Report 43r1

GRDC Report Series

HY_Features: a geographic information model for the hydrology domain

Concepts of the HY_FEATURES common hydrologic feature model

Global Runoff Data Centre

GRDC operates under the auspices of the World Meteorological Organization (WMO) with the support of the Federal Republic of Germany within the Federal Institute of Hydrology (BfG)

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About the Global Runoff Data Centre (GRDC):

The GRDC is acting under the auspices of the World Meteorological Organization (WMO) and is supported by WMO Resolutions 21 (Cg XII, 1995) and 25 (Cg XIII, 1999). Its primary task is to maintain, extend and promote a global database on river discharge aimed at supporting international organizations and programs by serving essential data and products to the international hydrologic and climate research and assessment community in their endeavour to better understand the Earth system. The GRDC was established at the German Federal Institute of Hydrology (BfG) in 1988. The National Hydrological and Meteorological Services of the 191 WMO Member states and territories are the principal data providers for the GRDC.

All questions regarding this document should be directed to the contributing authors.

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Abstract

Hydrologic features are abstractions of complex real world hydrologic processes, and relate to everyday concepts such as rivers, lakes, catchments etc. Different models of hydrologic processes, and different scales of detail, lead to a variety of information models to describe hydrologic features, and to different and mostly incompatible sets of feature identifiers.

This document describes the concepts of the HY_FEATURES common hydrologic feature model, a conceptual model for hydrologic features independent from approximate geometric representations at different scales. This model allows common reference to both the specific semantics and individual identifiers of hydrologic features across scientific sub-disciplines in hydrology.

The HY_FEATURES model is intended to form the basis for standard practices for referencing hydrologic features. These practices would be policy under the auspices of the WMO Commission for Hydrology (WMO-CHy) and recommended for general use in the wider community. HY_FEATURES is designed as a set of interrelated Application Schemas using ISO 19103:2005 Conceptual Schema Language and ISO 19109 General Feature Model. It is factored into relatively simple components that can be reviewed, tested and extended independently.

Keywords

data integration; feature; geographic information; hydrology; identification; information model; OGC; property; reference model; semantics; WMO

Foreword

The Global Runoff Data Centre (GRDC) is the worldwide archive of river discharge data. It operates under the auspices of the World Meteorological Organization (WMO) with support from the Federal Republic of Germany. The GRDC is operated by the German Federal Institute of Hydrology (BfG). The worldwide exchange of hydrologic data and information in support of climate research and integrated water resources management is the principal reason for the operation of the GRDC. GRDC has been serving for more than twenty-five years successfully as a facilitator between the producers of hydrologic data and the international research community using the Global Runoff Database.

The WMO promotes the utilization of international industry standards for transfer protocols, hardware and software enabling the routine data collection and automated dissemination of observed data as well as ad-hoc requests for data and products. Being a recognized international standardization body, WMO has the mandate to set standards in these areas.

The water related activities are shaped by the WMO Technical Commission for Hydrology (WMO-CHy). This includes advice on the standardization of various aspects of hydrologic observations, as well as on the sharing and exchanging of hydrologic data using modern information and communication technology.

Since mid 2009, a joint working group of the World Meteorological Organization (WMO) and the Open Geospatial Consortium (OGC) consisting of members from government, research and the commercial sectors has been working to improve the discoverability, accessibility and usability of water information and data. This WMO/OGC Hydrology Domain Working Group (WMO/OGC HDWG) brings organizations together to agree on the ways to significantly improve the ability to share water information, hydrologic data and data products. Focus of activities is on the development of WaterML2 as a series of domain-specific standards with the intention to provide a means by which diverse systems can encode their particular data in a standard way for communication with other systems and for aggregation of data from diverse sources. The GRDC has actively contributed to the development of domain-specific concepts for feature identification, especially those of general applicability across information systems that concern or interact with the hydrology domain.

This document describes a conceptual model for the identification of hydrologic features independent from geometric representation and scale. The HY_FEATURES common hydrologic feature model is intended for submission to WMO-CHy as a candidate WMO Best Practice for referencing hydrologic features in the context of the scientific and technical programmes of the WMO, particularly for implementation through the WMO Information System (WIS) and the WMO Integrated Global Observing System (WIGOS), and release to the hydrologic community of the WMO Member countries.

Preface

This document describes the general requirements of a common feature model and the concepts defined to describe hydrologic features and their fundamental relationships independent from implementation and scale in order to allow common reference to these features across scientific sub-disciplines in the hydrology domain and cross-domain.

The HY_FEATURES common hydrologic feature model (hereinafter referred to as HY FEATURES) uses as far as possible the term and definitions endorsed by WMO-CHy. The key reference is the *UNESCO/WMO International Glossary of Hydrology* (WMO-IGH) [WMO, 1992a]. Whenever an appropriate definition is provided in this glossary, the model captures this meaning, and the relationships inferred from that definition, to define relevant features and feature properties. The definitions, class relationships and attributes, their obligation and maximum occurrence may be taken from Annex A: HY_FEATURES Data Dictionary.

The common hydrologic feature model, HY_FEATURES, is designed as a set of interrelated Application Schemas using ISO 19103:2005 Conceptual Schema Language and ISO 19109:2005 General Feature Model. It is factored into relatively simple components that can be reviewed, tested and extended independently.

This document refers to the OGC 11-039r3 HY_Features Discussion Paper [OGC, 2013] which describes the proposed design of the HY_FEATURES model. The discussion paper has been prepared to initiate validating and testing of the hydrology-specific feature model in the geospatial information community. It was produced as part of the WMO/OGC HDWG activity and submitted to OGC by CSIRO (AU) and GRDC. GML schemas and OWL files are drafted and provided within Testbed 10 of the OGC Web Services (OWS-10). They need further checking, especially in the context of WIS and WIGOS activities that may need them. They may be subject to change in the course of validating and implementing the concepts of HY_FEATURES in domain-specific application schemas.

This report is distributed for review and comment by WMO-CHy Members and other interested parties. It documents work in progress and may be updated or replaced by other documents without notice. Recipients of this document are invited to provide supporting documentation. Suggested additions, changes, and comments on this report are welcomed and encouraged.

1 Introduction

Features are information objects describing real-world phenomena. Hydrologic features are referenced in various hydrologic datasets in current use. They are the sampled features of observation, the features for which water usage allocations are determined, and the reported features in national or international information systems. As such they are key criteria for discovery of hydrologic data and products. A stable referencing of these features is required to assist the organisation in their monitoring and modelling on global, regional, or basin scales as well as the aggregation of generated data into integrated suites of datasets.

An agreed set of definitions (semantics) is required to reference features and determine the concept they represent and the integration of data proceeds using the semantic framework such definitions provide. However there is no standard conceptual model for hydrologic feature identification. Different models of hydrologic processes, and different scales of detail, lead to a variety of information models to describe these features, and to different and mostly incompatible sets of feature identifiers.

The need for a domain-specific feature model emerges from the requirement to integrate data and information across multiple systems, emerging from the global geographic distribution of jurisdiction over water resources and the multiple systems and sub-domains that concern or interact with the hydrology domain. To communicate compatible data and information about a distinct state of a hydrologic process, to integrate multiple or cross-reference alternative representations of a hydrologic feature, it becomes necessary to identify the concepts shared in different application contexts and to express the semantics of hydrologic features commonly used in disparate and differently structured data products.

Linking data across multiple systems, e.g. on the Web, means linking references. With respect to hydrologic data, topologic and hydrologic references are needed rather than geometry. Geometric representations are imprecise and hard to interpret the significance of the interactions of different geometries. Identifiers must be able to stably reflect the hydrologic significance and network connectivity. Common semantics are required to enable declaring these relationships and sharing them unambiguously amongst the community.

2 Scope

The initial scope of the HY_FEATURES common hydrologic feature model is defined by the concerns of the WMO-CHy to facilitate the data sharing within the hydrologic community of the WMO Member countries and to improve the quality of data products based on these data. Interoperability of observing systems needs standardized formats and transfer routines such as WaterML2, however the compatibility of data products also requires commonly agreed concepts to describe the features of shared interest. In the hydrology domain these features represent results of the hydrologic processes at various stages of the water cycle, relevant to study and report 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, and their reaction with their environment* [WMO, 1992a]. This scope includes well-established data models and patterns in use in the hydrology domain, since the intended goal is to further support these using a common conceptual model.

The HY_FEATURES model defines the semantics of features which are the overall objects of study and reporting in hydrology and associated scientific disciplines. It provides a means to identify these features independent from scale of geographic representation. It also enables multiple representations of these features, with alternative data models, to be linked to the ultimate object of study or reporting. The model encompasses different approaches of modelling hydrologic features, but enforces the semantics of relationships between different levels of detail. This provides a semantic framework for feature identifiers to be developed and embedded in individual data products without constraining the flexibility required to model complex hydrologic processes at fine detail.

2.1 HY_FEATURES in the overall context of OGC standards

NOTE: Text in this section is taken from clause 6.1.1 in OGC 11-039r3 [OGC, 2013].

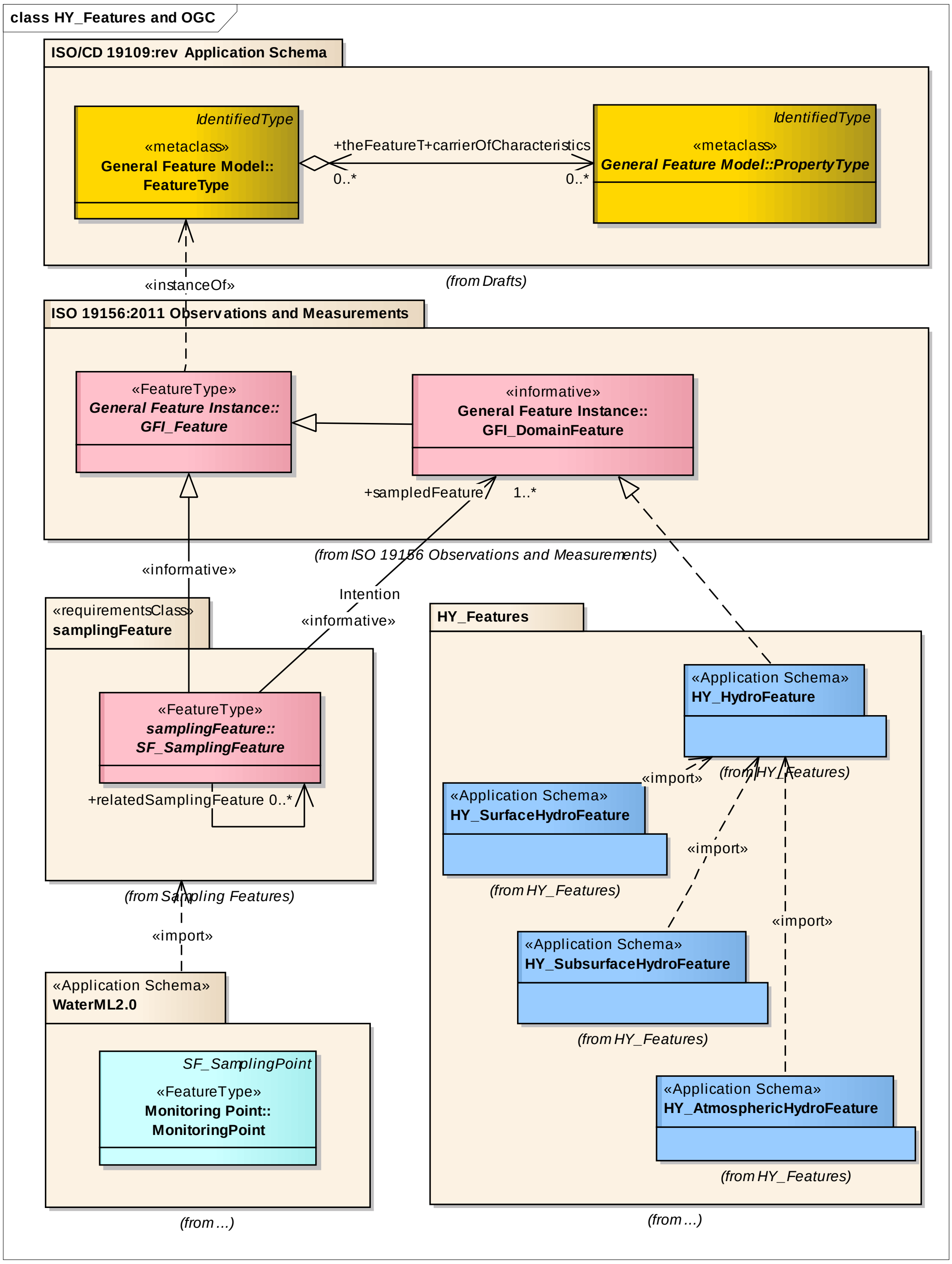

Figure 1: HY_FEATURES in the context of the OGC Abstract Specifications

The HY_FEATURES model defines hydrology-specific implementations of the general FEATURE TYPE (aka GF_FEATURETYPE) metaclass. Since its concern is primarily the issue of feature identification, a basic HY_HYDROFEATURE is defined wherever hydrologic features are required to be references. This is intended to specify the general feature instance in terms of the sampled feature of observation as currently required by the ISO 19156:2011 Observation and Measurements model (O&M). Specifically, this is expected to provide a model for use in applications of WaterML 2.0 Implementation Profile of O&M.

Figure 1 shows how the HY_FEATURES model might fit into the existing OGC feature landscape. For applications in hydrology, particularly in the context of hydrologic observation and sampling, the proposed HY_HYDROFEATURE will represent the ultimate subject of observation, the intended sampled DOMAIN FEATURE and may be used by observation-centric applications such as WaterML 2.0 [OGC, 2012].

2.2 HY_FEATURES in the context of the WMO Information System

NOTE: Text in this section is taken from clause 6.1.2 in OGC 11-039r3 [OGC, 2013].

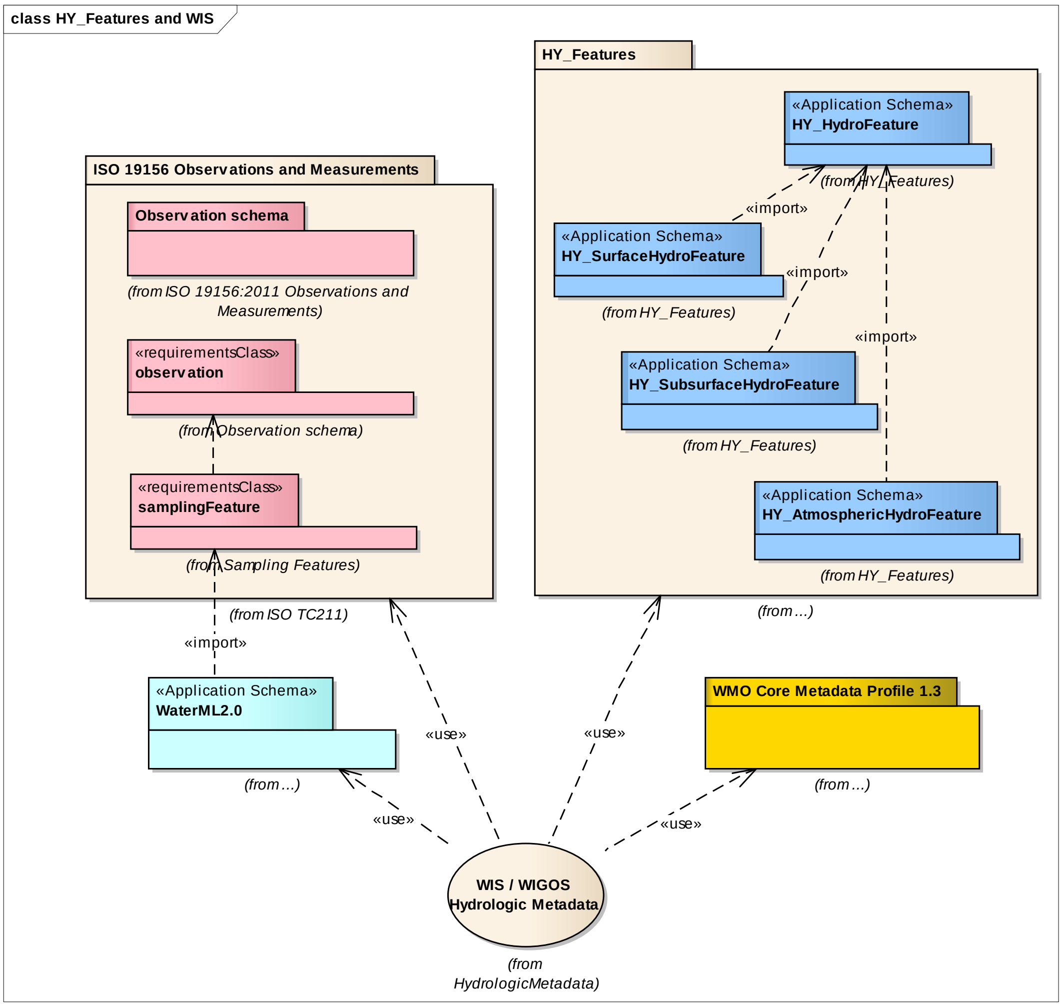

Figure 2: Placement of HY_FEATURES in the context of WIS / WIGOS

The WIS, the WMO Information System, provides mechanisms for the international exchange of information related to weather, climate and water. In this framework, the WMO Core Metadata Profile, version 1.3, was developed. This specification defines the content, structure and encoding of discovery metadata published within the WIS Discovery-Access-Retrieval (DAR) Catalogue. The metadata standard is defined as an informal category-1 profile of the ISO 19115:2003 Geographic information – Metadata.

WIGOS, the WMO Integrated Global Observing System, is a coordinated system which is comprised of the present WMO global observing systems. Complementary to the WMO Core Metadata Profile, a WIGOS Core Metadata Standard is under development that allows the essential observational information to be exchanged unambiguously, regardless of the format used for the transfer.

In this context, the HY_FEATURES model will provide a required component of a metadata model describing hydrologic datasets and products generated from observation. Other controlled vocabularies will be required as well as a binding mechanism to specify how these independently governed and published components can be combined.

An approach under consideration is the concept of GRDC HYDROLOGIC METADATA [GRDC, 2013] for the description of datasets, particularly time series, created by further processing of data from a preceding observation. This concept under development by the GRDC of the WMO refers to the basic concepts of the O&M model [ISO 19156:2011] and will use ISO19115-1:2012 Metadata-Fundamentals (under development) and the time series description of WaterML 2.0 [OGC, 2012]. The HY_FEATURES feature types are used to relate the spatial or temporal coverages to the river basin they represent (*Figure 2*) .

