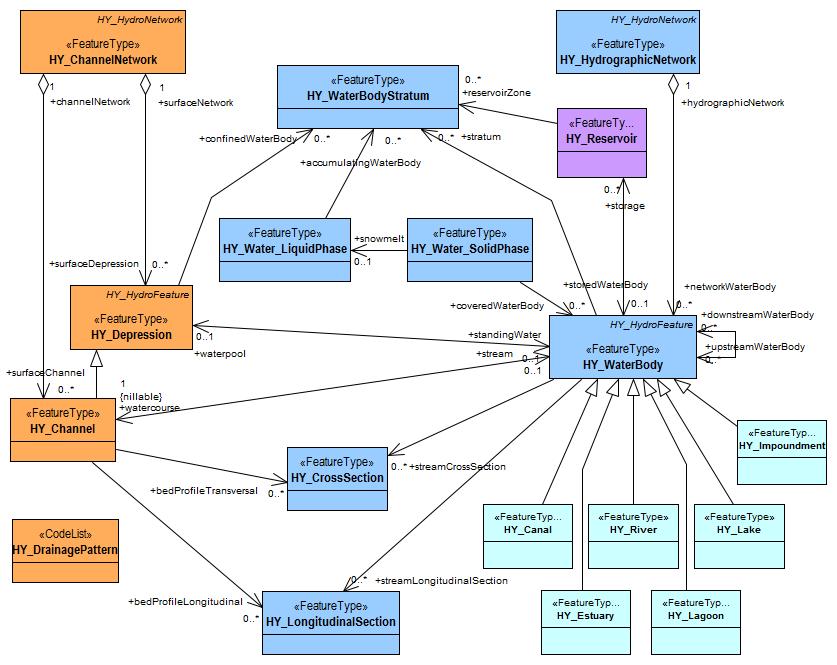


Figure 38: Surface Hydro Feature - Class Diagram

The Surface Hydro Feature model conceptualizes the accumulation of water on the land surface in water bodies (shown in Blue), each made unique by its origin, size, or movement. With respect to the management and storage of water resources, a concept of water storage is provided and allows any water body type to be considered a managed reservoir (shown in Purple).

Relying on a conceptual separation of water body and container, the Surface Hydro Feature schema defines a network of potentially connected depressions and channels on the land surface which periodically or continuously contain water (shown in Orange). Separate from the hydrographic network of permanent or temporary water bodies, the channel network can be used as the connecting system.

The definitions in this schema are rooted in the definitions given in the WMO/UNESCO Glossary of Hydrology which defines a network of watercourse regardless of the location in respect to the Earth's surface. The conceptual model defined here has been vetted in the context of surface water hydrology. In other words, in this standard, 'channel network' and 'hydrographic network' refer to surface channels or other containers for surface-water bodies.

The Surface Hydro Feature application schema contains the leaf packages: Channel Network, Hydrographic Network, Water Body Types and Storage. Figure 39 shows the external and internal dependencies.

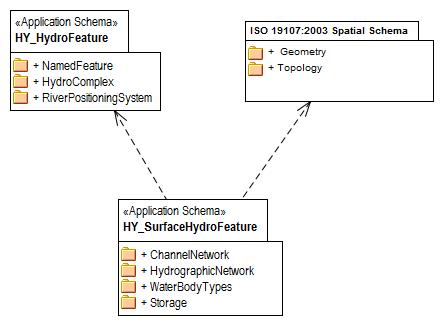


Figure 39: Surface Hydro Feature - dependencies

### The Channel Network model

The Channel Network model defines a network of connected depressions and channels which, in its entirety, can realize a logical catchment (Figure 40). Usually this is a network of linear flowpaths and/or water edges realizing catchments connected to each other within the containing catchment realized by the entire network. This allows representation of the drainage pattern even if logically connected features may or may not be connected in the context of a particular representation.

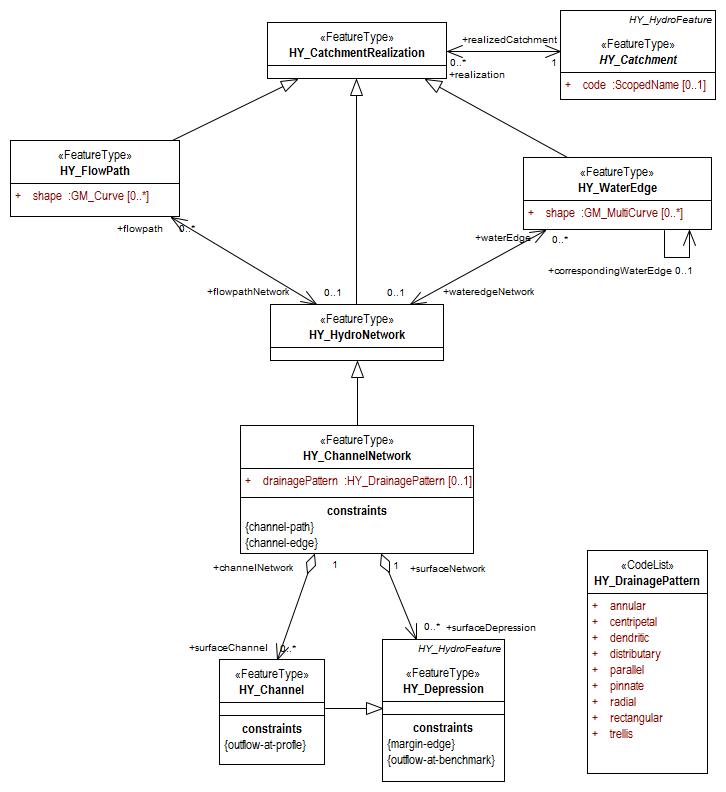


Figure 40: Channel Network realizing the catchment (UML class diagram)

The channel network is defined independent of the hydrographic network. This separates the concerns of hydraulics, focused on the analysis and design of channels and conduits, from the concerns of hydrology, focused on the occurrence and movement of water over land and in water bodies. It allows a logical catchment to be realized as a network of connected channels and depressions, regardless of whether water is contained therein or not.

A single depression or channel may realize the logical catchment, either as part of the network (Figure 40) or via a reference feature which realizes the conceptual outfall of the catchment (Figure 41). For example, a point at an associated cross or longitudinal section may be considered to realize the outflow of the catchment which is realized by the channel expressed as a flowpath.

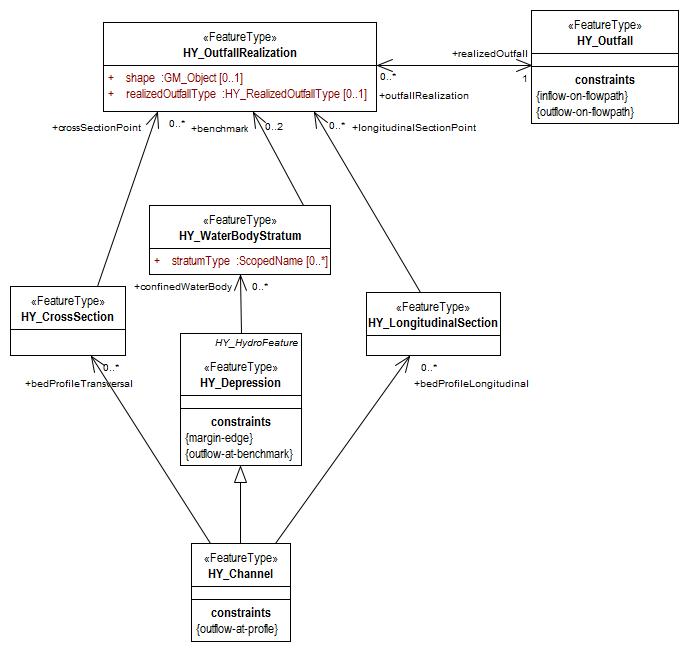


Figure 41: Depression and Channel realizing the outfall (UML class diagram)

#### Channel Network

The HY\_ChannelNetwork feature type specializes the HY\_HydroNetwork realization defined in the Hydro Feature core model, specifically as an aggregate of surface depressions and surface channels which continuously or periodically contain water, without imposing a particular drainage pattern. This allows to represent the network, even if logically connected features may or may not be connected at the representation level. If the realized catchment is connected with other catchments via an outfall, the channel network is considered connected to the channel network realizing these catchments. If required, an application focused on the structures containing a water body may use the defined relationships to describe the realization of a catchment by the channel network, or network parts associated with the hydrographic network.

HY\_ChannelNetwork associates the surfaceDepression and surfaceChannel, and carries a drainagePattern attribute; it inherits through generalization the realizedCatchment, flowpath and waterEdge associations as well as catchmentBoundary and catchmentArea associations. Depending on the application, the channel network and the related features may be described by suitable attributes. A channel-path and a channel-edge constraint are defined to support the recognition of channel and depression as flowpath realizing the catchment.

Table 21: HY\_ChannelNetwork

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***drainagePattern*** | drainage pattern. An implementation may use a term from the HY\_DrainagePattern code list. Note that alternative code lists may be used but should be related to the terms in Annex B.3 using an appropriate formalism. | Attribute |
| ***surfaceDepression*** | depression on the land surface which realizes the logical catchment either separately, or as part of the channel network. | Association |
| ***surfaceChannel*** | channel on the land surface which realizes the logical catchment either separately, or as part of the channel network. | Association |
| ***channel-path*** | defines that whenever a flowpath exists as part of a network, the surface depression and surface channel should be recognized as a flowpath. Geometrically represented as a curve, channel-path will support to ‘measure’ a position on, or along, the channel using its centreline as shape. | Constraint |
| ***channel-edge*** | defines that whenever a water edge exists as part of a network, the surface depression and surface channel should be recognized as a water edge. Geometrically represented as a curve, channel-edge will support to ‘measure’ a position on, or along, the channel using the line of intersection with a water body. | Constraint |

#### Depression

The HY\_Depression feature type specializes the general HY\_HydroFeature class. It describes land lower than the surrounding land as container for standing water. A depression is part of the network of channels and depressions that forms the connecting system wherein water bodies stand as parts of the hydrographic network. HY\_Depression inherits from generalization the name property, and the channel-path and channel-edge constraints. It associates the surfaceNetwork in which it participates, a body of standingWater and a confinedWaterBody. A waterbody-edge constraint is defined to support the recognition of the confined water body as water edge realizing the catchment. An outflow-at-benchmark constraint emphasizes the recognition of a benchmark on the confined water body as outflow of the catchment realized by the channel network.

Table 22: HY\_Depression

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***surfaceNetwork*** | **network of surface channels and depressions, the depression is part of.** | Association |
| ***standingWater*** | identifies the body of stagnant water contained in the depression. | Association |
| ***confinedWaterBody*** | identifies a stratum of water body contained in the depression. | Association |
| ***margin-edge*** | defines that whenever a water edge exists as part of a network, the water body confined by the depression should be recognized as a water edge. | Constraint |
| ***outflow-at-benchmark*** | defines that a benchmark which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the surface network the depression is part of. | Constraint |

#### Channel

The HY\_Channel feature type specializes the HY\_Depression class with respect to a natural or man-made, open or closed channel through or along which water may flow, or not. A channel is part of the network of channels and depressions which forms the connecting system for the hydrographic network; a channel may have vertical sections at right angles to the main (average) direction of flow or along its centerline.

HY\_Channel associates the channelNetwork in which it participates. It carries the associations: stream, bedProfileTransversal and bedProfileLongitudinal. HY\_Channel inherits from generalization the confinedWaterBody association and the constraints waterbody-edge and outflow-at-benchmark. An outflow-at-profile constraint emphasizes the recognition of vertical section as outflow of the catchment realized by channel network.

Table 23: HY\_Channel

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***channelNetwork*** | **network of surface channels and depressions, the channel is part of.** | Association |
| ***stream*** | identifies the water body periodically or continuously flowing in the channel, including subterranean streams. | Association |
| ***bedProfileTransversal and bedProfileLongitudinal*** | identifies a transversal or longitudinal vertical shape of a channel, carrying a permanent reference location which realizes the outfall of the catchment which is realized by the channel. | Association |
| ***outflow-at-profile*** | defines that a location at a vertical section of a channel which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the surface network the channel is part of. | Constraint |

### The Hydrographic Network model

The Hydrographic Network model defines a logical network of water bodies which in its entirety realizes a logical catchment (Figure 42), usually as a network of linear flowpaths and/or water edges realizing catchments connected to each other within a containing catchment that is realized by the entire network. This allows to represent the network of ‘blue lines’, even if logically connected features may or may not be connected at the representation level.

The hydrographic network is defined independent of the channel network. This conceptual separation references to the specific concerns of hydrology studying the occurrence, accumulation, and circulation of water. It and allows to realize the logical catchment as a network of moving or standing water bodies, regardless of the channel wherein it may move, or not.

A single water body realizes the logical catchment either as part of the hydrographic network (Figure 42), or via a reference location which realizes the conceptual outfall of the catchment realized by the water body (Figure 43). For example, a fixed landmark, or a point at an associated cross or longitudinal section is considered to realize the outflow of the catchment which is realized by the channel expressed as a flowpath.