2.3 Properties of hydrologic features and its observation

NOTE: Text in this section refers to clause 6.1.3 in OGC 11-039r3 [OGC, 2013].

Hydrologic objects (real-world phenomena) have characteristic properties that may change according to continuous hydrologic processes. Values expressing this change are usually obtained by observing a VARIABLE related to these characteristics. Such a VARIABLE may have different roles in different contexts: observable property, observed property, measurand of an instrument, reported characteristic, base of a derived variable, a process variable under control, an assessment criterion, etc.. Different concepts at different levels of detail from different perspectives are in use to identify these variables, quantities as well as nominal properties.

O&M defines observation as *an act that results in the estimation of a feature property* [ISO 19156:2011], thus in principle each such Variable shall be an instance of the general PROPERTY TYPE (aka GF_PROPERTYTYPE) metaclass. The determination of what such a named property may be called or means is bound to the observation processes themselves, and the variety of these cannot be determined in advance, Thus, observable characteristics are not generally in the scope of the HY_FEATURES model. The relation between the hydrologic feature and its observable variables needs to be specified at the application level. HY_FEATURES supports this allowing alternative sets of properties to be bound to a common concept of a named feature.

3 Normative references

The following normative documents contain provisions which, through reference in this text, constitute requirements 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.

ISO 19101:2002, Geographic Information—Reference Model

ISO 19103:2005, Geographic Information — Conceptual schema language

ISO 19107:2003, Geographic Information — Spatial schema

ISO 19108:2006, Geographic Information — Temporal schema

ISO 19109:2005, Geographic Information — Rules for application schemas

ISO 19115:2003, Geographic Information — Metadata – Fundamentals

ISO 19123:2005, Geographic information — Schema for coverage geometry and functions

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

ISO 19156:2011, Geographic Information — Observations and Measurements

4 Terms and definitions

The HY_FEATURES model uses as far as possible the terminology recommended for use in the WMO Member countries and represented by the UNESCO/WMO International Glossary of Hydrology (IGH) [WMO, 1992a].Whenever an appropriate definition is provided in this glossary, the model captures this meaning and relationships to define relevant features and feature properties.
For the purposes of this document, the following terms and definitions apply.

4.1 application schema

conceptual schema for data required by one or more applications
[ISO 19101:2002].

NOTE: In general, a schema is an abstract representation of an object's characteristics and relationship to other objects. An XML schema represents the relationship between the attributes and elements of an XML object (for example, a document or a portion of a document)

4.2 basin

hydrologic unit wherein all incoming water is channelled to a common outlet.

NOTE: The common outlet of a basin may be a particular location, but also a body of water. It may be a real place or a fictive one built from joining several places.

4.3 catchment

distinct unit catching something, e.g. water.

NOTE: Across scientific disciplines in the domain of hydrology, a catchment is commonly recognized as the basic unit of study and reporting.

4.4 domain feature

feature of a type defined within a particular application domain.
[ISO 19156:2011]

4.5 feature
abstraction of real-world phenomena
[ISO 19101:2002]

4.6 hydrographic network
aggregate of water bodies, aggregated using a connecting system.

4.7 hydrography
science dealing with the description and measurement of open bodies of water.
[WMO, 1992a]

NOTE: In this context, hydrography refers to the description of water bodies. Its measurement in terms of surveying, e.g. for navigational purposes, is not in the concern of the HY-Features model.

4.8 hydrologic feature
abstract notion of the hydrology phenomenon.

4.9 hydrometric feature
real-world phenomenon which forms part of a hydrometric network.

NOTE: The hydrometric feature refers to a physical structure intended to observe properties of a hydrologic feature. Used to sample a hydrologic feature, a hydrometric feature may be considered a sampling feature of observation. A sampling feature is described in general in ISO 19156:2011, the special monitoring point of hydrologic observation is described in the WaterML 2.0 Specification.

4.10 hydrometry
science of the measurement and analysis of water including methods, techniques and instrumentation used in hydrology.
[WMO, 1992a]

4.11 mapping
mapping of elements of disparate representations of a hydrologic feature.

NOTE: In the context of common semantics, it refers to concept mapping particularly to an agreed reference concept.

4.12 mileage system
linear system used to reference indirect positions along a watercourse.

NOTE: The concept of indirect position describes a location on the land surface relative to or as a distance to a reference point located in a hydrographic network on a hydrographic feature applying a linear coordinate system. Position may be described relative to the reference point as distance, percentage of this, or expressed verbally.

4.13 multilingual keyword
keyword used in a multilingual context.

NOTE: A keyword is generally described in ISO 19115:2003 Metadata.

4.14 representation
real-world phenomenon representing an abstract feature.

4.15 sampling feature
artefacts of an observational strategy … intended to sample some feature of interest in an application domain.
[ISO 19156:2011]

4.16 variable

feature attributes whose values may change with Space, Time, Observation or depending on another variable.

NOTE: Values expressing the change are usually obtained by observing the variable. A variable may take any value in a range of possible values (WMO, 1992). Variable values are displayed with respect to Space, Time or Observation in coverages (ISO 19156).

NOTE: A variable may be a quantity having a magnitude, additive or non-additive, or multitude expressed numerically, but also a nominal property expressed using words, alpha-numeric codes, or Boolean values.

5 Conventions

5.1 Symbols (and abbreviated terms)

CHy	WMO Commission for Hydrology
DEM	Digital Elevation Model
GFM	General Feature Model
GML	Geography Markup Language
GRDC	Global Runoff Data Centre
HDWG	WMO/OGC Hydrology Domain Working Group
IGH	UNESCO/WMO International Glossary of Hydrology [WMO, 1992a]
ISO	International Organization for Standardization
IMV	WMO International Meteorological Vocabulary [WMO, 1992b]
OGC	Open Geospatial Consortium
OWL	Web Ontology Language
UML	Unified Modeling Language
WaterML2	WaterML 2.0 – an observations model for hydrology
WIS	WMO Information System
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
XML	eXtensible Markup Language

6 Requirements for a common hydrologic feature model

NOTE: Text in this section is taken from clause 6.2 in OGC 11-039r3 [OGC, 2013].

Hydrologic processes are constrained by and interact with the landscape and the medium in which they occur. These interactions are complex and variable through time. It is common practice to identify and refer to specific instances of a hydrologic feature when describing the state of any of these hydrologic processes or associated human activities. Persistent landscape features such as catchment, basin, watershed or water body are classic examples of concepts, common in many fields of discourse, but yet different according to the focus on various aspects of the hydrology phenomenon.

Hydrologic processes commonly are studied and reported in logic units related to the behaviour of water. Depending on application and scale these units are multiple represented in the real world by a variety of phenomena, either single objects or a composite or network of these. The reference to the shared unit of study by different applications may be challenging if different semantics and identifiers are used for different delineations. Stable and persistent identifiers are required to reflect hydrologic significance and topological connectivity of features across disparate representations and different scales.

A re-usable core of generally applicable concepts, capable of being partially realized in existing implementations, may increase the acceptance of the model in the addressed community. The required governance by an accepted, internationally acting authority, like the WMO, will be supported by a canonical form, implementation neutrality and conformity to internationally recognized standards.

6.1 General Applicability

To be generally applicable to a wide range of applications where hydrologic feature identification needs to be shared, feature characterizations given in different systems must be supported without specifying what characteristics may be assigned in a specific context. Instead of being a comprehensive set of all, or commonly used characteristics, a re-usable core model is required that supports application specific specializations. For example, an application concerned with rainfall runoff could extend the model to include soil moisture and land cover parameters that are not necessary to define the unit of study itself. A representation such as a remote-sensed grid field can be applied for any parameter, as could a simple attribute for a characteristic value. Numerical model starting conditions and parameters may be provided on the basis of characterization of e.g. basin features, and model outputs may be reported at basin scale or combined into a single result on the basis of the hydrologic connectivity of basins.

In cross-border applications and as part of global information frameworks the naming of a feature within different cultures and languages is a fundamental issue. The same feature may be named differently according to locale and usage. Names may apply to part of a feature only. Provided practitioners in the field of hydrology can successfully share meaning and feature identifiers, a full conceptual model of toponymy is not required. Nevertheless, the cultural, political and historical variability and the relationships between alternative names needs to be handled.

6.2 Stability of Identifiers

Stability of identifiers means that factors that change the representation of a feature in an information system, should not change the identifier of the feature itself. Such factors may be the improved resolution or accuracy of representation, minor changes to physical characteristics of the feature that occur over time, but also changes of technology platform, implementation or custodian. It is a core requirement of general applicability (6.1) to support stability of identifiers across different representations to allow multiple systems to use, or map to, these identifiers.

With regard to hydrology, identifiers must be able to stably reflect the hydrologic significance of a feature regarding both its contributing catchment and its topological connectivity to upstream and downstream features. Those features that can be given stable identifiers in this context must be distinguished from those that are defined within the context of a specific representation. For example, a DEM derived drainage network will have many predicted flow lines, but these may be simply a function of the resolution of the DEM, and not reflect physical reality. Key features such as major confluences may be represented, often due to drainage enforcement from vector representations, but nevertheless identifiable features.

6.3 Scale-independence

Hydrologic features exist at any scale, from a continental scale river basin to the basin upstream of any point in a detailed river network. Whether observing, modelling or reporting, the choice of the scale made by the user depends on the special purpose of its study. Some scales seems to be more or less general because of their wide range of use, but always chosen for a specific purpose, e.g. for mapping or comparative reporting, they are still distinct.

Scaling up or down leads to multiple representations of the same hydrologic feature. A common model must support simplifications at small scales and details at large scales allowing hydrologic feature complexes to be potentially encapsulated within simpler features at a less detailed scale. The co-existence of multiple hierarchical aggregations of features into alternative networks needs to be supported.

The requirement for identifier stability (6.2) implies that the same features must be identifiable where present in different scales of mapping. Reporting on a coarse scale needs to be supported as well as aggregating features at finer levels of detail in a consistent fashion to generate information at coarser scales.

6.4 Governance

The introduction and enforcement of standard practices in a large, heterogeneous community require promotion, guidance and advice by an authority accepted within the addressed community. Being the authoritative voice of UN, the WMO provides the framework for the leadership of the WMO-CHy in administration and management of best practices in the hydrologic community of WMO Member countries.

To be accepted as a Best Practice by the WMO-CHy, a common model shall not contradict existing positions of the WMO. This implies two other requirements. The first and most important is conformity, where applicable, to existing definitions defined and endorsed by the WMO-CHy. The key reference here is the UNESCO/WMO International Glossary of Hydrology [WMO, 1992a]. The second implication is that the model has no dependencies on aspects not recognized by the WMO within its standardization agenda. This is addressed by the plan to submit the model to the WMO-CHy for implementation into WIS and WIGOS, upon satisfactory results of testing.

6.5 Implementation Neutrality

Intended to be released to a community of sovereign WMO Member countries, no national data standard or proprietary technology for implementation should be directly referenced.

Furthermore, existing standard implementations, industry or open, and implementations that are approved within the WMO standardization context are preferred. Implementation neutrality, i.e. no recommendation of a specific implementation or, particular technology, is fundamental to import new components in existing implementations.

The use of ISO 19103:2005 Conceptual Schema Language and Application Schema modelling idiom is commonly expected as well as the provision of XML schema definitions of the individual model components.

7 Feature concepts in geographic information

In the context of geographic information, a FEATURE denotes the "*abstraction of real world phenomena*" [ISO 19101:2002]. It is recognised as the "*fundamental unit of geographic information*" [ISO 19109:2005] and intended to convey identity through various stages of data processing from collection to discovery, access and retrieval.

Real-world objects own characteristics which distinguish them from others, denoted as PROPERTY: Attribute, Association or Operation. The perceived values of the PROPERTY are documented for communication as DATA. Arranged in datasets for a specific purpose, DATA are set into perspective to a particular domain of discourse. These COVERAGES represent the real-world object in respect to the specific viewpoint.

The relationship between FEATURE and PROPERTY is that of identification. It is defined for use in geographic information in the GENERAL FEATURE MODEL (GFM) and described in ISO 19109:2005 Application Schema. The GFM describes how a feature class shall be defined in an Application Schema and how instances of these are defined as feature classes in an Application Schema. (see also 7.1)

The relationship between FEATURE, PROPERTY and DATA is that of observation. The OBSERVATION model relates any data as result (of an observation) to a feature (of interest) of which a property is observed using an identified procedure. The details of observation are understood as the "*metadata concerning the determination of the value(s) of a property on a feature of interest*". The OBSERVATION model is described in ISO 19156:2011 Observations and Measurements. (see also 7.2)

The relationship between DATA and COVERAGE is that of data accumulation. A coverage arranges data by coupling them to a position in a given domain. The domain is a set of position values; it refers to the geometric representation of the feature e.g. point or grid cell. The range provides the attribute values at distinct positions. The COVERAGE model defines a coverage as a set of property (value) pairs, either explicitly coupled as geometry-value pairs or coupled by mapping the function between them. The COVERAGE model is described in ISO 19123:2005 Schema for coverage geometry and functions. (see also 7.3)

Spatio-temporal data are usually arranged in a set with respect to a particular domain, assuming other domains negligible. Most common is the arrangement of values according to a position in the SPACE (domain) or TIME (domain) in spatial or temporal coverages assuming time or location constant. A popular example for a temporal coverage is a time series: the sequence of data values arranged by date and time. With respect to data generated by observation and understanding observation as a non-repeatable event having a position in SPACE (e.g. coordinates) and a position in TIME (e.g. time instant), OBSERVATION may be understood as the domain of a spatio-temporal coverage in terms of positions set by several observation events.

However, datasets exist where the positions in the domain are pre-determined values of a related attribute. A very popular example in hydrology is the stage-discharge-relation, where values of water level serve as positions for the values of observed discharge. In case of a flow duration function, duration is the observed property whose values are arranged according to a set of discharge values; another example is the suspended load or oxygen concentration along a river, where the location is the observed property and the values are arranged in a domain of concentration values. These datasets, commonly expressed as tables and graphs, can be understood as coverages whose domain is the PROPERTY.

The relationship between COVERAGE and FEATURE is that of representation. Depending on the focus of a particular application, a feature is represented by spatial, temporal or "featural" coverage. An approach to relate different representations to the represented (hydrologic) feature is provided within the HY_FEATURES model. The core concepts of the HY_FEATURES model are described in section 8 of this report.

Figure 3 summarizes the most important "high-level" features modelled in the context of geographic information that are of relevance for hydrologic information from feature identification by topology up to variant geometric representations each referencing the feature represented in the coverage. Hydrologic FEATURES are identified with respect to hydrologic significance and network connectivity. They carry VARIABLES which are observed in observation events. OBSERVATION results vary in TIME and SPACE, sometimes with another observed PROPERTY. They are usually arranged in (spatial or temporal) COVERAGES for information. These coverages represent the feature that carries the properties whose distribution is displayed in the coverage.

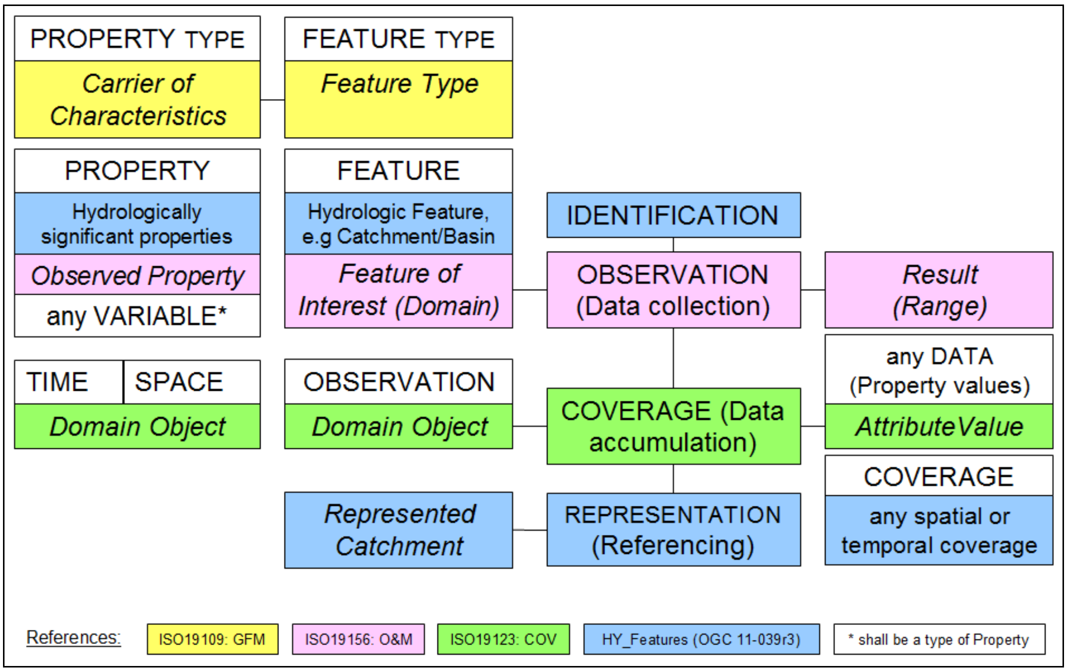

Figure 3: Geographic features concepts relevant for hydrologic information

NOTE: Colour of boxes indicates the standard model concept wherein the feature type is defined and described. The denoted *roles* are given in Italics. This figure does not display in detail the relationships defined between Feature, Property, Data and Coverage.

Features occur either as feature types, in the sense of concepts of a particular phenomenon, or as instances of these. For example, the „River Rhine“ is an instance of the concept (feature type) RIVER; the WMO Subregion „Rhine“ is an instance of a CATCHMENT feature type.

Even if FEATURE denotes the abstraction of a real-world phenomenon, it is used at different levels of abstraction. Generally applicable concepts of features and feature properties are defined at the „meta-level“ for use at application level. These meta-classes are instantiated into feature types within particular application schemas. A feature type at the application level may have multiple instances that will be realised when implementing a particular application schema.

7.1 Feature concept of the General Feature Model

NOTE: ISO 19109:2005, particularly the GFM, is currently under review. This section refers to a draft version of ISO 19109:2005 Application Schema documented in the ISO Harmonized Model in Oct 2013.