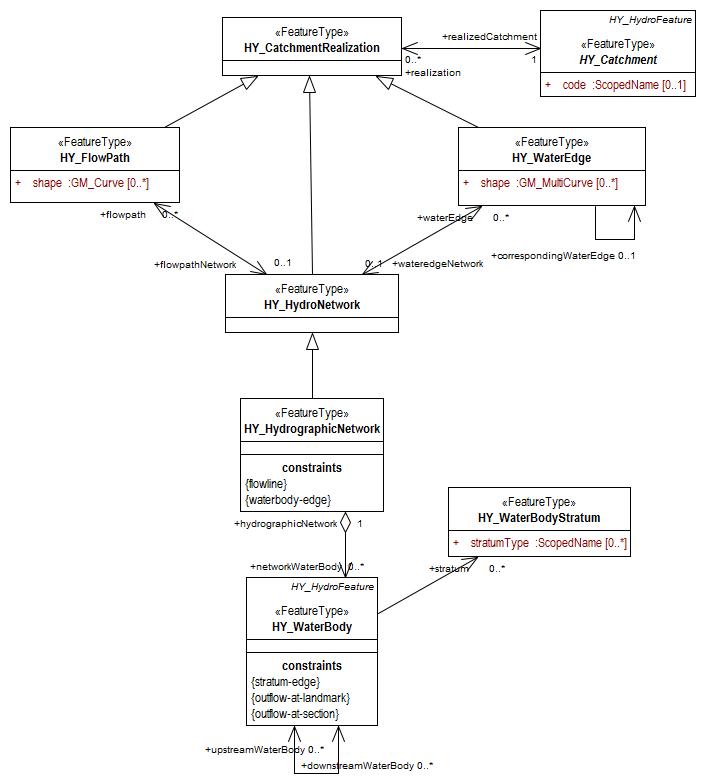


Figure 42: Hydrographic Network realizing the catchment (UML class diagram)

#### Hydrographic Network

The HY\_HydrographicNetwork feature type specializes the HY\_HydroNetwork realization defined in the Hydro Feature core model, specifically as aggregate of permanent or temporary bodies of water standing in depressions or moving in channels. If the realized catchment is connected with other catchments via outfall, the hydrographic network is considered connected to the network realizing these catchments. This allows to represent the network, even if logically connected features may or may not be connected at the representation level. If required, an application focused on surface-water bodies contained in channels or depressions may use the defined relationships to describe the realization of a catchment by the hydrographic network, or network parts associated with the channel network.

HY\_HydrographicNetwork inherits from generalization the realizedCatchment, flowpath and waterEdge, as well as catchmentBoundary and catchmentArea associations, and associates a networkWaterBody. A flowline and a water-edge constraint support the recognition of the water body as flowpath realizing the catchment.

Table 24: HY\_HydrographicNetwork

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***networkWaterBody*** | water body which realizes the logical catchment either separately, or as part of the hydrographic network. | Association |
| ***flowline*** | defines that whenever a flowpath exists as part of a network, the water body should be recognized as a flowpath. Geometrically represented as a curve, flowline will support to ‘measure’ a position on, or along, the water body using a centreline as shape. | Constraint |
| ***water-edge*** | defines that whenever a water edge exists as part of a network, the water body should be recognized as a water edge. Geometrically represented as a curve, water-edge will support to ‘measure’ a position on, or along, the channel using the line of intersection with a water body. | Constraint |

#### Water Body

The HY\_WaterBody feature type (Figure 43) specializes the general HY\_HydroFeature class. The water body is part of the hydrographic network, either standing in a water pool, or flowing as stream in a watercourse, which are parts of the channel network. A water body may be segmented in vertical sections at right angles to the main (average) direction of flow or along its centerline, and horizontal strata. Conceptually, each water body, or a stratum, is understood as a reservoir used for storage, regulation or control of water recourses.

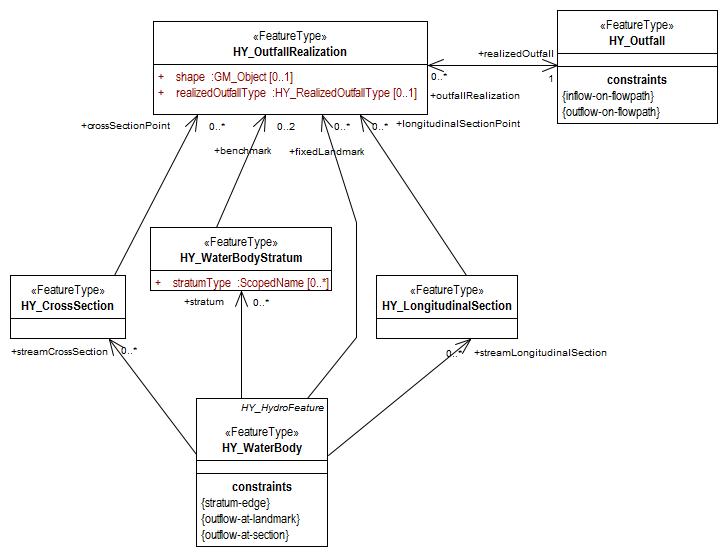


Figure 43: Water Body realizing the outfall (UML class diagram)

HY\_WaterBody inherits from generalization the name property, and the flow line and water edge constraints. It associates the hydrographicNetwork in which it participates, the containing waterpool and watercourse, the vertical streamCrossSection, streamLongitudinalSection, a horizontal stratum, and a reservoir for storage of water. A stratum-edge constraint is defined such that whenever the water body is part of the hydrographic network, the confined stratum is of type HY\_WaterEdge. *Outflow-at-section* and outflow-at-landmark constraint emphasizes the recognition of a fixed landmark as outflow of the catchment realized by hydrographic network.

Table 25: HY\_WaterBody

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***waterpool*** | identifies the natural or artificial depression which contains standing water, including large interstices in the ground, such as cave, cavern or a group of these. | Association |
| ***watercourse*** | identifies the natural or man-made channel which continuously or periodically contains moving water, including large interstices in the ground, such as cave, cavern or a group of these | Association |
| ***stratum*** | identifies a horizontal layer of consistent characteristics, or a storage zone of a reservoir, carrying a permanent reference location which realizes the outfall of the catchment which is realized by the water body. | Association |
| ***upstreamWaterBody*** and ***downstreamWaterBody*** | identifies another water body immediately upstream or downstream, allowing to trace the hydrographic network without knowing the inflow or outflow of the catchment realized by the water body. | Association |
| ***fixedLandmark*** | identifies a fixed landmark as permanent reference location which realizes the conceptual outfall of the catchment realized by the water body. | Association |
| ***streamCrossSection*** *and**streamL****ongitudinalSection*** | identifies a vertical section either at right angles to the main (average) direction of flow, or along a centerline, carrying a permanent reference location which realizes the outfall of the catchment which is realized by the water body. | Association |
| ***storage*** | identifies a reservoir storing water as a resource for future use. This may be used to describe storage characteristics of the water body participating in the hydrographic network. | Association |
| ***stratum-edge*** | defines that whenever a water edge exists as part of a network, the stratum should be recognized as a water edge. Geometrically represented as a curve, stratum-edge will support to ‘measure’ a position on, or along, the stratum using the line of intersection with a depression. | Constraint |
| ***outflow-at-landmark*** | defines that a fixed landmark on a water body which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the hydrographic network the water body is part of. | Constraint |
| ***outflow-at-section*** | defines that a location at a vertical section of a water body which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the hydrographic network the water body is part of. | Constraint |

#### Water-Body Stratum

The HY\_WaterBodyStratum feature type describes a horizontal layer in a stratified water body determined by differences in thermal or salinity characteristics or by oxygen or nutrient content, or by virtual storage zones of a reservoir. HY\_WaterBodyStratum carries the properties: stratumType and benchmark.

Table 26: HY\_WaterBodyStratum

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***stratumType*** | characterizes the stratum using a term from a controlled vocabulary. An implementation may use the ScopedName type described in ISO 19103: Conceptual Schema. | Attribute |
| ***benchmark*** | identifies a benchmark which realizes the conceptual outfall of the catchment realized by the water body as permanent reference location. | Association |

#### Cross-Section and Longitudinal Section

The HY\_CrossSection and HY\_LongitudinalSection feature types conceptualize the segmentation of a water body or a containing channel through vertical sections. Taking into account the conceptual separation of a watercourse, the cross section concept refers to both the cross section of a water body orthogonal to the direction of flow, and to the transversal bed profile of a channel, The longitudinal section concept refers to both the vertical section of a water body along its centerline, and to the longitudinal bed profile of a channel.

Both types of vertical section associate crossSectionPoint and longitudalinalSectionPoint which should be used to identify a permanent reference location at a vertical section which realizes the conceptual outfall of the catchment realized by the associated channel or water body.

#### Water-LiquidPhase and Water-SolidPhase

The HY\_Water\_LiquidPhase and HY\_Water\_SolidPhase feature types provide simple concepts of the accumulation of water in water bodies. This definition refers to the matter accumulated to a mass of water. In its liquid form water is considered accumulated in water bodies; in its solid phase water may be accumulated after melting, or as a layer of ice or snow on an open water body. The accumulation of water in the atmosphere or below the land surface, e.g. rain, soil moisture or groundwater, is not in scope of this standard, as well as the accumulation of snow and ice in glaciers which is subject of glaciology science.

Contextually related information models may use the HY\_Water\_LiquidPhase and HY\_Water\_SolidPhase feature types to build relationships to an accumulating water body, and ultimately to the catchment realized either by the water body or by the network of which the water body is part.

HY\_Water\_LiquidPhase associates the *accumulatingWaterBody*; HY\_Water\_SolidPhase associates water from snowmelt and coveredWaterBody. These associations may be used to identify the water body (as part of the hydrographic network) where liquid water is accumulated.

### The Surface-Water Body types

The Surface Water model defines typical specializations of a water body on the land surface. Being a specialization of the HY\_WaterBody class each subtypes inherits the stratum, waterpool, watercourse, upstreamWaterBody, *downstreamWaterBody*, fixedLandmark, *streamCrossSection* and streamLongitudinalSection properties. From the general HY\_HydroFeature class the special water bodies inherit the name property, which allows to handle names given to them in cross-jurisdiction and multi-lingual contexts. Each specialization is understood to be part of the hydrographic network. In other contexts other specializations, or a typical segmentation, may exist that do not conform to the types defined in this standard.

The HY\_River feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its property to permanently or temporarily flow.

The HY\_Canal feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its artificial origin (man-made).

The HY\_Lake feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its considerable size.

The HY\_Impoundment feature type defines the existence of body of surface water, participating in a hydrographic network, special due to be formed by collecting water, as by a dam.

The HY\_Lagoon feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its shallow depth and interaction with the open sea.

The HY\_Estuary feature type defines the existence of body of surface water, participating in a hydrographic network, special due to branching and its interaction with the open sea.

### The Storage model

The Storage model (Figure 44) provides a concept to describe any water body, in terms of a reservoir storing water for future use. The separate storage model allows to describe the hydrographic network without the details of storage capacities that a water body may have, and vice versa storage reservoirs to be referenced independent of their role within the hydrographic network.

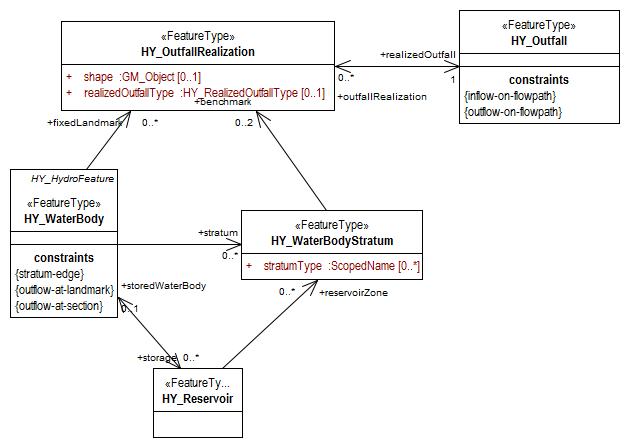


Figure 44: Reservoir realizing the outfall (UML class diagram)

The HY\_Reservoir feature type describes the water body, either natural or man-made, used for storage, regulation and control of water resources. The reservoir concept refers to a volume of water managed in zones between operating levels. HY\_Reservoir associates to a reservoir the storedWaterBody and a reservoirZone.

Table 27: HY\_Reservoir

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***storedWaterBody*** | identifies the network water body that specifies the connectivity of the storage reservoir in the hydrographic network. | Association |
| ***reservoirZone*** | identifies the water body stratum used for storage, for example a management zone, or flood control zone. | Association |

## The Hydrometric Network application schema

The Hydrometric Network application schema (Figure 45) defines a logical model to take into account a network of hydrometric stations as a specific realization of the catchment in the perspective of hydrologic observation, without the detail of an observation strategy.

The Hydrometric Network model specifies the concepts defined in the Hydro Feature core model (Figure 45). The general concept is that of a network of logically connected hydrometric stations realizing as a whole the catchment. This enables contextually related information models to relate monitoring stations and observing posts to hydrologic features, finally to the realized catchment, as usually required in the context of environmental reporting or when interpreting, comprising and processing observation results.

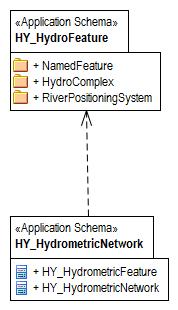


Figure 45: Hydrometric Network – dependencies

The hydrometric network model introduces the concept of a 'position on river' which allows an hydrologic station, even free from position, to be the realization of the logical outfall. This supports to establish upstream-downstream relationships between hydrometric features, to assign a position relative to a 'fixed' outfall, or to place a feature of interest relative to the hydrometric station.

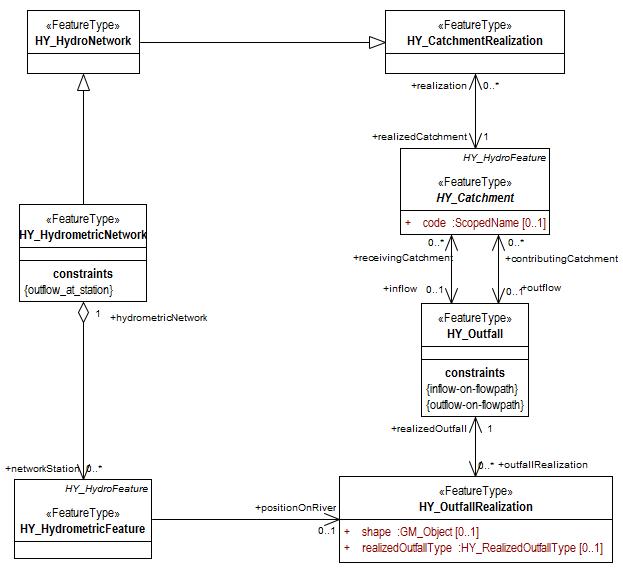


Figure 46: Hydrometric network and hydrometric feature realizing catchment and outfall (UML class diagram)

### Hydrometric Network

The HY\_HydrometricNetwork feature type specializes the HY\_HydroNetwork realization specifically as an aggregate of hydrometric features. HY\_HydrometricNetwork inherits through generalization the realizedCatchment, flowpath, waterEdge, catchmentBoundary and catchmentArea associations, and associates a *networkStation*. An outflow-at-station constraint emphasizes the recognition of a monitoring station as outflow of the catchment realized by hydrometric network the station is part of.