The GENERAL FEATURE MODEL (GFM) is a meta-model intended to serve as the general conceptual model to denote an identified real-world object as FEATURE in the overall context of geographic information.

The purpose of the GFM is described in ISO 19101:2002, the principles for using the concepts of the GFM in ISO 19109:2005 Rules for application schema. The GFM is expressed in UML [OMG, 2004].

A FEATURE (Feature Type) is by definition identified by a unique name, a definition (meaning) and typical properties (Property Type) such as attributes, association roles, or operations as well as by possible constraints applied to this. A (general) instance of FEATURE is defined in the observation context, representing all FEATURE types that may be defined in application schemas associated with a particular domain of discourse. Examples with respect to observations are SAMPLING FEATURE and DOMAIN FEATURE.

The PROPERTY (Property Type) is the identified *carrier of characteristics* [ISO 19109:2005]. This refers to the abstract notion of the characteristics owned by the real-world phenomenon of which the associated feature type is the abstract notion. Attributes, associations or operations are identified by name, definition (meaning), own properties and constraints. They need to be instantiated at the application level by an appropriate concept that supports the identification of quantities (values are magnitudes or multitudes) as well as nominal properties (values expressed by words and codes).

A concept in common use in hydrology is that of the VARIABLE *which may take any value of a specified set of values* [WMO, 1992a]. Variables have (multiple) names in common discourse, refer to a basic concept (definition), carry own properties such as unit of measure and may be multiple constrained e.g. by the sampled medium, a procedure configuration, or a probability function (in case of variate). An observed variable is often proxy for an ultimate variable. Examples in hydrology are the derivation of a quantity using ratings, the reference to the basin area, or the extrapolation of frequencies and probabilities; most popular example is the computation of stream discharge from gauge height, channel geometry and velocity.

To assure conformity to the GFM, all features and properties to be defined at the application level shall carry a localised, ideally registered name and a documented meaning (definition). Typical attributes and relationships (roles) may be defined with the application.

7.2 Feature concepts of Observation and Measurement

An observation in the real-world is a unique, non-repeatable event initiated to investigate the actual state of some real-world phenomenon. Its goal is to measure or otherwise determine the value of some property of this phenomenon. An observation is made at an identified location in space and time. An observation results in spatio-temporal data usually compiled into datasets such as spatial or temporal coverages, or further processed into data products.

An observation is modelled as a feature using the GFM. Each observation event is understood as an instance of OBSERVATION (feature) and provides an attribute value representing the domain feature of interest. The key properties of OBSERVATION are *featureOfInterest*, *observedProperty*, *procedure* and *result* [ISO 19156:2011].

The *featureOfInterest* (role) relates a domain-specific feature to the observation regarding which the observation is made, or in case of a proxy, the feature intended to sample (SAMPLING FEATURE) the ultimate feature of interest (DOMAIN FEATURE). Sampling features are *artefacts of an observational strategy, and have no significant function outside of their role in the observation process*. The sampled feature is by definition the *features from an application domain that are not artefacts of the observation process (sampling features)* [ISO 19156:2011]. It needs to be defined with the implementation whether the *feature of interest* is a DOMAIN FEATURE or a SAMPLING FEATURE.

The *observedProperty* (role) relates to the concept of *the phenomenon for which the observation result provides an estimate of its value. It must be a property type associated with the type of the feature of interest* [ISO 19156:2011]. The property of interest should be modelled as a PROPERTY using the GFM, maybe as an instance of the meta-class PROPERTY TYPE identified at least by a registered name and definition, or as a PROPERTY TYPE on its own in the sense of a particular concept such as VARIABLE or QUANTITY. As far as applicable, commonly agreed concepts should be used for modelling the characteristic properties within a particular application.

A very popular concept used in hydrology is that of a VARIABLE. This concept refers to a *quantity which may take any one of a specified set of values*" [WMO, 1992a]. It allows for property values varying in the scope of a given domain. Most variables change in TIME or SPACE. But even in the case of converting a variable into another, the dependent, derived variable "features" the independent, base variable.

The *procedure* (role) relates to the observation *the process used to obtain the result. This is often an instrument or sensor, but may be a human observer, a simulator, or a process or algorithm applied to more primitive results used as inputs. … The procedure must be appropriate for the observed property* …[,i.e.] *details of the observed property are constrained by the procedure used. …* [and] *may provide key parts of the intrinsic description of the feature of interest*.[ISO 19156:2011]

The *result* (role) defines the relation between the observation and the obtained property value, documented by any data. The observation result may be of any data type. This ranges from a set holding only one value up to a coverage comprising values varying with respect to a particular domain. Common examples of a coverage are data values displayed in maps or accumulated in time series. *The data type of the observation result must be suitable for the observed property; the scale or scope for the value must be consistent.* [ISO 19156:2011]

To assure conformity to the OBSERVATION model, an observation shall be described by the sampling feature (of interest), the sampled domain feature (of interest), the observed property and the procedure applied. Typical attributes and relationships (roles) may be defined with the application. The OGC standard WaterML 2.0 Part 1: Time Series describes an application schema applying the OBSERVATION concept for hydrologic observations. With respect to sampling as the *most common approach in hydrologic observation*, this standard defines a sampling feature, the MONITORING POINT, in terms of an in-situ point *on a river section to make inferences about the whole riv*er [OGC, 2012], the sampled domain feature.

The OBSERVATION model is described in detail in ISO 19156:2011Observations and Measurements and WaterML 2.0 Part 1: Time Series in the OGC Specification 10-126r3.

7.3 Coverage feature concepts of ISO 19123 and WaterML2

A COVERAGE is defined in ISO 19123:2005 Schema for coverage geometry and functions as a feature *that has pairs of distinguished properties consisting of a geometry property and a function that is defined over the coordinate set that is defined (delineated) by the geometry*. [ISO 19123:2005]. This concept may be applied to temporal coverages such as time series applying the geometry property to the TIME domain.

NOTE: The following section explaining a coverage with respect to time series is taken from clause 9.12.2 in the 10-126r3 OGC WaterML 2.0: Part1 – Timeseries where the Timeseries model is described in detail

"The ISO coverages model describes two approaches …: a 'domain-range' representation where the domain and range are encoded separately, with a mapping function that allows looking up of the range value for a given domain value; and a 'geometry-value', … whereby the geometry and value are coupled together – the coupling explicitly represents the mapping.

GML 3.2.1 notes that the geometry-value approach '... is typically used during data collection where a set or properties relating to a single location are managed together, or update of a datastore where only a small number of features are manipulated at one time." And the domain-range approach is '…more suitable for analysis, where spatio-temporal patterns and anomalies within a specific property are of interest.'

Within hydrology this is often the case. For example, a grid showing the spatial distribution of rainfall is often generated from observations using interpolation techniques such as kriging. The surface may be generated using point observations from in-situ sensors. The point observations are often represented using a geometry-value structure with the generated surface being represented using the domain-range approach, with a spatial grid (domain) mapped to its range values (representing total rainfall in the grid cell, for example). This provides a more efficient representation.

WaterML 2.0 defines a timeseries as a coverage whose domain consists of collection of ordered temporal elements and the spatial component relates to the feature of interest of the observation. For in-situ timeseries the spatial element will be fixed and need not be directly represented in the timeseries domain.

A timeseries may then be viewed in two ways from a coverage perspective: using the 'domainrange' view or the 'geometry-value' or interleaved view. Note that the term 'geometry' holds the domain object and is composed of varying spatial and temporal components (e.g. time instants).

The geometry-value view is consistent with the most common structuring in the hydrology domain: time and values are coupled together and represent discrete observations at time instants." [OGC, 2012]

7.4 Multiple representations of features

Multiple representation means referencing the same feature across various applications without loosing its identity. For example, spatial representations such as drainage area, watershed polygon, indicative blue lines, river network, or a set of grid cells reference the same, shared unit of study, and of information, the basin (*Figure 4*) . Likewise, time series of accumulated observation results arranged on a time scale at different levels of resolution represent the basin upstream of the monitoring point.

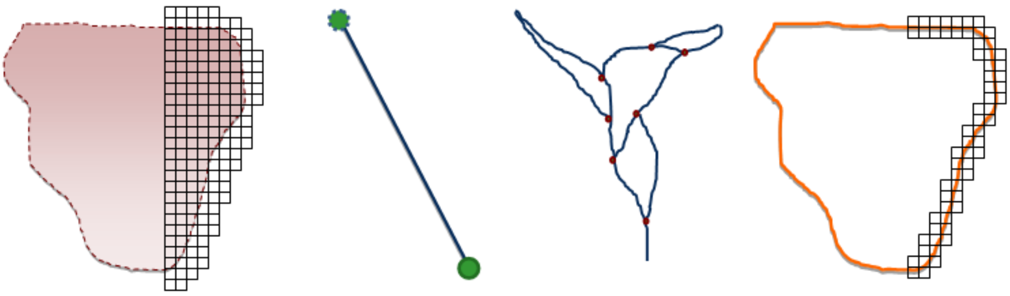

Figure 4: Multiple spatial representation of a river basin

Some spatial coverages are cartographic representations while others are focused merely on topological relationships. A hydrologic feature may be described geometrically using points, lines and polygons, but also topologically as a graph of nodes and links, or member of a hierarchy (*Figure 5*). Cartographic representations without topology can still be partitioned using the boundary on the river-system scale, forcing a simple relationship between a trivial topology and the spatial representation of these coarse features.

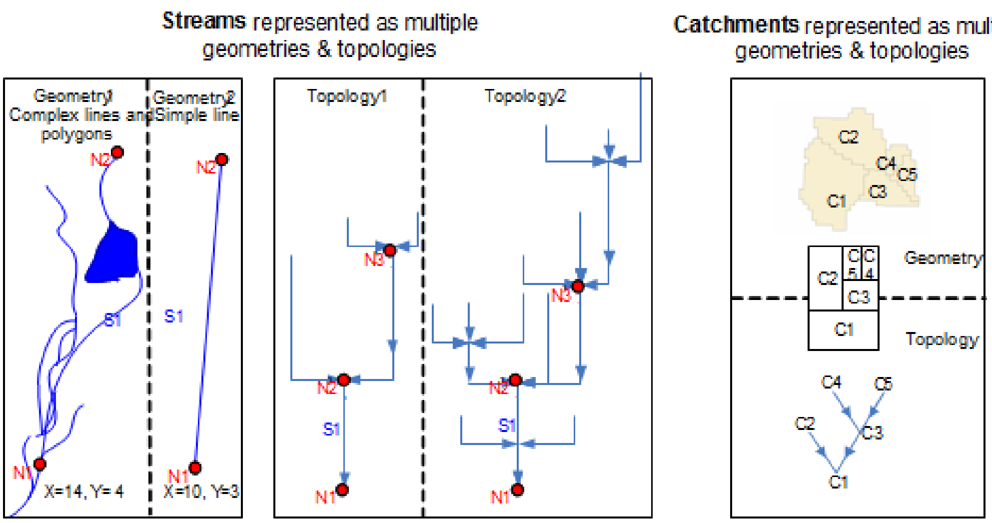

Figure 5: Cartographic representation vs. topological relationship

Similar to spatial coverages, temporal coverages may arranged equidistant or non-equidistant using a regular or non-regular temporal grid. It is common practice to display equidistant time series without specifying the individual time instant for each attribute value, but rather indicating a starting point (in time) and a constant spacing to specify the distance between time instants. Non-equidistant time series are usually transformed into processible equidistant series applying an expected spacing (by convention) and introducing substitutes for the missing values. See also OGC WaterML 2.0 Part 1: Timeseries [OGC, 2012] for more details on times series and their modelling in the context of hydrologic observation.

Sets of significant features may be defined in a particular domain to describe features, their typical properties and relationships. What features, attributes and roles are considered to be persistent identifiers depends on community recognition. With respect to hydrologic information, identifiers must stably reflect the hydrologic significance and network connectivity.

8 The concepts of the HY_FEATURES model

The HY_FEATURES it intended to realize the GFM for common usage in the domain of hydrology. The model describes hydrologic features and their fundamental relationships. It reflects common concepts in use in the hydrology domain.

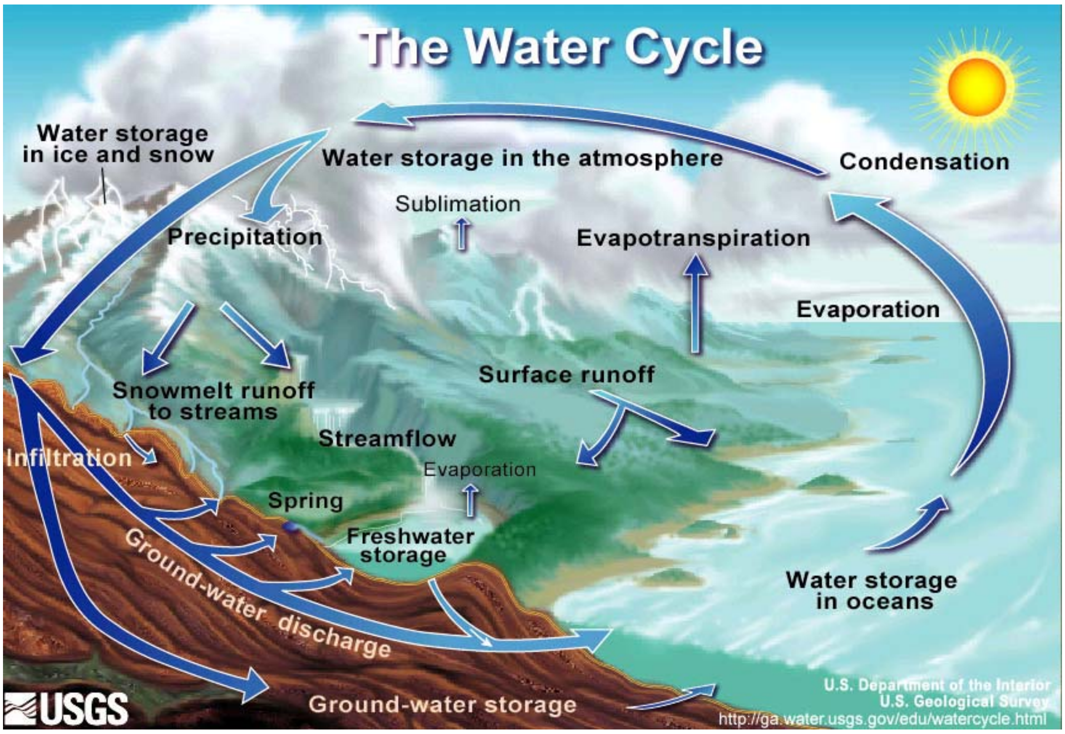

Figure 6: Processes of the Hydrologic Cycle

Depending on the focus of a particular application, an application-specific feature may reference the relevant concept defined within the HY_FEATURES model. For examples, an observation-centric application such as WaterML 2 may reference the sampled water body, a water-management application the allocated water resource, and a reporting service the reported water unit; a data service providing coverages may reference the represented catchment.

The core concept of HY_FEATURES is that a study of the Hydrology phenomenon will reflect common concepts of the real world by specific modelled features. A Hydrologic Feature is defined according to the GFM (see 7.1), as the fundamental unit of hydrologic information conveying the identity of a hydrologic feature through the data processing chain from "*measurement to hydrological information*" [WMO, 2008] as well as when referencing multiple represented features in the context of data exchange and information sharing. Depending on the scientific concern, the hydrologic feature represents different aspects of the hydrology phenomenon (*Figure 6*).

8.1 The Hydrologic Feature

Hydrology *(0623EN): 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. Science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the Earth, and treats the various phases of the hydrological cycle.* [WMO, 1992a].

The processes governing the continuous depletion and replenishment of water resources result at various stages in a wide range of hydrologic objects which are subject to monitoring, modelling and reporting in hydrology. With respect to these phenomena, the Hydro Feature schema defines the fundamental properties and relationships between features governed by the physical laws of hydrology: 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. Water bodies may be aggregated into a hydrographic network using a connecting system of channels expressed in flow or drainage patterns.

Water and water bodies are studied and reported in hydrologic or *water units* shared across disciplines and domains at national or international levels. Examples are the so-called *River Basin Districts* of the *European Water Framework Directive* [EC2010] designated not according to administrative or political boundaries, but rather according to the river basin as a natural hydrologic unit, or at national scale the *Hydrologic Unit Codes (HUC)* used by the US Geological Survey for the *National Water Information System (NWIS)* [USGS, 1992].

It is common practice in today's environmental reporting to assess and report the hydrologic processes and their results in a holistic approach at catchment scale. The catchment is the shared unit of study and information usually addressed in inter-disciplinary programs, inter-program collaboration and cross-domain research projects, and also the management unit agreed across administrative jurisdictions and the unit of joint monitoring and reporting.

8.1.1 Catchment and catchment representation

Basin *(0115EN): drainage area of a stream, river or lake.* [WMO, 1992a]

NOTE: Stream refers to a b*ody of water, generally <u>flowing</u> in a natural surface channel, water flowing in an open or closed conduit, a jet of water issuing from an orifice, or a body of flowing groundwater* (1226EN)

Drainage basin *(0360EN): area having a <u>common outlet</u> for its surface runoff.* [WMO, 1992a]

NOTE: Area refers to the geometric (2D) representation of the respective unit projected onto the Earth surface.

Groundwaterbasin *(0552EN): physiographic unit containing one large or several connected or interrelated aquifers, whose waters are flowing to a <u>common outlet</u>, and which is delimited by a groundwater divide.* [WMO, 1992a]

NOTE: Unit is understood in sense of a distinct, separate entity, organised in hierarchies.

The catchment model declares the CATCHMENT as the basic unit of hydrologic information. This definition follows the common recognition of the catchment as the unit wherein the hydrologic processes take place.

Each catchment may be multiple represented in any hydrologically meaningful "sub-domain" model, including by a simple tree network of „blue lines", or the nested network of catchments. The most popular spatial representations CATCHMENT AREA, CATCHMENT BOUNDARY, FLOWPATH, and HYDROGEOLOGIC UNIT as well as a (general) NETWORK are explicitly declared. NETWORK refers to the linkage of features using a connecting system like a channel network (aka drainage pattern), a system of connected aquifers, a technical water distribution system, or a system of logically connected hydrometric stations. Other representations of CATCHMENT such as spatial or temporal grids may be defined with a specific application or in the course of implementation. The CATCHMENT model connects alternative representations, allowing the hydrosphere to be divided into a hierarchy of catchments.

A catchment may be part of a containing high-order catchment. This supports a simple *is-part-of* hierarchy of catchments to be defined without the complexity of a surface or subsurface hydrologic feature model. It is intended that reporting applications may use this model for high-order organisation of management and reporting units.

Inferred from the definitions in WMO, 1992a, the BASIN is defined as CATCHMENT special due to its hydrologic determination by a common outlet towards all incoming water, surface and subsurface water, is channelled. Topologically, a BASIN is defined as the link between a single inflow-node and the common (single) outflow-node (*Figure 7*) encompassing the internal complexity of the contributing unit.

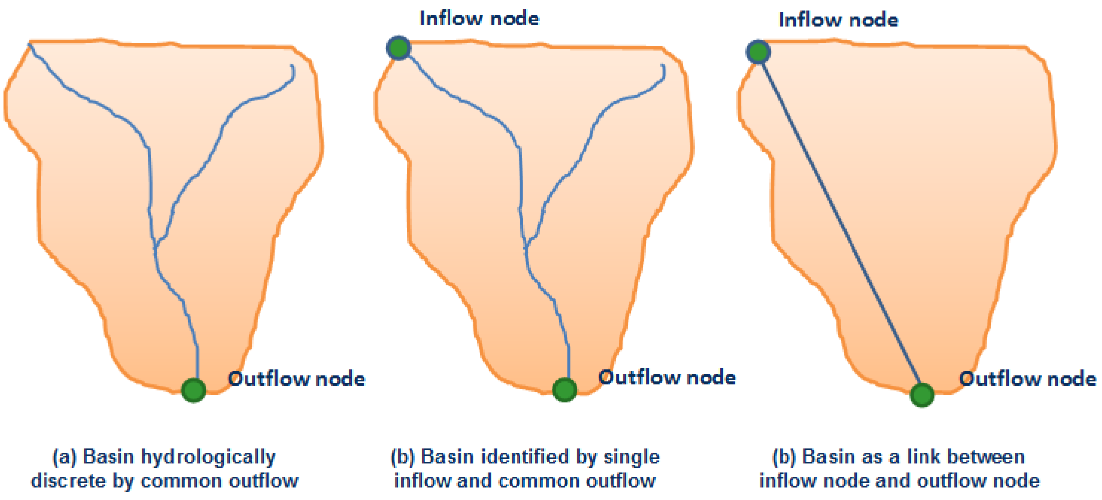

Figure 7: Hydrologic determination of a basin

The BASIN is modelled as sub-basin of an encompassing BASIN AGGREGATE wherein each basin may be associated with a BASIN immediately upstream. This reflects the commonly recognised organisation of basins in upstream network hierarchies and basin aggregates (*Figure 8*).

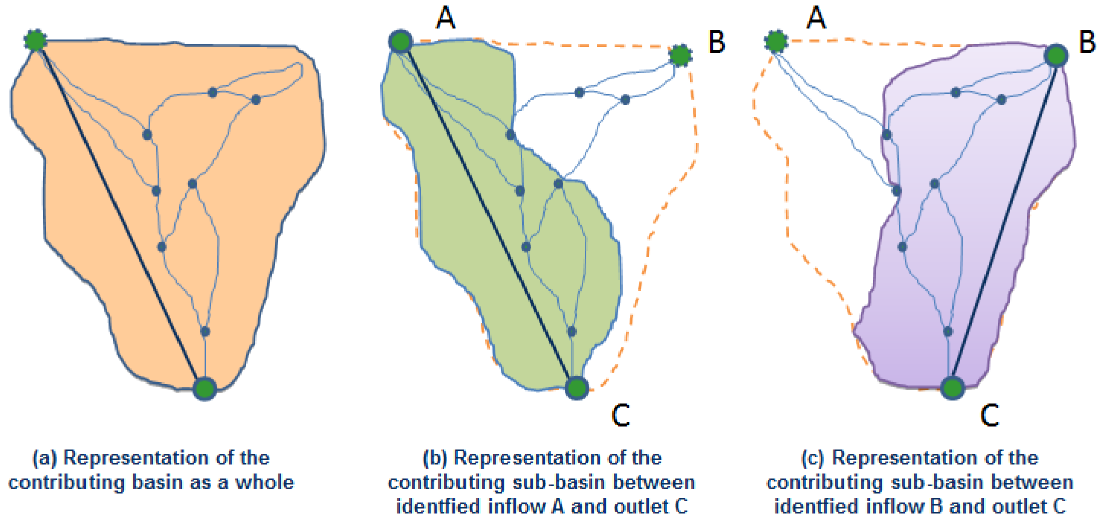

Figure 8: Representation of a basin as a whole or by arbitrary sub-basins

The BASIN AGGREGATE simply refers to the co-existence of sub-basins identified by its common outlet having diffuse or identified inflow. This allows for any type of basin division into (tributary) basins and interbasins (with identified inflow), using an ordering system like the Pfaffstetter coding, or not. The (downstream) nesting in a containing basin is inherited from the CATCHMENT type. *Figure 9* shows exemplarily for the Danube basin the nesting (a) and the aggregation (b) of sub-basins.

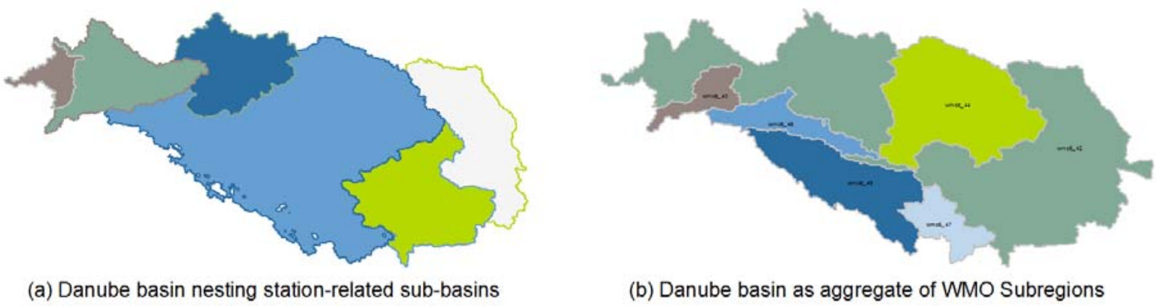

Figure 9: Nesting of basins vs. aggregation of sub-basins

The OUTFALL is the topological concept that considers an arbitrary location as the common outlet of a corresponding basin. OUTFALL represents a logic place and has no explicit location. Following the common practice to determine an unknown position in relation to a reference point fixed by coordinates, OUTFALL has an indirect position referencing an identified point in the basin network. This reference point may be a permanent landmark, a station, or the point where groundwater enters the surface; it may be a point projected onto the surface or created from merging disjoint locations. For example, vertically arranged points can be aggregated and projected onto surface, several locations may be mapped to a single point (*Figure 10*). The concept of INDIRECT POSITION is described in section 8.1.4.

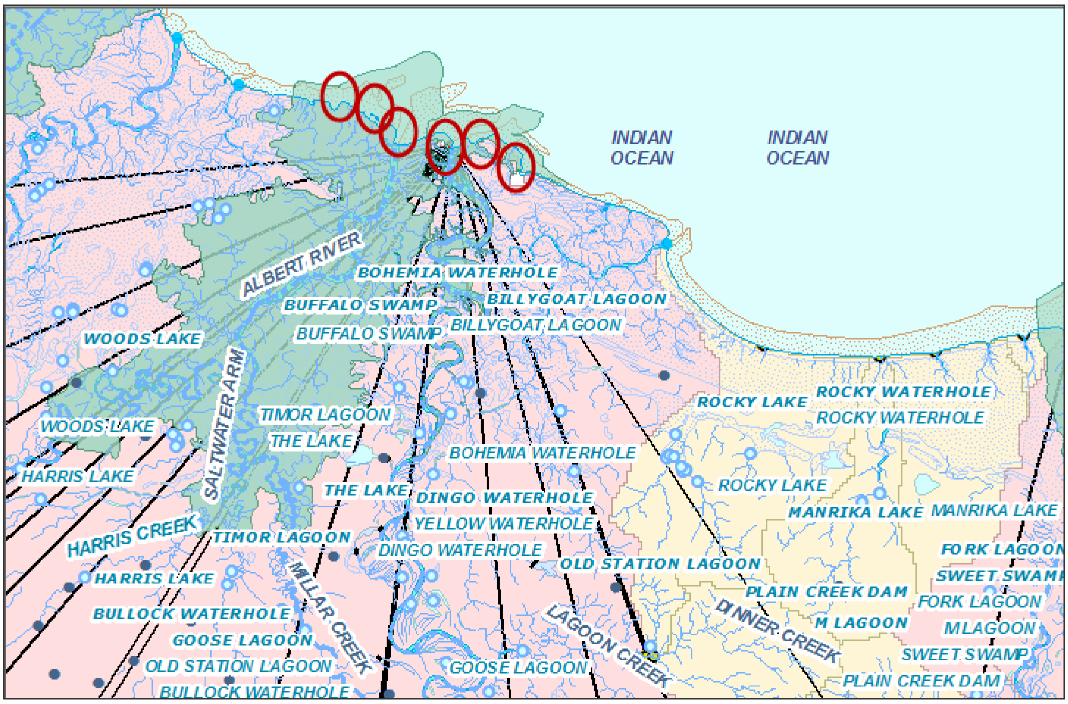

Figure 10: Many network nodes mapped to single logical node

Positioned in the hydrographic network, the OUTFALL provides an identifiable reference point to which alternative representations may refer. This allows for the existence of basins to be recognised, and identifiers assigned, based on the OUTFALL, even if stream networks, watersheds and drainage areas are not reliably determined.

OUTFALL has no explicit shape. Its geometric representation varies with the application. It may be a point, a curve, a surface or any geometry built from these. The geometry type needs to be declared with the particular application. The OUTFALL of the basin upstream of a monitoring station is usually interpreted as a point with coordinates: The OUTFALL upstream of a cross-section can be understood as a (plane) surface, and the OUTFALL of a groundwater basin may have a three-dimensional shape.

8.1.2 Hydrographic Network

Hydrographic Network *(0608EN): aggregate of rivers and other permanent or temporary watercourses, and also lakes and reservoirs.* [WMO, 1992a]

NOTE: River, stream, lake and reservoir are water bodies by definition [WMO, 1992a].

Water body *(1356EN): mass of water distinct from other masses of water*. [WMO, 1992a]

Stratification *(1225EN): existence or formation of distinct layers in a body of water identified by differences in thermal or salinity characteristics or by oxygen or nutrient content.* [WMO, 1992a]

Cross-section *(0276EN): section of a stream at right angles to the main (average) direction of flow*. [WMO, 1992a]

NOTE: Not to be confused with the transversal *bed profile* [WMO, 1992a], which refers to the containing channel.

Longitudinal section *(0753EN): vertical section [of a stream] along a channel at its centre line.* [WMO, 1992a]

NOTE: Longitudinal section refers to stream centre line: *line connecting the successive centres of cross sections of a stream*. [WMO, 1992a]

NOTE: Not to be confused with the longitudinal *bed profile* [WMO, 1992a], which refers to the containing channel.

The HYDROGRAPHIC NETWORK refers to an aggregate of water bodies and water body segments based on the definitions in WMO, 1992a. Each WATER BODY consist of at least one segment each consisting of one or more strata. Water body stratum is introduced to reflect the horizontal layers such as thermo-,halo- or chemo cline. The WATER BODY SEGMENT carries the *fixed landmark* association to the REFERENCE POINT allowing a water body to be related to a corresponding basin. The WATER BODY STRATUM carries a *storage* association to RESERVOIR, with respect to the storage and management of water in layered storage reservoirs (see 8.1.5). CROSS and LONGITUDINAL SECTIONS are introduced to reflect the vertical section in transversal or longitudinal direction, either as stream sections (of the water body) or bed profiles (of the containing channel). Identified points at the sections may be used as reference point to locate the OUTFALL of a corresponding BASIN.

The HYDROGRAPHIC NETWORK concept follows the separation of concerns between the body of liquid water and the containing unit shaping the water body inferred from the definitions in WMO, 1992a. A water body accumulates water from precipitation and snowmelt. Its shape is determined by the containing unit: the occupied landform, the hosting hydrogeologic unit, a man-made container, etc.. Concepts of water body confines are described in the section 8.4 and section 8.5. with respect to surface-water and subsurface-water bodies.

WATER is accumulated in water bodies, ice in glaciers or ice covers on a water body. GLACIER is introduced to provide a means to take the multiple relationships between a glacier and the fed water body into account at the application level. As glaciology is a science on its own, the relationships between glacier and water body are not in the scope of the HY_FEATURES model, and need to be described in detail with implementation.

8.1.3 Named Feature

The NAMED FEATURE concept extends the definitions of the GFM regarding localised names with respect to their usage and characteristics defined individually from the perspective of another domain. HYDRO FEATURE NAME is introduced to handle the cultural, political and historical variability as well as the relationships between alternative names. It may be applied to all features where geographic names are given through common usage, sometimes by convention, without a formal toponymy model. It allows to describe the geographic name by its usage, for example whether applied to a feature's part, fixed temporarily by convention.

The HYDRO FEATURE CONTEXT is intended to specify features (of other domains) that participate in hydrologic systems having individual characteristics, e. g. geologic or land use characteristics of a basin. Given the complexity the Hydrology phenomenon, for a given hydrologic feature a wide range of features may be relevant whose properties may be assigned to a hydrologic feature in a given spatial, temporal or classification context. HYDRO FEATURE CONTEXT may be used to identify the (hydrologic) VARIABLE whose changing *attribute values* are determined by observation (domain) and displayed in a coverage representing the NAMED FEATURE.

8.1.4 River Positioning

The RIVER POSITIONING refers to a concept of INDIRECT POSITION where each location on the land surface may be described relative to, or as the distance to, a reference point located in the hydrographic network. The distance to the reference point is provided as LENGTH, the relative position described as a percentage of the distance or using terms common in the hydrology domain such as *upstream*, *downstream*, *nearby*, etc..

INDIRECT POSITION requires a river mileage system whose origin is set at the position of the relevant point of interest, e.g. a water monitoring point, in the network. The coordinates are provided as distance upstream or downstream from this origin to the identified reference point. Since river mileage systems usually refer to a line (such as thalweg or stream centre line) assuming a horizontal curve, the RIVER MILEAGE system uses the one-dimensional linear reference system supporting at least one horizontal axis. The axis description should provide information about the direction (upstream / downstream) and the precision (smallest unit of axis division).

The concept of INDIRECT POSITION allows to relate the OUTFALL of a basin to an identified REFERENCE POINT. In this way basins may be related topologically and a network of basins (as the links between outfalls) established. Considering an arbitrary hydrometric station as OUTFALL of a basin, it may be located depending on its *position on river* without having local coordinates. This allows to establish topological relationships between hydrometric stations as a relationship between the outlets of the contributing basins.

8.1.5 Storage

Reservoir *(1011EN): body of water, either natural or man-made, used for storage, regulation and control of water resources.* [WMO, 1992a]

> NOTE: Not to be confused with underground reservoir with groundwater reservoir which refers to a containing aquifer. [WMO, 1992a]

Storage *(1215EN): impounding of water in surface or underground reservoirs, for future use.* [WMO, 1992a]

> NOTE: Storage refers to a water body in terms of a usable water resource.

The STORAGE concept provides a means to describe a water body in terms of a RESERVOIR wherein the accumulated water may be stored for future use, regulation or control.

The management of the reservoir as human action with the objective to efficient and sustainable use the resource, is not in the scope of the HY_FEATURES model. Yet, often an indication is required whether a water body is used for storage. RESERVOIR is introduced to generally take in account the storage characteristics of the (stratified) water body participating in the hydrologic network. Special types of surface or underground reservoirs may be defined with application.

The STORAGE concept allows networks to be described without details of storage capacities, and storage reservoirs to be referenced independently of their representation within a network.

8.2 Atmospheric Hydro Feature

Hydrometeor *(H0970): meteor consisting of an ensemble of liquid or solid water particles falling through or suspended in the atmosphere, blown by the wind from the Earth's surface or deposited on objects on the ground or in the free air.* [WMO, 1992b]

> NOTE: May be specialised to different types of hydrometeors, e.g. precipitation, cloud.

***Precipitation** (0933): liquid or solid products of the condensation of water vapour falling from clouds or deposited from air on the ground.* [WMO, 1992a]

***…** (P1360): hydrometeor consisting of a fall of an ensemble of particles.* [WMO, 1992b]

NOTE: May be specialised to different forms of precipitation such as rain, drizzle, snow, snow grains, snow pellets, diamond dust, hail and ice pellets.

NOTE: Not to be confused with the amount of precipitation measured by means of rain gauge, which is a property (rainfall).

***Water** (1353EN): liquid phase of a chemical compound consisting of approximately two parts by weight of hydrogen and 16 parts by weight of oxygen.* [WMO, 1992a]

***Ice** (0639EN): solid form of water.* [WMO, 1992a]

The ATMOSPHERIC HYDRO FEATURE schema defines concepts of the hydrology phenomenon above the land surface. The HYDROMETEOR is introduced to generally take into account atmospheric hydrologic features as part of the Hydrologic Cycle. This allows hydrometeorologic features to be associated with the catchment to which water from precipitation is distributed without the complexity of a rainfall-runoff model.

The PRECIPITATION concept simply differentiates between the liquid phase (*water fraction*) and solid phase (*ice fraction*) of water. This allows to separately address both water accumulated in water bodies, and ice accumulated in glaciers. It is intended that applications in surface water or glacier hydrology, particularly runoff modelling, may use the model to reference the represented hydrologic feature.

8.3 Surface Hydrologic Feature

***Channel** (0185EN): watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. also: deepest portion of a river bed, in which the main current flows.* [WMO, 1992a]

***Channel network** (0363EN): arrangement of natural or man-made drainage channels.* [WMO, 1992a]

***Reach** (0987EN): length of open channel between two defined cross-sections.* [WMO, 1992a]

***Bank** (0106EN): rising land bordering a river margin of a channel at the left-hand (right-hand) side when facing downstream.* [WMO, 1992a]

***River bed** (1042EN): lowest part of a river valley shaped by the flow of water and along which most of the sediment and runoff moves in inter-flood periods.* [WMO, 1992a]

***Watercourse** (1359EN): natural or man-made channel through or along which water may flow.* [WMO, 1992a]

NOTE: The stream moving in a watercourse refers to a *body of water, generally flowing in a natural surface channel … in an open or closed conduit, a jet of water issuing from an orifice, or a body of flowing groundwater*. This includes through-flow lakes, underground/subterranean streams, or streams in or beneath a glacier. [WMO, 1992a]

The SURFACE HYDRO FEATURE schema provides concepts of the most popular SURFACE WATER bodies and of SURFACE WATER CONFINES. They are defined with respect to a water body, aggregated in a hydrographic network using a connecting system of confining channels, to be realised with an identified entity.