Table 28: HY\_HydrometricNetwork

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***networkStation*** | identifies the hydrometric feature which realizes the logical catchment either separately, or as part of the hydrometric network. | Association |
| ***outflow-at-station*** | defines that a monitoring station which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the hydrometric network the station is part of. | Constraint |

### Hydrometric Feature

The HY\_HydrometricFeature feature type provides a concept of a monitoring station at which data on water are obtained, which realizes the logical catchment either separately, or as part of the hydrometric network (Figure 46). HY\_HydrometricFeature associates the hydrometricNetwork in which it participates, and a positionOnRiver.

Table 29: HY\_HydrometricFeature

|  |  |  |
| --- | --- | --- |
| **Property** | **Concept or definition** | **Relation** |
| ***positionOnRiver*** | identifies the position of the hydrometric feature in the hydrographic network as permanent reference location which realizes the conceptual outfall of the catchment corresponding to the hydrometric feature. | Association |

# ANNEX A Conformance Class Abstract Test Suite (Normative)

## A.1 Introduction

These test suites verify the compliance of the conformance targets for the HY\_Features conceptual module with the HY\_Features specification. Each instance of hydrologic feature data is encoded according to a specific implementation schema, so conformance of a schema or a mapping to/from such a schema with the abstract specification is defined as a clear derivation of schema or mapping entities from the concepts, definitions, and constraints of HY\_Features.

## A.2 Conformance class: HY\_Features implementation schema equivalence

|  |  |  |
| --- | --- | --- |
| **Conformance Class** | | **/conf/hy\_features\_conceptual\_model** |
| **Requirements Class** | | [/req/hy\_features\_conceptual\_model](#_The_HY_Features_conceptual) |
| **Test** | | /conf/hy\_features\_conceptual\_model/mapping |
| Requirement | An implementation schema conforming to HY\_Features SHALL implement one or more feature types defined by the HY\_Features UML model in this standard, including all mandatory properties, associations, and default values.  A mapping implementation conforming to HY\_Features SHALL implement mappings between existing feature types and one or more HY\_Features feature types as defined in the HY\_Features UML model in this standard, including all mandatory properties, associations, and default values. |
| Test purpose | All relevant elements of an implementation schema or data exchange mapping including hydrologic features are valid implementations of HY\_Features concepts, associations, and constraints. |
| Test method | Inspect the correspondence between implementation schema or data exchange mapping elements and the HY\_Features model to determine that all relevant elements are mapped to HY\_Features concepts, associations, and constraints. |
| Test type | Inspection |
| **Test** | | /req/hy\_features\_conceptual\_model/GF\_Feature |
| Requirement | Each implemented HY\_Features feature type SHALL be an instance of the GF\_FeatureType (aka FeatureType) «metaclass» |
| Test purpose | All relevant elements of an implementation schema or data exchange mapping including hydrologic features are also valid instances of the GF\_FeatureType «metaclass». |
| Test method | Inspect the definitions of relevant schema or mapping elements to determine that defined features are valid instances of the GF\_FeatureType «metaclass». |
| Test type | Inspection |

# ANNEX B - Code lists for the HY\_Features model

## B.1 Terms identifying a fixed landmark determined to realize the conceptual outfall

|  |  |
| --- | --- |
| **Code list** | **Realized Outfall Type** |
| barrage | barrier across a stream provided with a series of gates or other control mechanisms to control the water-surface level upstream, to regulate the flow or to divert water supplies into a canal. |
| bifurcation | division of a stream into two branches. |
| confluence | joining, or the place of junction, of two or more streams. |
| dam | barrier constructed across a valley for impounding water or creating a reservoir. |
| diversion of water | transfer of water from one watercourse to another, such watercourses being either natural or man-made. |
| fork | (1) place where two or more streams flow together to form a larger stream. (2) place where a stream divides into two or more streams. |
| hydrometric station | station at which data on water in rivers, lakes or reservoirs are obtained on one or more of the following elements: stage, streamflow, sediment transport and deposition, water temperature and other physical properties of water, characteristics of ice cover and chemical properties of water. |
| inlet | structure admitting water supplies from the source or through an intake structure built upstream. |
| intake | structure or site, the purpose of which is to control, regulate, divert, and admit water directly from the source, through an inlet built upstream. |
| outlet | opening through which water flows out or is extracted from a reservoir or stream. |
| ponor | hole or opening in the bottom or side of a depression where a surface stream or lake flows either partially or completely underground into a karst groundwater system |
| rapids | reach of a stream where the flow is very swift and shooting, and where the surface is usually broken by obstructions, but has no actual waterfall or cascade. |
| reference climatological station | climatological station the data of which are intended for the purpose of determining climatic trends. This requires long periods (not less than thirty years) of homogeneous records, where man-made environmental changes have been and/or are expected to remain at a minimum. Ideally the records should be of sufficient length to enable the identification of secular changes of climate. |
| river mouth | place of discharge of a river into a sea or a lake. |
| sinkhole | place where water disappears underground in a limestone region. It generally implies water loss in a closed depression or blind valley. |
| source | origin of river. |
| spring | place where water flows naturally from a rock or soil onto land or into a body of surface water. |
| waterfall | vertical fall or the very steep descent of a stream of water. |
| weir | overflow structure which may be used for controlling upstream water level or for measuring discharge or for both. |

## B.2 Terms commonly used in hydrology to describe a spatial relation between two locations

|  |  |
| --- | --- |
| **Code list** | **Distance Description** |
| at | located at the (reference) location |
| between | located between two (reference) locations |
| downstream | located downstream of the (reference) location, e.g. in the direction of the current in a river or stream. |
| left | located left-hand of the (reference) location when facing downstream. |
| nearby | located in a short distance to the (reference) location. |
| right | located right-hand of the (reference) location when facing downstream. |
| upstream | located upstream of the (reference) location, e.g. in the direction towards the source of a stream. |

## B.3 Terms commonly used in hydrology to describe a drainage pattern

|  |  |
| --- | --- |
| **Code list** | **Drainage Pattern** |
| annular | main rivers have circular pattern with subsidiary channels at right angles. |
| centripetal | streams flow inward to center. |
| dendritic | spreading treelike arrangement; no evident orientation of channels (random orientation). |
| distributary | one main channel divides into many channel-ways ending with many outlets. |
| parallel | main channels regularly spaced and parallel or sub-parallel to each other; tributaries join at very acute angles. |
| pinnate | featherlike, closely grouped , short tributaries (fine texture). |
| radial | streams flow outward from center. |
| rectangular | drainage forms a perpendicular net with the two directions equally developed. |
| trellis | a dominant drainage direction with a secondary direction perpendicular to this; primary tributaries join main stream at right angles, secondary tributaries parallel main stem. |

## B.4 Terms commonly used to indicate the type of name usage.

|  |  |
| --- | --- |
| **Code list** | **Usage Type** |
| conventional | accepted, used, or practiced by most people ('agreed by convention') |
| historical | restricted to or based on fact in history |
| official | ordered or allowed by those in authority |
| vernacular | used in or suitable for speech, usually not used in formal writing |

# ANNEX C: HY\_Features - AHGF Mapping

This is a descriptive mapping for the Australian Hydrological Geospatial Fabric (AHGF) [11]. It is intended to provide an understanding of the basic relationship of HY\_Features concepts and the AHGF hydrologic feature implementation.