SURFACE WATER features may be specialised by the property to move (e.g. river), by origin (e.g. canal), by extent (e.g. lake), by branching (e.g. estuary), or by their interaction with the open sea (e.g. lagoon). Depending on the application, any special type of Surface Water feature may be described by suitable attributes.

SURFACE WATER CONFINES defines the CHANNEL NETWORK, each consisting of at least one CHANNEL SEGMENT. The channel segment, particularly the REACH, is confined by river bed and banks which may be described by *transversal* or *longitudinal bed profiles* at cross- and longitudinal sections. Each channel (segment) may be associated with the contained water body (segment) in the sense of a watercourse.

The SURFACE HYDRO FEATURE model allows to separately address the water body and the connecting watercourse, or parts thereof. Even if channel hydraulics and river morphology are recognised as scientific disciplines on their own, it is however intended that applications in surface water hydrology, modelling hydraulics and morphology of streams may apply the concepts of SURFACE WATER CONFINES for referencing the represented hydrologic feature.

8.4 Subsurface Hydrologic Feature

***Aquifer** (0064EN): permeable water-bearing formation capable of yielding exploitable quantities of water.* [WMO, 1992a]

***Groundwater** (0551EN): subsurface water occupying the saturated zone.* [WMO, 1992a]

***Vadose water** (1327EN): Any water that occurs in the unsaturated zone.* [WMO, 1992a]

NOTE: Examples: soil water (discharged by evapotranspiration), soil moisture (held by molecular attraction), and gravitational water (moving due to gravity).

***Well** (1397EN): shaft or hole sunk, dug or drilled into the Earth to extract water.* [WMO, 1992a]

The SUBSURFACE HYDRO FEATURE schema summarizes the most popular types of liquid water occupying empty space in soil and aquifers. GROUNDWATER and VADOSE WATER are defined with respect to water accumulated under ground as well as the effects of groundwater interaction on a gaining/losing water body. Depending on the implementation, special types of water in the saturated and unsaturated zone may be described by suitable attributes.

The HYDROGEOLOGIC UNIT and AQUIFER are introduced to provide a simple means for taking into account the hydrologically significant characteristics of geologic formations of soil or rock yielding water, particularly groundwater. WELL is introduced to consider the well extracting water from aquifer as REFERENCE POINT that may be used to locate the OUTFALL of a basin.

Recognising hydrogeology as a science on its own, the special relationships between groundwater and a water body are not in the scope of HY_FEATURES model. However, the SUBSURFACE HYDRO FEATURE model allows to separately address types of subsurface water as well as the containing aquifer without details of accumulation and movement of water under ground. It is intended that applications modelling groundwater and soil moisture may use this concepts to reference the represented hydrologic feature.

8.5 Hydrometric Feature Network

***Hydrometric network** (0616EN): network of hydrological stations and observing posts situated within any given area in such a way as to provide the means of studying the hydrological regime.* [WMO, 1992a]

NOTE: Not to be confused with the natural network of rivers and lakes (hydrographic network)

NOTE: Not to be confused with network sampling as distinct method of sampling.

***Station** (0627EN): : 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.* [WMO, 1992a]

NOTE: A hydrometric feature is physical artefact, or a collection of these. Some may be fictive ones.

Water bodies are observed using monitoring stations and observing posts. In the observation context, the station represents a sampling feature. Even if the description of sampling features is not in the scope of HY_FEATURES, the HYDROMETRIC FEATURE NETWORK is introduced to provide a means to relate logic network of (sometimes fictive) hydrometric stations to the catchment they represent, without the detail of the observation strategy, as usually required in the context of processing primary data from preceding observations into new data products.

The HYDROMETRIC FEATURE NETWORK schema defines a hydrometric network as an aggregate of hydrometric features which are logically connected, for example along a river. The HYDROMETRIC FEATURE may have localised names, typical properties and individual characteristics. A hydrometric feature may be further disjoined to segments.

The hydrometric feature is free from any position. It is located in the hydrographic network depending on its *position on river*, which associates the REFERENCE POINT that coincides with the OUTFALL of a corresponding basin.

The HYDROMETRIC NETWORK concept allows to relate a logic network of (fictive) hydrometric stations, or parts of this, to the catchment they represent, without the detail of the observation strategy as required in the context of processing primary data into a new set of secondary data interpreting and comprising the results of preceding measurements. Applications capturing the monitoring of hydrologic features, the observation and measurement of their properties may use this model to locate a WATER MONITORING POINT such as of WaterML2 on the sampled hydrologic feature.

9 Compatibility with similar concepts of relevance

NOTE: Text in this section is taken from clause 8.1. in OGC 11-039r3 [OGC, 2013].

NOTE: Compatibility of concepts means that similar concepts are able to exist or perform together in combination without conflicts.

The HY_FEATURES model is intended to form the basis for standard practices for feature identification under the auspices of the WMO-CHy. To achieve this goal, compatibility with similar concepts must be supported. At least the basic concepts of CATCHMENT and BASIN, HYDROGRAPHIC NETWORK and RIVER POSITIONING should fit together. HY_FEATURES provides generally applicable concepts for reference, to which application-specific concepts may refer either by specialization or by mapping.

9.1 Basin vs. DrainageBasin as of INSPIRE Hydrography theme

The INSPIRE (Infrastructure for Spatial Information in the European Community) Directive addresses the Hydrology issues in the data specification D2.8.I.8: INSPIRE Data Specification on Hydrography, v.3.0.1 [EC, 2010] as the basic reference for use within the INSPIRE context. This specification defines an abstract HYDRO OBJECT covering all PHYSICAL WATERS including the relation between DRAINAGE BASIN and SURFACE WATERS (*Figure 11*). Drainage Basin may have many outlets which are SURFACE WATERS, and may contain sub-basins.

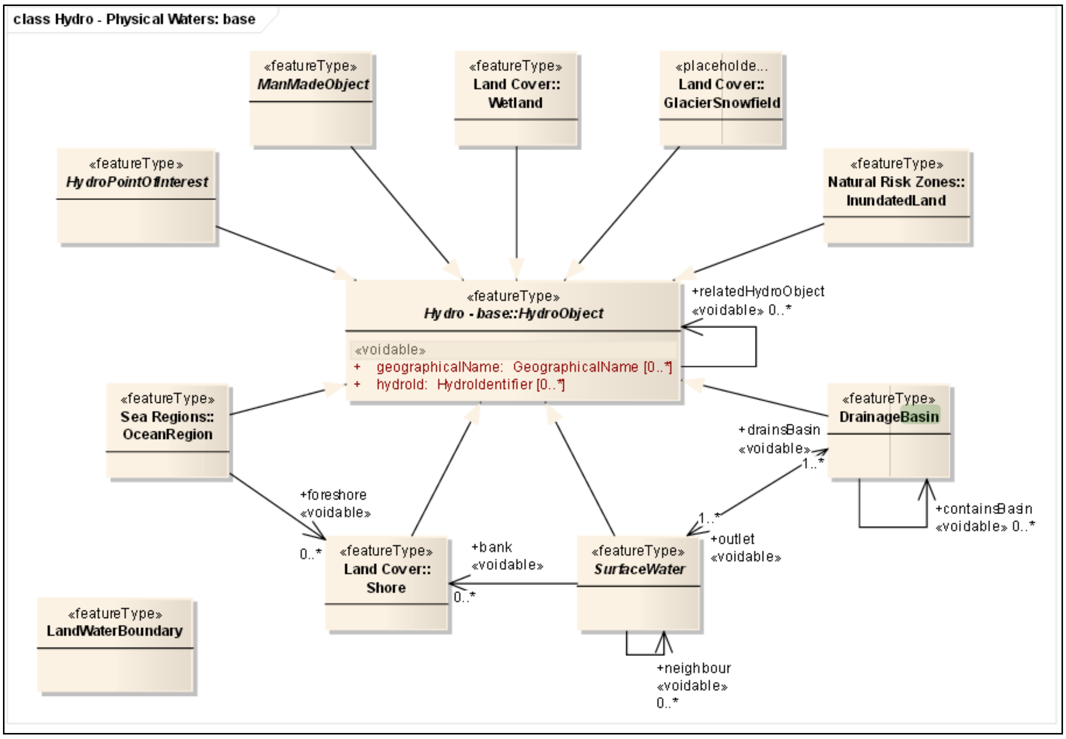

Figure 11: INSPIRE Hydrography, v3.0.1 – HydroObject

NOTE: *SurfaceWaters* refers to any physical body of water. [EC, 2010]

NOTE: *DrainageBasin* refers to the area having a common outlet for its surface runoff. [EC, 2010]

This definition corresponds to the definition of BASIN AGGREGATE (in HY_FEATURES), rather than BASIN which is defined as a link between single inflow and outflow nodes. Therefore, the BASINAGGREGATE aggregating one or more sub-basins may be addressed for referencing. Each sub-basin is identified by an OUTFALL whose location may be a surface water body. Outfall vs. Contracted Node as of AU Hydrological Geofabric

The AUSTRALIAN HYDROLOGICAL GEOFABRIC (AHGF) [McDonald, E.R., 2009] identifies important water features in the landscape as well as the connections between these features. Identifying persistent CONTRACTED NODES that are points of hydrologic significance that carry identity, the AHGF supports multiple representations of water features. Such a contracted node may be the OUTFALL of a basin as defined in the HY_FEATURES model. The concepts of CATCHMENT, BASIN AGGREGATE, BASIN and OUTFALL of the HY_FEATURES model have been implemented within the Geofabric as HR_CATCHMENTS, as CONTRACTED CATCHMENTS and AHGF NODE. LINK, in terms of basin as a link, represents the topological connection between the catchment hierarchy.

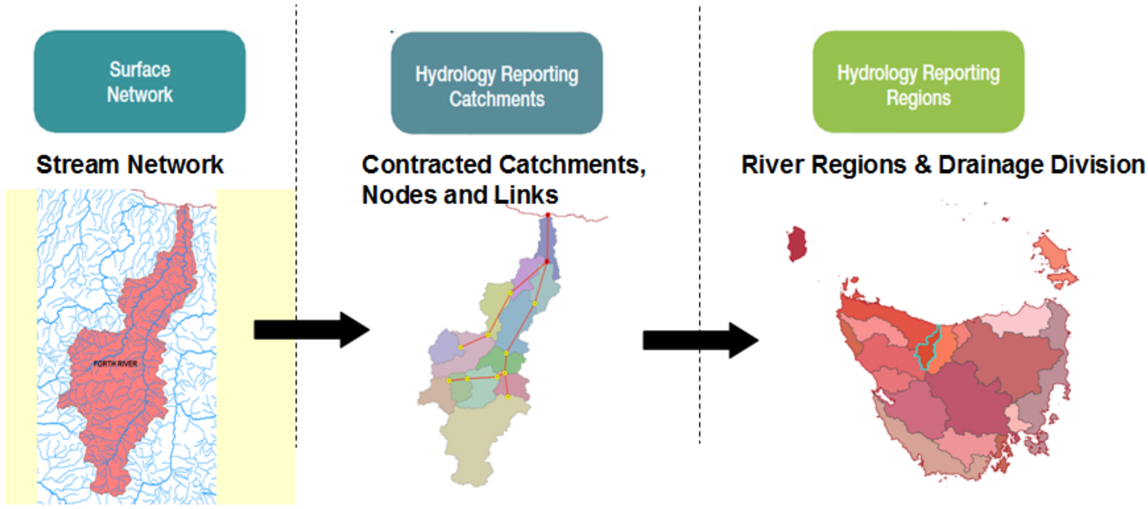

Figure 12: AHGF Hydrological Reporting Catchment

A hierarchical set of catchments from individual stream segments to CONTRACTED CATCHMENTS are defined in the SH_NETWORK and HR_CATCHMENTS products with each catchment defined by a polygon shape draining to an outfall contracted node. CONTRACTED CATCHMENTS are then aggregated to create stable HYDROLOGY REPORTING REGIONS, as shown for the Tasmanian Forth River Basin in *Figure 12* [Atkinson, R. and T. Boston, 2013].

9.2 IndirectPosition vs. NetworkPosition as of ISO19133

INDIRECT POSITION is introduced to describe the position of OUTFALL in the hydrographic network using a river mileage system as linear reference system (LRS). The underlying concept is that of a distance between two locations. One, which is the origin of the LRS, is the OUTFALL determined by its network position; the other is the (geometric) REFERENCE POINT fixed directly by coordinates. Since OUTFALL may be of any geometry, INDIRECT POSITION may address (via REFERENCE POINT) both the node or the link the position is on. INDIRECT POSITION associates a REFERENCE POINT, as a specific *marker* [ISO 19133:2005] and the MILEAGE SYSTEM in the sense of a *link measure* [ISO 19133:2005].

The navigation on watercourses is not in the scope of the HY_FEATURES model. However, this similarity allows to address OUTFALL or REFERENCE POINT as start and stop positions of a ROUTE as of ISO 19133:2005.

9.3 HydrometricFeature vs. WaterMonitoringPoint as of WaterML2

NOTE: *WaterMonitoringPoint* is defined within *WaterML 2.0* Part 1: Timeseries as (point) location where water flow or properties are reported, such as a stream gauge, rainfall gauge, or water quality monitoring site.

Hydrologic observations make use of hydrometric stations as proxy to measure the characteristic properties of the ultimate object of study. WaterML 2.0 [OGC, 2012] defines a WATER MONITORING POINT using the SAMPLING FEATURE concept of the observation model [ISO 19156:2011]. Against this background, the description of sampling features is not in the scope of HY_FEATURES.

However, a HYDROMETRIC NETWORK is introduced to provide a means to relate a logic network of (fictive) hydrometric stations to the catchment they represent, without the details of the observation strategy, as usually required in the context of processing primary data from preceding observations into new data products. HYDROMETRIC FEATURE is introduced to provide a means to define a persistent identifier positioned in the hydrographic network (see also 8.5).

9.4 RiverML, under development

NOTE: The development of a RiverML is under discussion in the framework of the WMO/OGC HDWG for exchanging river channel and floodplain geometry in a standardized way.

Against the background of an evolving RiverML, the channel hydraulics and river morphology are not in the scope of HY_FEATURES.

However, CHANNEL and CHANNEL SEGMENT as well as RIVER BED and BANK are introduced to provide a means to generally take into account the hydrologically significant hydraulic and morphological characteristics of conduits and open channels. *Longitudinal* and *transversal bed profiles* are introduced to provide a means to define a persistent identifier at CROSS SECTION and LONGITUDINAL SECTION. (see also 8.3)

9.5 GroundwaterML, under development

NOTE: A groundwater interoperability experiment (GW2 IE) will develop and test the GroundWater Markup Language 2, by harmonizing and advancing existing modelling initiatives such as: GWML1, relevant EU-INSPIRE models (Geology, Hydrogeology, Environmental monitoring facilities), GeoSciML, and others.

Against the background of the evolving GroundwaterML [Boisvert, E. and B. Brodaric, 2007Boisvert, E. and B. Brodaric, 2007], the accumulation of groundwater as well as the interaction between surface water and groundwater are not in the scope of HY_FEATURES. Bodies of groundwater, or parts of these, may be related to WATER BODY, -SEGMENT or –STRATUM for reference, or in case of storage to (underground) RESERVOIR.

HYDROGEOLOGIC UNIT is introduced to provide a means to generally take into account the hydrologically significant geologic characteristics of a formation of rock or soil representing a catchment. VADOSE WATER, GROUNDWATER, AQUIFER and WELL are introduced to provide a means to define a persistent identifier at the representation level for groundwater and soil water related features (see also *8.4*)

9.6 Outfall vs. Pour point of ArcHydro GIS

OUTFALL is defined under the premises that all waters in the basin are channelled to a common outlet. The same meaning is applied to the *eight-direction pour point* of ArcHydro GIS [Maidment, D.R.,2002], defined to model the flow from a grid cell into the adjacent cell according to the flow paths. Consequently, the drainage lines, catchment and watersheds created using ArcHydro GIS are representations of a BASIN in terms of HY_FEATURES.

10 Organization of HY_FEATURES UML model

The HY_FEATURES model is a set of inter-related modules containing definitions for key aspects of hydrologic systems. The model is managed in sub-domain specific packages, allowing extension to the core set and involvement of relevant expert groups in the governance of individual models.

The HY_ prefix follows the ISO naming conventions for UML elements. It refers to the Greek hydro and means water in general because of waters above and below the land surfaces of the Earth is the principal object of study in hydrology [WMO, 1992a]. There is no explicit requirement that these names have to be used in implementing systems for the same semantic elements. It is not yet specified how mappings between abstract element names and implementations should be recorded. Nevertheless it is expected that future interoperability will be facilitated by making such mappings available as a component of dataset documentation.

The HY_FEATURES model comprises the following packages:

- *EXT_Utilities*, containing utility classes for common patterns required by the domain model that are not hydrology-specific*;*

  NOTE: The EXT-prefix refers to “external”, common patterns that are required, but not hydrology-specific, and should be imported when available from an external source.

- *HY_HydroFeature*, incl. *HY_Catchment*, *HY_HydrographicNetwork*, *HY_NamedFeature*, *HY_RiverPositioningSystem* and *HY_Storage;*
- *HY_AtmosphericFeature;*
- *HY_SubsurfaceHydroFeature*, incl. *HY_SubsurfaceWater* and *HY_SubsurfaceWaterConfines;*
- *HY_SurfaceHydroFeature*, incl. *HY_SurfaceWater and HY_SurfaceWaterConfines;*
- *HY_HydrometricNetwork.*

Figure 13 shows the general organization into packages and the dependencies among them.

The HY_FEATURES model is specified using UML according to ISO 19103. This allows a GML Application Schema to be generated by following the encoding rules in ISO DIS 19136 to assure conformity with GML requirements. GML 3.2, GML 3.1.1 and OWL schemas are drafted by the WMO/OGC HDWG and will be provided within the OWS-10 (see 11.2).