## C.1 Catchment Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **AHGF Class** | **Comment** |
| HY\_Catchment | ConCatID | Logical features identified via ConCatID with topological relationships defined via ConNodeID (HY\_Outfall). Can also be seen as the contributing set of logical features sharing a common ConCatID. |
| HY\_DendriticCatchment | ConCatID | All logical HY\_Catchment features are constrained to be dendritic in the Geofabric. |
| HY\_InteriorCatchment | Not represented | All catchment areas defined by a particular DEM are considered to flow to a single common outlet.  Note: Areas not flowing to a common outlet are aggregated with areas that do according to saddle points in the terrain model. |
| HY\_CatchmentAggregate | Collections of ConNodeID | Network following connectivity via ConNodeID encapsulating divergent flows to remain dendritic in nature. |
| HY\_Outfall | ConNodeID | All ConNodeID act in the role of outflow node (To\_Node) for one or more ConCatID catchment(s) and most also act in the role of inflow node (From\_Node) for a single ConCatID catchment. |
| HY\_Outfallrealization | AHGFNetworkNode | HY\_OutfallRealization can be used as a reference location for any point associated with a feature. In reality this will normally be a realization of a ConNodeID (with associated coordinates) or the Geofabric realization of event locations (AHGFNetworkNode::GhostNode) used to register Hydrometric features on the network. |
| HY\_CatchmentRealization | Feature identified by ConCatID | Any feature or collection of features identified by a single ConCatID. Single instances of AHGFContractedCatchment and AHGFLink as well as collections of AHGFNetworkStream, AHGFNetworkNode, AHGFCatchment (low level sub-catchments) and AHGFWaterbody. **Note**: features of subtype AHGFContractedCatchment::NoFlowArea do not have a ConNodeID (i.e. No HY\_Outfall) |
| HY\_CatchmentArea | AHGF Contracted Catchment, AHGFCatchment | A single AHGFContractedCatchment or a collection of AHGFCatchment (both 2D simple surfaces derived from a common Digital Elevation model). |
| HY\_CatchmentBoundary | Not represented | Can be seen as the boundary (or boundaries) of the polygon feature(s) that realise HY\_CatchmentArea. |
| HY\_CartographicRealization | AHGFMappedStream | AHGFMappedStream is a feature class of the Geofabric Surface Cartography product, perhaps all feature classes in this product can be considered as HY\_CartographicRealization. |

## C.2 Hydrographic Network

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **AHGF Class** | **Comment** |
| HY\_Hydrographic Network | AHGFNetworkStream | Subset of AHGFNetworkStream features (subtypes: NetworkFlowSegment & NetworkWaterAreaSegment) provides a particular HY\_CatchmentRealization. This network realization can be supplemented with its corresponding HY\_ChannelNetwork instance. |
| HY\_WaterBody | AHGFNetworkStream | AHGFNetworkStream features (subtypes: NetworkFlowSegment & NetworkWaterAreaSegment) |
| HY\_ChannelNetwork | AHGFNetworkStream | Subset of AHGFNetworkStream:: NetworkArtificialFlowSegment provides a particular HY\_CatchmentRealization. This network realization is only complete when combined with the corresponding HY\_HydrographicNetwork instance. |
| HY\_Depression | Not represented |  |
| HY\_Channel | AHGFNetworkStream | AHGFNetworkStream features (subtype: NetworkArtificialFlowSegment). For version 3 products AHGFNetworkStream features are related to the relevant logical HY\_Catchment via ConCatID. |
| HY\_Reservoir | AHGFWaterbody::Reservoir | Reservoir subtype of AHGFWaterbody. |
| HY\_FlowPath | AHGFLink | Note: Geofabric currently has no FlowPath for headwater (AHGFContractedCatchment) areas. |
| HY\_WaterEdge | Not represented |  |
| HY\_LongitudinalSection | Not represented |  |
| HY\_CrossSection | Not represented |  |
| HY\_WaterBodyStratum | Not represented |  |
| HY\_Water\_LiquidPhase | Not represented |  |
| HY\_Water\_SolidPhase | Not represented |  |
|  |  |  |

## C.3 Hydrometric Network

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **AHGF Class** | **Comment** |
| HY\_HydrometricNetwork | Not represented | Possible future plans to produce a geoschematic representation of the hydrometric features at some stage. |
| HY\_HydrometricFeature | AHGFNetworkNode:: AHGFGhostNode | Ghost Nodes are a representation of Hydrometric features located on a Hydrographic Network representation. **Note**: Currently, V3 has a separate AHGFGhostNode feature class for ghost nodes. There are plans to include these features as part of the Hydrology Reporting Catchments product forming outfalls for AHGFContractedCatchment (HY\_DendriticCatchment) features. |
| HY\_RiverReferenceSystem | Not represented | Measures are not yet explicitly included in AHGF. |
| HY\_IndirectPostition | Not represented | Measures are not yet explicitly included in AHGF. |

# ANNEX D: HY\_Features - NHDPlus Mapping

This is a descriptive mapping for the USGS National Hydrography Dataset Plus (NHDPlus)[10]. It is intended to provide an understanding of the basic relationship of HY\_Features concepts and the NHDPlus hydrologic feature implementation.