HY_FEATURES is not intended for direct implementation as a data product, but the features it defines may be used as inline references to hydrologic features to avoid introducing platform specific schemas for referenced features into independent data products. HY_FEATURES classes may also be exposed from underlying data products using HY_FEATURES to provide a well-known schema for hydrologic features in distributed, federated contexts.

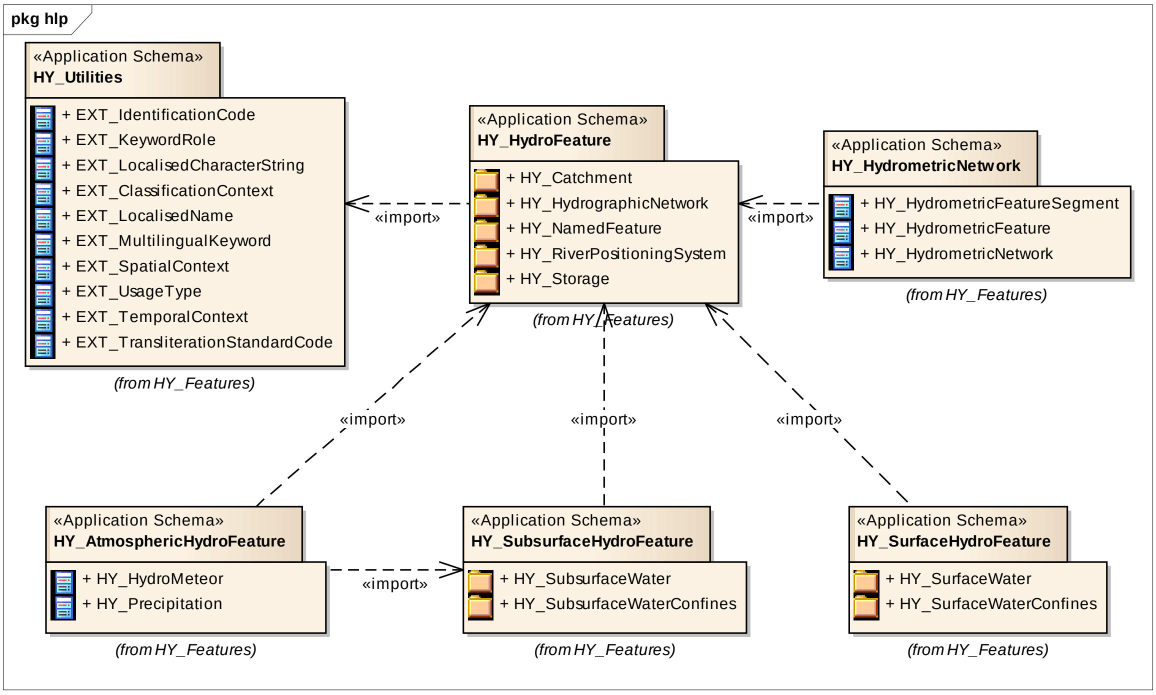

Figure 13: HY_FEATURES – Package dependencies

The HY_FEATURES model is described in detail in the OGC Discussion Paper OGC 11_039r3 [OGC, 2013]. The definitions, class relationships and attributes, their obligation and maximum occurrence may be taken from Annex A: HY_FEATURES Data Dictionary.

11 Outlook

The HY_FEATURES model is developed in a multi-step process whereby the requirements for hydrologic referencing is reconciled with typical dataset designs and semantics endorsed by the WMO-CHy. Module identification aims to simplify the scope of each part of the model in order to improve its accessibility and separate scope for testing. It is intended that each implemented data product needs to consider only those parts implicated by its scope.

11.1 Conformance Requirements of HY_FEATURES model

NOTE: Text in this section is taken from clause 2 in OGC 11-039r3 [OGC, 2013].

The standardization (conformance) target of the HY_FEATURES model is a related application schema for a data product describing hydrologic features. Such an application schema may be either the direct encoding of HY_FEATURES or another schema formally mapped to HY_FEATURES equivalent classes and properties. The conceptual model addresses the general requirements to integrate hydrologic data and information available across the scientific and technical programs of the WMO, to assist the WMO Members to discover, access und use hydrologic data from different sources.

However, the conceptual model raises a series of opportunities and requirements for testing in the context of many application domains related to hydrologic processes. Appropriate conformance requirements need to be defined with respect to the use of the model to support hydrologic referencing and system interoperability of information services and in data infrastructures.

Conformance to the HY_FEATURES model requires that an implementation is able to:

a) map the feature type of each implemented feature to the equivalent concept in HY_FEATURES, wherever such an instance of such a feature may be referenced as a hydrologic feature

b) map all properties of the implemented feature to the equivalent property expressed by feature properties within the HY_FEATURES model where such a mapping exists.

Differences in terminology may be explored through reconciling accepted definitions endorsed by the WMO-CHy and represented by the UNESCO/WMO International Glossary of Hydrology with the different aspects reflected in various datasets and products. It is expected to apply, wherever appropriate, the terms from the IGH to the identified semantic constructs. This has the effect of augmenting the accepted definitions with explicit semantics for the relationships with other terminology.

11.2 Hydrologic Referencing and Linked Data

NOTE: Text in this section refers to clause 8.2 in OGC 11-039r3 [OGC, 2013].

The HY_FEATURES model supports using the LINKED DATA principle: a hydrologic feature can be assigned a Web address (URI) that can return a description cross-referenced to a base concept definition and linked to multiple representations. For example, the name (URL) for a particular basin may link to a Web Feature Service that provides information on what is “known” about the identified basin and the “blue lines” dataset representing this basin. This will support the development of common tools for discovery, access and sharing of hydrologic information.

Linking data across multiple systems, e.g. on the Web, means linking references. The HY_FEATURES model provides referencable concepts of the fundamental relationships between the most important hydrologic features, particularly the relation to the catchment they represent. It provides a concept of persistent identifier across multiple representations independent from application and scale. Expressed in a platform-independent form, the model may be used as a basis for referencing hydrologic features that have persistent identity across multiple data systems. It is intended that applications in hydrology refer to the common concepts to relate individual features to the shared unit of study, management or reporting. For example, the Australian Hydrological Geofabric (AHGF) is mapped to concepts of HY_FEATURES model to link alternative representations through a set of common contracted nodes that are persistent between representations, versions and scales of the Geofabric products. [Atkinson and Boston, 2013].

Providing common semantics for reference, the HY_FEATURES model supports the mediation between services for Discovery, Access and Retrieval (D-A-R) allowing to address alternative data models and structures in use by numerous agencies to collect and provide hydrologic data for specific needs. Within the OGC Web Service Testbed 10 (OWS-10) a Cross-Community Interoperability (CCI) thread will explore, how the HY_FEATURES model can help the mediation between various conceptual models, and enable the access to hydrologic data from multiple sources [OGC, 2013/14]. The OWS-10 Hydro thread is intended to develop support services to demonstrate the use of the LINKED DATA approach in conjunction with the HY_FEATURES model to provide feature identity and representation linking services. This may support the developments initiated under guidance of WIS and WIGOS.

12 References

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ANNEX: HY_FEATURES Data Dictionary

This document provides the Data Dictionary of the HY_FEATURES common hydrologic feature model (OGC11-039r3). It is distributed for review and comment. It will be updated whenever required in the course of the further development of the UML model and is subject to change without notice.

The HY_FEATURES model is a conceptual UML model. This data dictionary describes the packages of the model, the relationships between classes and general attributes, their obligation and maximum occurrence.

The data dictionary lists for all elements of the HY_FEATURES model:

- name of the model component
- description
- source of external description
- element type
- target (of relation)
- source specification of the target (external), e.g. ISO19103
- obligation/condition (mandatory, conditional, optional)
- maximum occurrence

Each table column is named, each row is numbered.

Tables in Annex:

Table 1: HY_FEATURES (main)

	A	B	C	D	E	F	G	H
1	**Name**	**Description**	**Source of description (external)**	**Element**	**Target**	***Target specified externally in:***	**Obligation/Condition - mandatory (M) - conditional (C) - optional (O)**	**Maximum Occurrence**
2	HY_FEATURES	The HY_FEATURES model contains a component application schema (modelled according to ISO 19103 Conceptual Schema Language and ISO 19109 General Feature Model) defining semantic models for hydrologic features. These models are managed in sub-domain specific packages, allowing extension to a core set and involvement of relevant expert groups in the governance of individual models. A hydrologic feature is the abstract notion of the hydrology phenomenon. Commonly recognised as the abstract unit where hydrologic processes take place, a catchment is considered the abstract hydrologic feature which is multiple represented in the real world. Depending on applications and scales a variety of real-world representations may exist. *Note 1: In this context, hydrography refers to the cartographic representation of water bodies, aggregated through a connecting system of drainage channels. The hydrographic survey in the sense of measurement of depth of an open water body is not a concern of* HY_FEATURES*.* *Note 2: In this context, the measurement and analysis of water including methods, techniques and instrumentation used in hydrology (hydrometry) is not a concern of* HY_FEATURES*.* *Note 3: Whenever an appropriate definition is provided in the "International Glossary of Hydrology", a joint publication of WMO and UNESCO, the model captures the meaning of relevant features and feature properties as published in the electronic version.*						
3		*intentionally left blank*						
4		*intentionally left blank*						

Table 2: HY_HydroFeature

	A	B	C	D	E	F	G	H
5	HY_HydroFeature	HY_HydroFeature schema defines fundamental properties and relationships between features governed by the physical laws of hydrology. The core concept introduced here is that a study of hydrology will reflect common concepts of the real world by specific modelled features (as per ISO 19019 General Feature Model). Depending on the scientific concern, the relevant hydrologic feature may represent different aspects of the hydrology phenomenon, typically catchment or basin area, watershed (boundary), flowlines and connectivity (network). HY_HydroFeature connects the disparate representations of the shared unit of study, allowing the hydrosphere to be divided into a hierarchy of catchments.						
6		*intentionally left blank*						
7	HY_NamedFeature	HY_NamedFeature provides an abstract pattern shared by all hydrologic features where names are given to a feature, through common usage, without necessarily have a formal model. These named features are further elucidated in different concrete feature types which specify the properties each representation uses to define one or more aspects of the hydrology of a feature. This includes related phenomena that participate in hydrologic systems but have specific characteristics. Given the complexity of the domain, and the nature of real world physical phenomena, for any given feature a wide range of possible characteristics, states and representations may be relevant.						
8	HY_HydroFeature	abstract notion of the hydrology phenomenon. depending on application and scale, hydrologic features may be multiple and differently represented in the real world. *Note: refers to waters above, on and below the land surfaces of the Earth, whose occurrence, circulation and distribution in time and space, whose biological, chemical and physical properties, and whose reaction with the environment is object of scientific interest.*	according to *hydrology* (IGH 0623). [WMO, 1992a]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object
9	identifier	external identifier of the feature.		attribute	EXT_IdentificationCode		O	N
10	name	name taking cultural, political or historical context into account.		association	HY_HydroFeatureName		O	N
11	context	characteristics assigned to the hydrologic feature in a spatial, temporal or classification context.		association	HY_FeatureContext		O	N
12	HY_FeatureContext	generally applicable characteristics assigned to the hydrologic feature in a spatial, temporal or classification context.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object

13	temporalContext	existence or behaviour in time.		association	EXT_TemporalContext		O	N
14	spatialContext	interaction with an external spatial feature.		association	EXT_SpatialContext		O	N
15	classificationContext	position or rank in a system of ordering or classification system.		association	EXT_ClassificationContext		O	N
16	hydroFeature	carrier of the characteristic property.		association	HY_HydroFeature		O	1
17	HY_HydroFeatureName	localised name for all or part of a hydrologic feature.		generalisation	EXT_LocalisedName		use obligation / condition from referencing object	use maximum occurrence from referencing object
18	namesPart	identifier, whether the name applies to a part of feature only or not.		attribute	Boolean	*ISO 19103*	O	1
19	preferredBy	specifies that this name is the preferred name according to the named entity.		attribute	CI_ResponsibleParty	*ISO 19115*	O	1
20	source	source of the name identifying its origin.		attribute	CI_Citation	*ISO 19115*	O	1
21	variantSpelling	identifier, whether the name is a variant spelling or not. False = preferred name in specified language.		attribute	Boolean	*ISO 19103*	O	1
22		*intentionally left blank*						
23	HY_Catchment	HY_Catchment defines a logical network of catchments. Each catchment may be represented in any hydrologically meaningful sub-domain model, including by a stream network, or a nested network of catchments. HY_Catchment provides the topological concept to consider an arbitrary point on, or projected onto, the land surface as the outfall of a corresponding basin. Positioned in the hydrographic network, this point provides the identifiable reference point to which alternative representations may refer. The catchment model allows for the existence of catchments to be recognised, and identifiers assigned based on outflow nodes even if stream networks and watersheds and areas are not reliably determined. The catchment model is sufficient for the case of simplified hierarchies of basins to be defined. It is intended that hydrological reporting applications may use this model without the full complexity of surface water hydrology feature models. The catchment model provides for a logical network, without unnecessary detail of stream flow, cartographic interpretation and varying conditions. This is sufficient to allow the topological relationships between hydrometric stations to be established.						

24	HY_Catchment	distinct unit wherein hydrologic processes take place. a catchment is commonly recognised as the basic unit of study, management or reporting in hydrology, and multiple and differently represented in the real world. a catchment is part of a containing catchment, in a nested or aggregate hierarchy of catchments, as typically used for high order organisation of management and reporting units.		generalisation	HY_HydroFeature		use obligation / condition from referencing object	use maximum occurrence from referencing object
25	containingCatchment	containing catchment in a nested hierarchy of catchments. *Note: refers to simple hierarchy of catchments and sub-catchments, as typically used for high order organisation of management and reporting units.*		association	HY_Catchment		O	1
26	HY_CatchmentRepresentation	representation of a catchment, typically by catchment area, flowpath, boundary line, or a network structure. *Note: each catchment representation may be realised with an appropriate geometric representation.*		class (abstract)			O	N
27	representedCatchment	catchment represented by area, boundary line, network, etc.		association	HY_Catchment		M	1
28	HY_CatchmentArea	delineated surface area representing a catchment. *Note: the geometric representation of the catchment area needs to be defined with the application.*		generalisation	HY_Catchment Representation		use obligation / condition from referencing object	use maximum occurrence from referencing object
29	HY_CatchmentBoundary	boundary (line) representing a catchment. Example: watershed representing a basin. *Note: the geometric representation of the catchment boundary needs to be defined with the application.*		generalisation	HY_Catchment Representation		use obligation / condition from referencing object	use maximum occurrence from referencing object
30	HY_FlowPath	flowpath, described by a moving particle of water, representing a catchment. *Note: This class allows a line, e.g. directed straight line, representation of a catchment. the geometric representation of the flowpath needs to be defined with the application.*		generalisation	HY_Catchment Representation		use obligation / condition from referencing object	use maximum occurrence from referencing object

31	HY_Network	network structure (topology) representing a catchment. Example: hydrographic network representing a basin. *Note 1: the geometric representation of the network needs to be defined with the application.Note 2: network refers to the linkage of features using a connecting system like a channel network (drainage pattern), a system of connected aquifers, a technical water distribution system, or a system of logically connected hydrometric stations.*		generalisation	HY_Catchment Representation		use obligation / condition from referencing object	use maximum occurrence from referencing object
32	HY_BasinAggregate	highest level hierarchy containing the network of basins, a set of discrete upper-level systems that are hydrologically discrete. Typically, this will be a river system flowing into a sea or an internal sink.		generalisation	HY_Catchment		use obligation / condition from referencing object	use maximum occurrence from referencing object
33	subBasin	basin that is aggregated part of the encompassing aggregate basin .		association	HY_Basin		1	N

34	HY_Basin	special, hydrologically determined catchment whose waters, surface and subsurface waters, are flowing to a common outlet caused either by gravity or by pumping. a basin may have one identified inflow, multiple inflows into a basin may be described by aggregation of basins into an encompassing, aggregate basin. identified upstream basins of the basin may be described using the upstreamBasin relation. N*ote 1: this concept requires a stable identifier that is not merely a function of an arbitrary delineation of the surface, and that basins are delineated within a simple hierarchy (tree structure). More complex structures can be described as representations using HY_Network Representation pattern.* *Note 2: this concept provides an explicit model of a link between the identified inflow (inflowNode) and the common outlet (outflowNode) of a basin.* *Note 3: the concept refers to the continuous interaction of surface and subsurface waters within the basin. if required, drainage basin and groundwaterbasin may be differentiated with the application.*	according to *drainage basin* (IGH 0360) and *groundwaterbasin* (IGH 0552). [WMO, 1992a]	generalisation	HY_Catchment		use obligation / condition from referencing object	use maximum occurrence from referencing object
35	code	unique identifier of a basin in a classification or coding system.		attribute	ScopedName	*ISO 19103*	O	1
36	encompassingBasin	aggregate encompassing one or more sub-basins.		association	HY_BasinAggregate		M	1
37	upstreamBasin	basin located immediately upstream of the actual basin. *Note: this defines the topological hierarchy between basins. the nesting in a containing basin is inherited from the catchment class.*		association	HY_Basin		O	N
38	outflowNode	basin which contributes water to the outflow node. identifies the basin determined by the common outlet.	according to *outflow* (IGH 0867). [WMO, 1992a]	association	HY_Outfall		M	1
39	inflowNode	location served as the node where the receiving basin gets inflow.	according to *inflow* (IGH 0672). [WMO, 1992a]	association	HY_Outfall		O	1

40	HY_Network	network structure (topology) representing a catchment. Example: hydrographic network representing a basin. *Note: network refers to the linkage of features using a connecting system like a channel network (drainage pattern) or a system of connected aquifers.*		generalisation	HY_Catchment Representation; HY_HydroFeature		use obligation / condition from referencing object	use maximum occurrence from referencing object
41	HY_Outfall	topological concept that considers an arbitrary location as the outfall of a corresponding basin. *Note 1: Outfall represents a logic place and may not have an explicit location. This may be a fixed landmark, a station, or the location where groundwater enters the surface, but also a point projected onto the surface or created from the merger of disjoint locations. Examples: vertically arranged points may be aggregated and projected onto surface. a delta of a river system may be logically merged to a point located at the mouth, diffuse groundwater discharge may be focused into springs, rivers or lakes. Note 2: Outfall has no explicit geometry. Depending on the application the shape may be a point, line, area, etc. and needs to be defined with application.Note 3: For waters flowing due to gravitational forces the outfall coincides with the lowest point on the summit line bounding the corresponding basin.*		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
42	contributingBasin	basin which contributes water to the outflow node. identifies the basin determined by the common outlet.		association	HY_Basin		M	N
43	receivingBasin	basin which receives water over the identified inflow node. identifies the basin as the link between the inflow and the outflow node.		association	HY_Basin		O	N
44	position	position of outfall in the hydrographic network relative to a point referenced by coordinates.		association	HY_IndirectPosition		M	1
45	HY_ReferencePoint	permanent, stable reference location point such as a landmark fixed and referenced by coordinates.	according to *station description* (GHP, 2.5.2) [2]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object