## D.1 Catchment Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_Catchment | comid catchment | The comid catchment is the feature that takes part in PlusFlow topology table, has associated accumulated characteristics, etc. Could also be the collection of catchments that contribute to a given reachcode reach, HUC watershed outlet, or other identifiable watershed outlet. |
| HY\_DendriticCatchment | comid catchment | NHDPlus catchments not following any diversions in the flow tables |
| HY\_InteriorCatchment | comid catchment | NHDPlus catchments that do not contribute flow. |
| HY\_CatchmentAggregate | collection of comid catchments | Including interior catchments and not following diversions in the flow tables |
| HY\_Outfall | fromNode or toNode | NHDPlus nodes are inflow (fromNode) and outflow (toNode) nodes of a given comid catchment. |
| HY\_OutfallRealization | fromNode or toNode location, point location of point events, etc. | HY\_OutfallRealization can be used as a reference location for any point associated with a feature. Typically this is for outfalls and monitoring locations, but may be used for many other feature types. |
| HY\_CatchmentRealization | Any entity that is identified by a comid | In NHDPlus, the comid identifier represents an unrealized catchment. Any geometric or topologic data that is referenced to a comid can be said to realize that catchment. This includes upstream aggregations of the network or catchment areas to form complete watersheds. |
| HY\_CatchmentArea | Not Represented | While the polygon representing a catchment might be thought of as an area, the subset of a DEM or another land cover dataset would be more in line with the meaning of CatchmentArea. |
| HY\_CatchmentBoundary | comid catchment polygon | The polygon representing a comid catchment should be thought of as both the catchmentBoundary |
| HY\_CartographicRealization | A map of a catchment | The NHDPlus dataset doesn't include any, but if a map view of a catchment is created at any scale, it could be said to be a cartographic visualization realization of the catchment. |

## D.2 Hydrographic Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_HydrographicNetwork | collection of flowlines and waterbodies | The collection of perennial and ephemeral flowlines as well as so-called double line streams and on-network lakes within any collection of catchments (an HY\_Catchment) can be considered it's hydrographic network. |
| HY\_WaterBody | Perennial flowlines and waterbodies | Perennial flowlines are thought to represent water bodies as well as waterbody polygons that represent wide streams and lakes. These features indicate that there is water contained in some channel or other container. |
| HY\_ChannelNetwork | Not represented |  |
| HY\_Depression | Not represented |  |
| HY\_Channel | Ephemeral flowlines. | While NHD doesn't have an explicit channel concept, ephemeral flowlines can be thought of as a channel in that they indicate that water can flow there, but may not be present in the flowline container at all times. |
| HY\_Reservoir | waterbodies that are reservoirs | Any waterbody that can be categorized as a reservoir |
| HY\_FlowPath | flowlines and reaches | A flowline or reach is the linear representation of a catchment. For NHD Events, the reach is the flowpath because it is the linear element used for linear referencing. |
| HY\_WaterEdge | Not represented |  |
| HY\_LinearSegment | flowline | For reachcode linear referencing, the reachcode flowpath is made up of a collection of linear segments that are flowlines |
| HY\_LongitudinalSection | Not represented |  |
| HY\_CrossSection | Not represented |  |
| HY\_WaterBodyStratum | Not represented |  |
| HY\_Water\_LiquidPhase | Not represented |  |
| HY\_Water\_SolidPhase | Not represented |  |

## D.3 Hydrometric Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_HydrometricNetwork | Not Represented |  |
| HY\_HydrometricFeature | event | A hydrometric feature, such as a stream gaging station, is represented as an event. |
| HY\_RiverReferenceSystem | reachcode and measure | A reachcode reach is the river reference system's shape, the origin is the outlet of the reach, and the indirect position is the measure. |
| HY\_IndirectPosition | measure | The measure is an indirect position of type relative position because it is a percent. |

# ANNEX E: HY\_Features - INSPIRE Hydrography Theme

This table assigns core features as defined in the INSPIRE Hydrography theme [2] to HY\_Features core concepts. It also indicates relationship between both terms and potential conditions in which they can be associated.

This table should not be understood in terms of a ‘conceptual mapping’ of clearly defined relationships between two logical concepts, but rather as a simple approach to show compatibility of concepts, based on the meaning expressed in the definitions, and without imposing a particular implementation. Since each dataset that implements the INSPIRE theme will have a different legacy of documentation and information modeling, a conceptual mapping would be expressed differently. Applications implementing the INSPIRE Hydrography theme can use this listing to understand how a particular dataset may relate to the HY\_Features concepts.

## E.1 Catchment Model

|  |  |  |  |
| --- | --- | --- | --- |
| **HY\_Features Name** | **Relationship between concepts** | **INSPIRE Hydrography Name + potential condition(s)** | **Definition / Description** |
| HY\_Catchment | Is like | DrainageBasin  In case that HY\_Catchment is realized by HY\_CatchmentArea | Area having a common outlet for its surface runoff.  NOTE 1 Regarding the different classifications of drainage basins, no distinction is made between drainage basins / sub-basins since this will vary with application. It is possible to build basins from other basins.  NOTE 2 The outlet of a drainage basin may be a canal or a lake.  NOTE 3 Synonyms for drainage basin include: catchment; catchment area; drainage area; river basin; watershed. |
| HY\_DendriticCatchment | Is narrower than | DrainageBasin  In case that HY\_Catchment is realized by HY\_CatchmentArea  With one outlet | Area having a common outlet for its surface runoff.  NOTE 1 Regarding the different classifications of drainage basins, no distinction is made between drainage basins / sub-basins since this will vary with application. It is possible to build basins from other basins.  NOTE 2 The outlet of a drainage basin may be a canal or a lake.  NOTE 3 Synonyms for drainage basin include: catchment; catchment area; drainage area; river basin; watershed. |
| HY\_InteriorCatchment |  | Not represented |  |
| HY\_CatchmentAggregate | Is like | RiverBasin  In case that HY\_Catchment is realized by HY\_CatchmentArea | The area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta. |
| HY\_Outfall | Is like | HydroNode  In case that HY\_Catchment is realized by HY\_FlowPath | A node within the hydrographic network.  NOTE May represent a physical confluence, bifurcation/confluence/vanishing point etc., or it may be associated with a hydrographic point of interest or facility. |
| HY\_OutfallRealization | Is like | HydroPOI | A natural place where water appears, disappears or changes its flow.  EXAMPLE Fluvial points (waterfall, cascade, rapids, breaker), spring/water hole (spring, source, geyser, thermal spring, natural fountain, well, also fumarole, artesian), sinkhole (sinkhole, drainage loss).  NOTE A hydro point of interest may create a flow constriction in the network. |
| HY\_CatchmentRealization |  | Not represented |  |
| HY\_CatchmentArea | Is like | DrainageBasin | Area having a common outlet for its surface runoff.  NOTE 1 Regarding the different classifications of drainage basins, no distinction is made between drainage basins / sub-basins since this will vary with application. It is possible to build basins from other basins.  NOTE 2 The outlet of a drainage basin may be a canal or a lake.  NOTE 3 Synonyms for drainage basin include: catchment; catchment area; drainage area; river basin; watershed. |
| HY\_CatchmentBoundary |  | Not represented |  |
| HY\_CartographicRealization |  | Not represented |  |

## E.2 Hydrographic Network Model

|  |  |  |  |
| --- | --- | --- | --- |
| **HY\_Features Name** | **Relationship between concepts** | **INSPIRE Hydrography Name + potential condition(s)** | **Definition / Description** |
| HY\_HydrographicNetwork | Is narrower than | WatercourseLinkSequence  In case that features of interest are water bodies and not channels.  AND  In case that network is non branching. | A sequence of watercourse links representing a non-branching path through a hydrographic network. |
| HY\_WaterBody | Is narrower than | WatercourseLink  In case that features of interest are water bodies and not channels. | A segment of a watercourse within a hydrographic network. A watercourse link may be fictitious, with no direct correspondence to a real-world object and included only to ensure a closed network. |
| HY\_ChannelNetwork | Is narrower than | WatercourseLinkSequence  In case that features of interest are channels and not water bodies.  AND  In case that network is non branching. | A sequence of watercourse links representing a non-branching path through a hydrographic network. |
| HY\_Depression | Is like | StandingWater  In case that geometry is surface or point. | Any known inland waterway body.  EXAMPLE Lake/pond, reservoir, river/stream, etc.  NOTE: May include islands, represented as 'holes' in its geometry. Islands may be surrounded by a shore and / or land-ware boundary. |
| HY\_Channel | Is narrower than | WatercourseLink  In case that features of interest are channels and not water bodies. | A segment of a watercourse within a hydrographic network. A watercourse link may be fictitious, with no direct correspondence to a real-world object and included only to ensure a closed network. |
| HY\_Reservoir | Is like | StandingWater  In case that geometry is surface or point. | Any known inland waterway body.  EXAMPLE Lake/pond, reservoir, river/stream, etc.  NOTE: May include islands, represented as 'holes' in its geometry. Islands may be surrounded by a shore and / or land-ware boundary. |
| HY\_FlowPath | Is like | WatercourseLink  With a fictitious representation | A segment of a watercourse within a hydrographic network. A watercourse link may be fictitious, with no direct correspondence to a real-world object and included only to ensure a closed network. |
| HY\_WaterEdge | Is like | LandWaterBoundary | The line where a land mass is in contact with a body of water. |
| HY\_LongitudinalSection |  | Not represented |  |
| HY\_CrossSection |  | Not represented |  |
| HY\_WaterBodyStratum |  | Not represented |  |
| HY\_Water\_LiquidPhase |  | Not represented |  |
| HY\_Water\_SolidPhase |  | Not represented |  |

# ANNEX F: HY\_Features - SANDRE Mapping

This is a descriptive mapping for the French National Service for Water Data and Reference-dataset Management (SANDRE) [12]. It is intended to provide an understanding of the basic relationship of HY\_Features concepts and the SANDRE hydrologic feature dictionary for Hydrography.

Please notice that terms for SANDRE are based on French words.

## F.1 Catchment Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **SANDRE Name** | **Comment** |
| HY\_Catchment | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro  OR  ZoneHydro | SANDRE make distinction between basins and sub-basins |
| HY\_DendriticCatchment | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro  OR  ZoneHydro | SANDRE: all catchments are dendritic |
| HY\_InteriorCatchment | Not represented |  |
| HY\_CatchmentAggregate | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro | SANDRE: RegionHydro are aggregation of SecteurHydro that are aggregation of SousSecteurHydro that are aggregation of ZoneHydro |
| HY\_Outfall | NoeudHydrographique | HY\_Outfall can be seen as a specific NoeudHydrographique |
| HY\_OutfallRealization | NoeudHydrographique | HY\_Outfall can be seen as a specific NoeudHydrographique |
| HY\_CatchmentRealization | Not represented |  |
| HY\_CatchmentArea | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro  OR  ZoneHydro | While the polygon representing a catchment might be thought of as an area, the subset of a DEM or another land cover dataset would be more in line with the meaning of CatchmentArea. |
| HY\_CatchmentBoundary | LimiteHydroBassin | SANDRE : LimiteHydroBassin is the boundary of a catchment. It has a linear representation. |
| HY\_CartographicRealization | Not represented |  |

## F.2 Hydrographic Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **SANDRE Name** | **Comment** |
| HY\_HydrographicNetwork | Not represented | SANDRE focuses on channels, not on water bodies |
| HY\_WaterBody | Not represented | SANDRE focuses on channels, not on water bodies |
| HY\_ChannelNetwork | CoursEau  OR  TronconHydrographique | SANDRE: CoursEau is an aggregation of TronconHydrographique that is an aggregation of TronconHydrograElt.  All of them have a linear representation. |
| HY\_Depression | EntiteHydroSurface  OR  EltHydroSurface | SANDRE: EntiteHydroSurface is an aggregation of EltHydroSurface. Both have a surfacic representation. |
| HY\_Channel | TronconHydrographique  OR  TronconHydrograElt  OR  EltHydroSurface | SANDRE: CoursEau is aggregation of TronconHydrographique that is an aggregation of TronconHydrograElt. All of them have a linear representation.  EntiteHydroSurface |
| HY\_Reservoir | EntiteHydroSurface  OR  EltHydroSurface  OR  PointEauIsole | SANDRE: EntiteHydroSurface is an aggregation of EltHydroSurface. Both have a surfacic representation.  PointEauIsole can be used in case that HY\_Reservoir is not linked to the hydrographic network and is represented by a point |
| HY\_FlowPath | Not represented |  |
| HY\_WaterEdge | Not represented |  |
| HY\_LongitudinalSection | Not represented |  |
| HY\_CrossSection | Not represented |  |
| HY\_WaterBodyStratum | Not represented |  |
| HY\_Water\_LiquidPhase | Not represented |  |
| HY\_Water\_SolidPhase | Not represented |  |

## F.3 Hydrometric Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_HydrometricNetwork | Not Represented |  |
| HY\_HydrometricFeature | Not Represented |  |
| HY\_RiverReferenceSystem | Not Represented |  |
| HY\_IndirectPosition | Not Represented |  |

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# ANNEX H: Revision history

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Date | Release | Author | Paragraph modified | Description |
| 08.10.2014 | 0.1 | Irina Dornblut | Initial version | Initial draft in OGC template |
| 12.11.2014 | 0.2 | Irina Dornblut | Section7, Annex D included | Editing requirements classes, Annex D included |
| 15.08.2016 | 0.3 | David Blodgett; Irina Dornblut | Completely revised version | Draft in OGC template |
| 18.08.2016 | 0.4 | Irina Dornblut | Section 6 | Catchment + UML figures added |
| 31.08.2016 | 0.5 | David Blodgett, Darren Smith, David Arctur | Entire Document | General edit for clarity and consistency. |
| 12.09.2016 | 0.6 | Irina Dornblut | Entire document | More edits for clarity and consistency  Translation into American English |
| 11.10.2016 | 0.7 | HYF-SWG at Orlando TC meeting  Irina Dornblut | Entire Document | Reconciling comments from the initial OAB review  Review of conformance and requirements classes  Conformance to OGC Abstract Specification standards  Edits for consistency |
| 11.10.2016 | 0.8 | David Blodgett | Entire Document | Figures updated  Edits for clarity |
| 11.18.2016 | 0.9 | Josh Lieberman  David Blodgett | Entire Document | Edits in reference to conformance and topological concepts.  Class associations, attributes, and constraints formatted into tables.  Conformance classes clarified. |
| 9.01.2017 | .10 | Irina Dornblut | Section 6 and 7 | Reconciling comments from the second OAB review |

1. https://cite.opengeospatial.org/ [↑](#footnote-ref-1)
2. also online, http://webworld.unesco.org/water/ihp/db/glossary/glu/aglo.htm [↑](#footnote-ref-2)