46	refPoint	accepted location of a reference point, given that a single point may have several reported locations depending on its nature and the precision of measurement. *Note: The reference point is the basis for which linear measures within a network may be determined.*		attribute	GM_Point	*ISO 19107*	O	1
47	refPointType	term from a codelist identifying the reference point.		attribute	HY_RefPointType		O	1
48	networkLocation	location of reference point in the related network of basins. *Note: According to the concept of catchment, the reference point is outfall of the corresponding basin.*		association	HY_Outfall		O	1
49	HY_RefPointType	term identifying a fixed landmark determined as reference point. *Source: station description. (2008). In: WMO Guide to Hydrological Practices. 6th ed. (2008). Chapter 2.5.2: Station identification. WMO; 168*		codelist				
50	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.	*barrage* (IGH 0110). [WMO, 1992a]	codelist item				1
51	bifurcation	division of a stream into two branches.	*bifurcation* (IGH 0131). [WMO, 1992a]	codelist item				1
52	confluence	joining, or the place of junction, of two or more streams.	*confluence (IGH 0235). [WMO, 1992a]*	codelist item				1
53	dam	barrier constructed across a valley for impounding water or creating a reservoir.	*dam.*(IGH 0285). [WMO, 1992a]	codelist item				1
54	hydrometricStation	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.	*hydrometric station.*(IGH 0627). [WMO, 1992a]	codelist item				1
55	diversionOfWater	transfer of water from one watercourse to another, such watercourses being either natural or man-made.	*diversion of water.*(IGH 0349). [WMO, 1992a]	codelist item				1
56	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.	*fork (IGH 0499). [WMO, 1992a]*	codelist item				1

57	inlet	structure admitting water supplies from the source or through an intake structure built upstream.	*inlet (IGH 0679). [WMO, 1992a]*	codelist item				1
58	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.	*intake (IGH 0684). [WMO, 1992a]*	codelist item				1
59	outlet	opening through which water flows out or is extracted from a reservoir or stream.	*outlet (IGH 0868). [WMO, 1992a]*	codelist item				1
60	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.	*ponor (IGH 0925). [WMO, 1992a]*	codelist item				1
61	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.	*rapids (IGH 0980). [WMO, 1992a]*	codelist item				1
62	referenceClimatologicalStation	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.	*reference climatological station (IGH 0998). [WMO, 1992a]*	codelist item				1
63	riverMouth	place of discharge of a river into a sea or a lake.	*river mouth (IGH 1043). [WMO, 1992a]*	codelist item				1
64	sinkhole	place where water disappears underground in a limestone region. It generally implies water loss in a closed depression or blind valley.	*sinkhole (IGH 1116). [WMO, 1992a]*	codelist item				1
65	source	origin of river.	*source (IGH 1166). [WMO, 1992a]*	codelist item				1
66	spring	place where water flows naturally from a rock or soil onto land or into a body of surface water.	*spring (IGH 1185). [WMO, 1992a]*	codelist item				1
67	waterfall	vertical fall or the very steep descent of a stream of water.	*waterfall (IGH 1365). [WMO, 1992a]*	codelist item				1
68	weir	overflow structure which may be used for controlling upstream water level or for measuring discharge or for both.	*weir (IGH 1396). [WMO, 1992a]*	codelist item				1
69	any	any other fixed landmark used as accepted reference point.		codelist item				N

70	HY_Watershed	summit or boundary line separating adjacent drainage basins.	*watershed (IGH 0350). [WMO, 1992a]*	generalisation	HY_Catchment Boundary		C/ HY_CatchmentRepresentation.representedCatchment: HY_Basin	use maximum occurrence from referencing object
71	outfall	lowest point on the summit or boundary line of the basin.	according to *outfall* (IGH 0866). [WMO, 1992a]	association	HY_Outfall		O	1
72		*intentionally left blank*						
73	HY_HydrographicNetwork	The HY_HydrographicNetwork schema provides for topological relationships to be declared between the major elements of the hydrosphere, including the segmentation of a watercourse. The HydrographicNetwork introduces concepts of segmentation of hydrographic features which may or may not be topologically connected at the representational level. The HydrographicNetwork is defined in the context of a higher order identification of the network each element participates, hence the dependency on the abstract catchment model, HY_Catchment.						
74	HY_HydrographicNetwork	aggregate of rivers and other permanent or temporary watercourses, and also lakes and reservoirs, over any given area. *Note: not to be confused with the hydrometric network of hydrological stations and observing posts.*	*hydrographic network (IGH 0616). [WMO, 1992a]*	generalisation	HY_Network		C / HY_CatchmentRepresentation.representedCatchment: HY_Basin	use maximum occurrence from referencing object
75	HY_Glacier	accumulation of ice of atmospheric origin generally moving slowly on land over a long period.	*glacier (IGH 0535). [WMO, 1992a]*	generalisation	HY_HydroFeature		use obligation / condition from referencing object	use maximum occurrence from referencing object

76	HY_WaterBody	mass of water distinct from other masses of water. *Note 1: refers to real-world objects above, on and below the land surface, or a fiction of these.* *Note 2: water bodies have names within common experience, but different names in different contexts.* *Note 3: shape and extent of a (liquid) water body are determined by the properties of the containing object, i.e. the occupied landform, the hosting hydrogeologic unit, manmade container, etc.* *Note 4: shape and extent of a (liquid) open water body are bound to atmospheric pressure exerted on its surface. lakes and rivers levels are tuned to the surrounding water table.* *Note 5: in the context of observation the water body is the intended object of observation, i.e. sampled feature.*	*water body (IGH 1356). [WMO, 1992a]*	generalisation	HY_HydroFeature		use obligation / condition from referencing object	use maximum occurrence from referencing object
77	overallArea	average area of the overall surface of the water body.		attribute	Area	*ISO 19103*	O	1
78	totalLength	average length of the (entire)w water body, expressed as distance from the origin to the base level location.		attribute	Length	*ISO 19103*	O	1
79	hydrographicNetwork	hydrographic network the water body is part of		aggregation	HY_HydrographicNetwork		M	1
80	HY_WaterBodySegment	segment of a water body (mass of water).		generalisation	HY_HydroFeature		use obligation / condition from referencing object	use maximum occurrence from referencing object
81	length	average length of the water body segment, expressed as distance from the origin to the base level location.		attribute	Length	*ISO 19103*	O	1
82	surfaceArea	average area of the surface of the water body segment.		attribute	Area	*ISO 19103*	O	1
83	waterBody	water body the segment is part of.		aggregation	HY_WaterBody		M	1
84	upstreamSegment	immediately upstream segment connected to the relevant feature segment. *Note: refers to a simple upstream/downstream relation of two neighbouring parts.*		association	HY_WaterBody Segment		O	N

85	downstreamSegment	immediately downstream segment connected to the relevant feature segment. *Note: refers to a simple upstream/downstream relation of two neighbouring segments of the same geometry.*		association	HY_WaterBody Segment		O	N
86	fixedLandmark	permanent landmark, fixed and referenced by coordinates		association	HY_Reference Point		M	N
87	streamCrossSection	vertical section of a stream at right angles to the main (average) direction of flow.	*cross section* (IGH 0276) [WMO, 1992a]	association	HY_CrossSection		O	N
88	streamLongitudinalSection	vertical section (of a stream) along a channel at its centre line, e.g. stream centre line.	*longitudinal section* (IGH 0753) [WMO, 1992a]	association	HY_LongitudinalSection		O	N
89	HY_WaterBodyStratum	distinct layer within a (stratified) body of water. *Note: refers to the vertical stratification within the water body by differences in thermal (thermocline) or salinity (halocline) characteristics or by oxygen or nutrient content (e.g. chemocline).*	according to *stratification* (IGH 1225) [WMO, 1992a]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object
90	stratumType	term from a controlled vocabulary expressing the type of the stratum (layer).	according to *stratification* (IGH 1225) [WMO, 1992a]	attribute	URI	*ISO 19103*	O	N
91	storage	water storage characteristics of the water body participating in the hydrological network. *Note: storage refers to the impounding of water in surface or underground reservoirs, for future use.*	similar to *storage* (IGH 1215). [WMO, 1992a]	association	HY_Reservoir		O	N
92	waterBodySegment	water body (segment) the stratum (layer) is part of.		aggregation	HY_WaterBody Segment		M	1
93	HY_Water_LiquidPhase	liquid phase of a chemical compound consisting of approximately two parts by weight of hydrogen and 16 parts by weight of oxygen. *Note 1: this refers to the material having no extent and no shape* *Note 2: depending on application HY_Water_LiquidPhase may be specialised, e.g. for surface water, groundwater, soil water, soil moisture, gravitational water, etc.*	*water (IGH1353). [WMO, 1992a]*	class				
94	accumulatingWaterBody	water body (stratum) wherein liquid water is accumulated.		association	HY_WaterBody Stratum		O	N

95	HY_Water_SolidPhase	solid form of water.	*ice (IGH 0639). [WMO, 1992a]*	class				
96	coveredWaterBody	body of water whose surface is covered by ice or snow	*ice cover (IGH 0664). [WMO, 1992a]*	association	HY_WaterBody Segment		O	N
97	movingWater	water periodically or continuously moving in the channel (segment)		association	HY_ChannelSegment		O	N
98	snowmelt	liquid water from melting of snow.		association	HY_Water_LiquidPhase		O	1
99	accumulatingGlacier	glacier accumulating ice of atmospheric origin		association	HY_Glacier		O	N
100	HY_CrossSection	vertical section of an object at right angles to the main (average) direction of flow. - the geometric representation (plane or space curves, polygon) may vary with application and needs to be defined there. e.g. stream cross section (blue):=section of a stream at right angles to the main (average) direction of flow. e.g. transversal bed profile:=transversal shape of a stream bed in a vertical plane.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
101	upstreamCrossSection	cross section immediately upstream of the cross section		association	HY_CrossSection		O	1
102	crossSectionPoint	point located on the cross-section referenced by coordinates, e.g. centre point, bank points.		association	HY_Reference Point		O	N

103	HY_LongitudinalSection	vertical section of an object along a channel at its centre line. - the geometric representation (plane or space curves, polygon) may vary with application and needs to be defined there. e.g. stream centre line:=line connecting the successive centres of cross sections of a stream. e.g. stream line:=line envelope of the tangents to the instantaneous flow direction at a given time e.g. thalweg:=line following the deepest part of a streambed or channel or of a valley e.g. shore line/bank line:=line of intersection of a water body with the rising land not to be confused with: path line syn. flow line:=curve described by a moving particle of water		class					
104	longitudinalSectionPoint	point on the longitudinal section referenced by coordinates, e.g. point at the stream centre line		association	HY_Reference Point			O	N
105		*intentionally left blank*							
106		*intentionally left blank*							
107	HY_RiverPositioning System	The HY_RiverPositioningSystem schema provides a means to reference positions on a hydrographic feature via its topology and geometry. The HY_RiverPositioningSystem introduces the concept of indirect position where each location on the land surface may be described relative to or as a distance to a reference point located in a hydrographic network on a hydrographic feature.This concept is suitable to locate an arbitrary hydrometric station depending on its location on a hydrographic feature without having local coordinates. The reference point is identified by coordinates and may be a fixed landmark, but also a physical artefact.							
108	HY_IndirectPosition	indirect position of a point feature, either expressed as the distance to a reference point or as position relative to reference point or distance.		class				use obligation / condition from referencing object	use maximum occurrence from referencing object
109	distanceToRefPoint	distance to the identified reference point. In case of a direct position (when coordinates are known) the distance to the reference point equals to 0.00.		attribute	HY_DistanceTo RefPoint			O	1

110	relativePosition	position relative to the identified reference point.		attribute	HY_RelativePosition		O	1
111	mileageCS	linear coordinate system used.		association	HY_RiverMileageCS		O	1
112	referencePoint	landmark fixed and referenced by coordinates.		association	HY_ReferencePoint		M	N
113	HY_DistanceToRefPoint	distance to a reference point including indication of accuracy (closeness to the true value) and precision (smallest unit of measurement) . *Note: Accuracy has to do with quality of measurement, precision has to do with the resolution of the reported measurement.*	*accuracy of hydrological measurements* (GHP, 2.3.3) [2]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object
114	accuracyStatement	statement whether the distance value agrees with the value accepted as being true. (statement in the sense of exact, greater than or less than the value accepted as being true) . *Note: This statement assumes that all known corrections have been applied.*	*accuracy of hydrological measurements* (GHP, 2.3.3) [2]	attribute	DQ_RelativeInternalPositionalAccuracy	*ISO 19157 (draft)*	O	1
115	distanceValue	distance value expressed as length, incl. unit of length applied.		attribute	Length	*ISO 19103*	M	1
116	precisionStatement	statement on the smallest unit of division on the scale of measurement.	*accuracy of hydrological measurements* (GHP, 2.3.3) [2]	attribute	Distance	*ISO 19103*	O	1
117	HY_RelativePosition	relative position, expressed as percentage of the total distance to the reference point, or as a verbal description of the spatial relationship to a reference point.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
118	description	verbal description of the spatial relationship to the reference point.		attribute	HY_RelativePositionDescription		O	1
119	percentage	positive value, expressing a percentage of the total distance to the reference point.		attribute	Real	*ISO 19103*	O	1

120	HY_RiverMileageCS	linear coordinate system used to represent arbitrary water observation points along a stream. origin of the CS is position of the relevant point feature. coordinates are provided as distance (length) upstream or downstream from this origin (e.g. water monitoring point) to a reference point . *Note: This type should use ISO19111::Referencing by coordinates::CS_LinearCS, complemented by information about the precision (resolution) of the axis applied for mileage.*		generalisation	CS_LinearCS	*ISO 19111*	use obligation / condition from referencing object	use maximum occurrence from referencing object
121	axis	upstream or downstream directed axis.		association	HY_MileageSystemAxis		M	N
122	HY_MileageSystem Axis	axis of the mileage system applied.*Note: This type uses ISO19111::Referencing by coordinates.CS_CoordinateSystemAxis - added for information about precision (resolution) of the axis applied for mileage.*		generalisation	CS_Coordinate SystemAxis	*ISO 19111*	use obligation / condition from referencing object	use maximum occurrence from referencing object
123	precision	smallest unit of division on the mileage system axis.	*accuracy of hydrological measurements* (GHP, 2.3.3) [2]	attribute	Distance	*ISO 19103*	O	1
124	HY_RelativePosition Description	list of general terms commonly used in hydrology to describe a spatial relation between two points.		codelist				
125	at	located at the (reference) point		codelist item				1
126	between	located between two (reference) points		codelist item				1
127	downstream	located downstream of the (reference) point, e.g. in the direction of the current in a river or stream.		codelist item				1
128	left	located left-hand of the (reference) point when facing downstream.		codelist item				1
129	nearby	located in a short distance to the (reference) point.		codelist item				1
130	right	located right-hand of the (reference) point when facing downstream.		codelist item				1
131	upstream	located upstream of the (reference) point, e.g. in the direction towards the source of a stream.		codelist item				1
132	any	any other spatial relation between points not determined.		codelist item				
133		*intentionally left blank*						

134	HY_Storage	HY_Storage schema provides an abstract pattern to describe any hydrologic feature in terms of a resource stored in surface or underground reservoirs for future use, independent of its network connectivity. This allows networks to be described without details of storage capacities, and storage reservoirs to be referenced independently of their representation within a network.						
135	HY_Reservoir	body of water, either natural or man-made, used for storage, regulation and control of water resources. *Note 1: this refers to surface and subsurface water; special concepts of surface or underground reservoirs may be defined with application.* *Note 2: do not confuse underground reservoir with groundwater reservoir which refers to the containing aquifer.*	*reservoir (IGH 1011). [WMO, 1992a]*	class (abstract)			use obligation / condition from referencing object	use maximum occurrence from referencing object
136		*intentionally left blank*						
137		*intentionally left blank*						

Table 3: HY_ATMOSPHERICFEATURE

	A	B	C	D	E	F	G	H
1	**Name**	**Description**	**Source of description (external)**	**Element**	**Target**	***Target specified externally in:***	**Obligation/ Condition - mandatory (M) - conditional (C) - optional (O)**	**Maximum Occurrence**
138	HY_AtmosphericHydroFeature	This ApplicationSchema defines concepts of the hydrology phenomenon above the land surface. *Note: Considering the water falling through the atmosphere the main source of freshwater accumulated on and below the land surface, only precipitation is considered so far. Special concepts of water suspended in the atmosphere may by defined by application.*						
139	HY_HydroMeteor	meteor consisting of an ensemble of liquid or solid water particles falling through or suspended in the atmosphere, blown by the wind from the Earth's surface or deposited on objects on the ground or in the free air. *Note: may be specialised to different types of hydrometeors, e.g. precipitation.*	*hydrometeor* (IMV H0970). [4]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object
140	HY_Precipitation	hydrometeor consisting of a fall of an ensemble of particles. *Note 1: may be specialised to different forms of precipitation such as rain, drizzle, snow, snow grains, snow pellets, diamond dust, hail and ice pellets.* *Note 2: not to be confused with the amount of precipitation measured by means of raingauge, which is a property (rainfall).*	*precipitation* (IMV P1360). [4]	generalisation	HY_HydroMeteor		use obligation / condition from referencing object	use maximum occurrence from referencing object
141	iceFraction	solid particles from precipitation		association	HY_Water_SolidPhase		O	1
142	waterFraction	liquid particles from precipitation		association	HY_Water_LiquidPhase		O	1
143		*intentionally left blank*						
144		*intentionally left blank*						

Table 4: HY_SubsurfaceHydroFeature

	A	B	C	D	E	F	G	H
1	**Name**	**Description**	**Source of description (external)**	**Element**	**Target**	***Target specified externally in:***	**Obligation/ Condition - mandatory (M) - conditional (C) - optional (O)**	**Maximum Occurrence**
145	HY_SubsurfaceHydroFeature	This ApplicationSchema contains concepts of the hydrology phenomenon below the land surface taking into account the geological conditions. *Note: Considering water occupying a formation of rock or soil, water accumulated below the land surface is considered as water body confined by these. Special concepts of geologic confines may be defined by application.*						
146		*intentionally left blank*						
147	HY_SubsurfaceWater	concepts of water accumulated in water bodies below the Earth's surface incl. their interaction with surface water bodies. subsurface water may by specialised by pressure head and the property to move due to gravity and capillary action.						
148	HY_Groundwater	subsurface water occupying the saturated zone.	*groundwater* (IGH 0551). [WMO, 1992a]	generalisation	HY_Water_LiquidPhase		use obligation / condition from referencing object	use maximum occurrence from referencing object
149	groundwaterReservoir	aquifer yielding groundwater in the saturated zone.		association	HY_Aquifer		O	N
150	HY_VadoseWater	water that occurs in the unsaturated zone.	*vadose water* (IGH 1327). [WMO, 1992a]	generalisation	HY_Water_LiquidPhase		use obligation / condition from referencing object	use maximum occurrence from referencing object
151	bearingAquifer	aquifer yielding vadose water in the unsaturated zone.		association	HY_Aquifer		O	N

152	HY_GravitationalWater	water in the unsaturated zone which moves under the influence of gravity. This abstract class needs to be specified with implementation.	*gravitational water* (IGH 0545). [WMO, 1992a]	generalisation	HY_VadoseWater		use obligation / condition from referencing object	use maximum occurrence from referencing object
153	HY_SoilMoisture	moisture contained in the portion of the soil which is above the water table, including water vapour, which is present in the soil pores. *Note: moisture refers to the presence of water within a body or substance.*	*soil moisture* (IGH 1151). [WMO, 1992a]	generalisation	HY_VadoseWater		use obligation / condition from referencing object	use maximum occurrence from referencing object
154	HY_SoilWater	water suspended in the uppermost belt of soil, or in the zone of aeration near the ground surface, that can be discharged into the atmosphere by evapotranspiration.	*soil water* (IGH 1160). [WMO, 1992a]	generalisation	HY_VadoseWater		use obligation / condition from referencing object	use maximum occurrence from referencing object
155		*intentionally left blank*						
156	HY_SubsurfaceWaterConfines	concepts of the key elements containing and confining subsurface water.						
157	HY_HydroGeologicUnit	formation or zone of geological material (rock or soil) with hydrologically significant characteristics. *Note: the geometric representation of the hydrogeologic unit needs to be defined with the application.*		generalisation	HY_Catchment Representation		use obligation / condition from referencing object	use maximum occurrence from referencing object
158	containingUnit	containing (hosting) hydrogeologic unit in a (nested) hierarchy of geologic units. *Note: refers to a simple hierarchy, as typically used for high order organisation of management and reporting units.*		association	HY_HydroGeologicUnit		O	1
159	HY_Aquifer	permeable water-bearing formation capable of yielding exploitable quantities of water. an aquifer may be part of a system of hydraulically connected aquifers. Note: *not to be confused with (underground) reservoir which refers to a body of water used for storage.*	*aquifer* (IGH 0064). [WMO, 1992a]	class				
160	extractingWell	well used to extract water from aquifer.		association	HY_Well		O	N

161	HY_Well	shaft or hole sunk, dug or drilled into the Earth to extract water. *Note: conceptionally, a well may be a single feature, but also a composite of e.g. vertically arranged extraction locations or a discharge area, logically condensed to single extraction point projected onto the land surface.*	*well* (IGH 1397). [WMO, 1992a]	class			use obligation / condition from referencing object	use maximum occurrence from referencin g object
162	extractionPoint	point where the well extract water, referenced by coordinates.		association	HY_Reference Point		O	N
163		*intentionally left blank*						
164		*intentionally left blank*						

Table 5: HY_SurfaceHydroFeature

	A	B	C	D	E	F	G	H
1	**Name**	**Description**	**Source of description (external)**	**Element**	**Target**	***Target specified externally in:***	**Obligation/ Condition - mandatory (M) - conditional (C) - optional (O)**	**Maximum Occurrence**
165	HY_SurfaceHydroFeature	This ApplicationSchema contains concepts of the hydrology phenomenon on the land surface taking into account the segmentation of water courses without imposing a particular network scale.						
166		*intentionally left blank*						
167	HY_SurfaceWater (informative)	concepts of water accumulated in water bodies on the Earth's surface. *Note: informative, i.e. this concepts may be realised with an identified entity.*						
168	HY_Canal	man-made open channel, usually of regular cross-sectional shape. *Note: This class defines the existence of the canal, as a participant in a hydrographic network. This body of water is special due to its origin (man-made).*	*canal* (IGH 0162). [WMO, 1992a]	generalisation	HY_WaterBody		use obligation / condition from referencing object	use maximum occurrence from referencing object
169	HY_Estuary	generally broad portion of a stream near its outlet. *Note: defines the existence of the estuary, as a participant in a hydrographic network. This body of water is special due to branching and its interaction with the open sea.*	*estuary* (IGH 0000). [WMO, 1992a]	generalisation	HY_WaterBody		use obligation / condition from referencing object	use maximum occurrence from referencing object
170	HY_Impoundment	body of water formed by collecting water, as by a dam. *Note: This class defines the existence of the impoundment, as a participant in a hydrographic network. This body of water is special due to the collection of water.*	*impoundment* (IGH 0658). [WMO, 1992a]	generalisation	HY_WaterBody		use obligation / condition from referencing object	use maximum occurrence from referencing object

171	HY_Lagoon	shallow body of water which has a shallow, restricted inlet from the sea. *Note: This class defines the existence of the lagoon, as a participant in a hydrographic network. This body of water is special due to its shallow depth and interaction with the open sea.*	*lagoon* (IGH 0272). [WMO, 1992a]	generalisation	HY_WaterBody		use obligation / condition from referencing object	use maximum occurrence from referencing object
172	HY_Lake	inland body of water of considerable size. *Note: This class defines the existence of the lake, as a participant in a hydrographic network. This body of water is special due to its considerable size.*	*lake* (IGH 0729). [WMO, 1992a]	generalisation	HY_WaterBody		use obligation / condition from referencing object	use maximum occurrence from referencing object
173	HY_River	large stream which serves as the natural drainage channel for a drainage basin. *Note: This class defines the existence of the river, as a participant in a hydrographic network. This body of water is special due to its property to permanently or temporarily flow.*	*river* (IGH 1014). [WMO, 1992a]	generalisation	HY_WaterBody		use obligation / condition from referencing object	use maximum occurrence from referencing object
174		*intentionally left blank*						
175	HY_SurfaceWaterConfines	concepts of the key elements confining surface water bodies.						
176	HY_ChannelNetwork	arrangement of natural or man-made drainage channels within an area. *Note: channel network provides the connecting system for the hydrographic network of water bodies.*	*channel network (IGH 0363). [WMO, 1992a]*					use maximum occurrence from referencing object
177	drainagePattern	pattern describing the arrangement of drainage channels.		attribute	HY_DrainagePattern		O	1
178	HY_Channel	watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. also: deepest portion of a river bed, in which the main current flows. *Note: watercourse refers to natural or man-made channel through or along which water may flow, including throughflow lakes, underground/subterranean streams, or streams in or beneath a glacier.*	according to *watercourse* (IGH 1359). [WMO, 1992a]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object
179	channelNetwork	network of channels the channel is aggregated part of		aggregation	HY_ChannelNetwork		M	1

180	HY_ChannelSegment	segment of the channel (watercourse) between two or more cross-sections.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
181	channel	channel the segment is aggregated part of.		aggregation	HY_Channel		M	1
182	containedWaterBody	water body (segment) contained in the channel (segment)		association	HY_WaterBody Segment		O	1
183	bedProfileTransversal	transversal shape of a stream bed in a vertical plane.	according to *bed profile* (IGH 0125). [WMO, 1992a]	association	HY_CrossSection		O	N
184	bedProfileLongitudinal	longitudinal shape of a stream bed in a vertical plane, e.g. thalweg, bank line.	according to *bed profile* (IGH 0125). [WMO, 1992a]	association	HY_LongitudinalSection		O	N
185	HY_Reach	open channel between defined cross-sections.	similar to *reach* (IGH 0987). [WMO, 1992a]	generalisation	HY_ChannelSegment		use obligation / condition from referencing object	use maximum occurrence from referencing object
186	HY_Coast	rising land affected by waves (in a water body), between uppermost landward and lowermost seaward impacts of surf action.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
187	coastalArea	area of the coast.		attribute	Area	*ISO 19103*	O	1
188	coastalWaterBody	water body whose waves therein affect the land.		association	HY_SurfaceWaterBody		O	1
189	HY_Bank	rising land bordering a river margin of a channel at the left-hand (right-hand) side when facing downstream.	*bank* (IGH 0106). [WMO, 1992a]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object
190	borderedChannel	channel (reach) bordered by the bank/s.		association	HY_Reach		O	N
191	HY_RiverBed	lowest part of a channel shaped by the flow of water and along which most of the sediment and runoff moves in interflood periods.	similar to *river bed* (IGH 1042). [WMO, 1992a]	class			use obligation / condition from	use maximum occurrence from

								referencing object	referencin g object
192	channel	channel (reach) whose bottom is the river bed.	according to *channel* (IGH 0185). [WMO, 1992a]	association	HY_Reach			O	1
193	HY_DrainagePatter n	terms describing the arrangement of drainage lines.		codelist					
194	annular	main rivers have circular pattern with subsidiary channels at right angels.	*basic drainage patterns* (table 10.4) [5].	codelist item					1
195	centripetal	streams flow inward to center.	*basic drainage patterns* (table 10.4) [5].	codelist item					1
196	dendritic	spreading treelike arrangement; no evident orientation of channels (random orientation).	*basic drainage patterns* (table 10.4) [5].	codelist item					1
197	distributary	one main channel divides into many anastomozing channelways ending with many outlets.	*basic drainage patterns* (table 10.4) [5].	codelist item					1
198	parallel	main channels regularly spaced and parallel or subparallel to each other; tributaries join at very acute angels.	*basic drainage patterns* (table 10.4) [5].	codelist item					1
199	pinnate	featherlike, closely grouped , short tributaries (fine texture).	*basic drainage patterns* (table 10.4) [5].	codelist item					1
200	radial	streams flow outward from center.	*basic drainage patterns* (table 10.4) [5].	codelist item					1
201	rectangular	drainage forms a perpendicular net with the two directions equally developed.	*basic drainage patterns* (table 10.4) [5].	codelist item					1
202	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.	*basic drainage patterns* (table 10.4) [5].	codelist item					1
203		*intentionally left blank*							
204		*intentionally left blank*							

Table 6: HY_HydrometricNetwork

	A	B	C	D	E	F	G	H
1	**Name**	**Description**	**Source of description (external)**	**Element**	**Target**	***Target specified externally in:***	**Obligation/ Condition - mandatory (M) - conditional (C) - optional (O)**	**Maximum Occurrence**
205	HY_HydrometricNetwork	network of hydrometric stations which are logically connected, e.g. stations along a watercourse. A hydrometric network is an aggregate of one or more hydrometric features. *Note: Special concepts of hydrometric features, e.g. monitoring point, may be defined by application.*						
206	HY_HydrometricNetwork	aggregate of hydrological stations and observing posts situated within any given area (river basin, administrative region) in such a way as to provide the means of studying the hydrological regime. *Note 1: not to be confused with the natural network of hydrographic features (hydrographicNetwork)* *Note 2: not to be confused with network sampling as distinct method of sampling.*	according to *hydrometric network* (IGH 0616). [WMO, 1992a]	generalisation	HY_Network		use obligation / condition from referencing object	use maximum occurrence from referencing object
207	HY_HydrometricFeature	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. *Note 1: in observation context, the hydrometric feature represents a special sampling feature.* *Note 2: hydrometric feature is physical artefact, or a collection of these. Some may be a fictive ones.*	according to *hydrometric station* (IGH 0627). [WMO, 1992a]	class			use obligation / condition from referencing object	use maximum occurrence from referencing object
208	hydrometricNetwork	hydrometric network the hydrometric feature is part of.		aggregation	HY_HydrometricNetwork		M	1
209	positionOnRiver	permanent location of the hydrometric feature in the hydrographic network, usually on a river.		association	HY_ReferencePoint		O	1

210	HY_HydrometricFeatureSegment	segment or component of a hydrometric feature.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
211	hydrometricFeature	hydrometric feature the segment is part of.		aggregation	HY_HydrometricFeature		M	1
212		*intentionally left blank*						
213		*intentionally left blank*						

Table 7: EXT_UTILITIES (within HY_FEATURES)

	A	B	C	D	E	F	G	H
1	**Name**	**Description**	**Source of description (external)**	**Element**	**Target**	***Target specified externally in:***	**Obligation/ Condition - mandatory (M) - conditional (C) - optional (O)**	**Maximum Occurrence**
214	HY_Utilities	The HY_Utilities package contains utility classes for common patterns required by the HY_FEATURES domain model, that are not hydrology-specific. A toponymy model should handle most of these concerns. These classes should be provided in an external library for cross-domain usage. It is expected that future evolution of the ISO standards will provide a replacement for these components. At that point this package can be replaced with references to this library.						
215	EXT_IdentificationCode	*Note: This type is equivalent to ISO19115-1(draft)::Metadata information::MD_Identifier - but we don't want to import the 19115 metadata model for this single concept. (ISO 19115 has circular dependencies and is not safe to use as a conceptual model.)*		codelist				
216	EXT_KeywordRole	extensible by domain, so empty. *Note: this avoids the anti-pattern in the ISO 19115 Codelists pre-populated with semi-complete lists.*		codelist				
217	EXT_LocalisedCharacterString	*Note: This type is equivalent to ISO19139::Cultural and linguistic adaptability::LocalizedCharacterString - but we don't want to import the 19139 metadata model for this single concept. (ISO 19139 Cultural and linguistic adapdability, informative package)*		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
218	EXT_ClassificationContext	information about the classification used to arrange a feature or feature property according to established criteria.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object

219	class	controlled vocabulary term assigned to a feature or a feature property expressing the position or rank in a classification system.		attribute	ScopedName	*ISO 19103*	O	1
220	classification	name of the related classification system.		attribute	ScopedName	*ISO 19103*	O	1
221	topic	controlled vocabulary term expressing the upper-level topic or theme the related classification system refers to.		attribute	ScopedName	*ISO 19103*	O	1
222	EXT_LocalisedName	information about a name whose use is bound to a locale.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
223	name	individual name used in a country or region under the conditions of nation and language.		attribute	ScopedName	*ISO 19103*	M	1
224	transliteration	SO standards used for romanisation, transcription or transliteration of characters of another alphabet into Latin characters.		attribute	EXT_TransliterationStandardCode	HY_FEATURES	O	1
225	usage	controlled vocabulary term expressing the mode of usage in a specific community.		attribute	EXT_UsageType	HY_FEATURES	O	1
226	EXT_MultilingualKeyword	keyword used in an multilingual context.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
227	keyword	significant word, phrase or name commonly or conventionally used describing an agreed meaning.		attribute	EXT_LocalisedCharacterString	HY_FEATURES	M	N
228	type	role of the keyword. Note: *This is a domain specific context, so not using the (broken) ISO 19115 keyword list, but choosing an empty container that can be appropriately populated with relevant terms in an extension model.*		attribute	EXT_KeywordRole	HY_FEATURES	M	1
229	EXT_SpatialContext	information about the source feature describing the interaction with a target spatial feature. This characterisation may be specialised to simplify the nature of this information, such as a single numeric value. Examples: number of countries (or admin unit) in catchment, soil types in catchment, wmo-subregion in catchment.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object

230	domain	domain within which a spatial context is described.		attribute	ScopedName	*ISO 19103*	O	1
231	overlapsCount	number of specified features in the target domain that the source feature overlaps.		attribute	Number	*ISO 19103*	O	1
232	relatedFeatureType	identifier from related domain specifying the related source feature.		attribute	ScopedName	*ISO 19103*	O	1
233	spatialContextDescriptor	controlled vocabulary term from a related domain characterising the spatial context of the source feature, e.g. country.		attribute	ScopedName	*ISO 19103*	O	1
234	EXT_TemporalContext	information about the source feature describing the existence or behaviour in time. This characterisation may be specialised to simplify the nature of this information, such as a single numeric value. Examples: lifespan, permanence.		class			use obligation / condition from referencing object	use maximum occurrence from referencing object
235	extent	temporal extent of the feature.		attribute	TM_Period	*ISO 19108*	O	1
236	statusIdentifier	identifier, whether a feature characteristic applies or not.		attribute	Boolean	*ISO 19103*	O	1
237	temporalContextDescriptor	controlled vocabulary term characterising the temporal context of the source feature, *e.g. lifespan.*		attribute	ScopedName	*ISO 19103*	O	1
238	EXT_UsageType	terms indicating the type of name usage.		codelist				
239	conventional	accepted, used, or practiced by most people.		codelist item				1
240	historical	restricted to or based on fact.		codelist item				1
241	official	ordered or allowed by those in authority.		codelist item				1
242	vernacular	used in or suitable for speech and not formal writing.		codelist item				1
243	EXT_TransliterationStandardCode	ISO standards used for the romanisation, transcription or transliteration of characters of another alphabet into Latin characters.		codelist				
244	iso11940	Transliteration of Thai characters into Latin characters		codelist item				1
245	iso11941	Transliteration of Korean script into Latin characters		codelist item				1
246	iso15919	Transliteration of Devanagari and related Indic scripts into Latin characters		codelist item				1
247	iso233	Transliteration of Arabic characters into Latin characters.		codelist item				1
248	iso259	Transliteration of Hebrew characters into Latin characters.		codelist item				1
249	iso6302	Romanization of Japanese (kana script)		codelist item				1
250	iso7098	Romanization of Chinese		codelist item				1
251	iso843	Conversion of Greek characters into Latin characters		codelist item				1

252	iso9	Transliteration of Cyrillic characters into Latin characters: Slavic and non-Slavic languages.		codelist item					1
253	iso9984	Transliteration of Georgian characters into Latin characters		codelist item					1
254	iso9985	Transliteration of Armenian characters into Latin characters		codelist item					1
255		*intentionally left blank*							
256		*intentionally left blank*							

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