S-104

Water Level Information for Surface Navigation Product Specification

Edition 1.0.0 – August 2021

IHO

International Hydrographic Organization

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TABLE OF CONTENTS

Document History

Changes to this Product Specification are coordinated by the IHO Tides, Water Level and Currents Working Group (TWCWG). New editions will be made available via the IHO web site. Maintenance of the Product Specification shall conform to IHO Technical Resolution 2/2007 (as amended).

Version Number	Date	Author	Purpose
0.0.0	15 Feb 2015	Z Jayaswal	Initial Draft
0.0.1	1-May-16	Z Jayaswal	TWCWG 1 – Working group input incorporated from Brazil meeting
0.0.2	Aug-16	Z Jayaswal	TWCWG – incorporate feedback on Portrayal and Attributes
0.0.3	Mar-17	Z Jayaswal	Extract commonality from S-111 v0.1.10 to ensure consistency between standards.
0.0.4	May-17	Z Jayaswal	As edited during TWCWG 2
0.0.5	Nov-17	Z Jayaswal	Feedback from TWCWG and S100 WG
0.0.6	Sep-18	Z Jayaswal	Feedback from TWCWG3 and S-129 WG
0.0.7	Mar 19	Z Jayaswal	Feedback from S100 Test Strategy Working Group Sep 2018
0.0.8	Apr 19	Z Jayaswal, K Hess & G. Seroka	Feedback from NOAA and 4th TWCWG
0.0.9	Apr 21	Z Jayaswal, G. Seroka, R. Malyankar Review by TWCWG and S-104 project team	Feedback from TWCWG5
1.0.0 Draft 1	30 June 2021	R. Malyankar	Applied review comments on Ver. 0.0.9. Added carrier metadata attributes for coordinate systems approved by S-100WG. Added Exchange Set structure and use cases
1.0.0	23 Aug. 2021	R. Malyankar. Review by ZJ, GS.	Release 1.0.0

FOREWORD

The International Hydrographic Organization Tides, Water Level and Currents Working Group (TWCWG) remembers Kurt Hess, and acknowledges his invaluable and significant contributions in developing this Product Specification within the TWCWG.

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1 Overview

S-104 is the Water Level Information for Surface Navigation Product Specification, produced by the IHO.

The development of electronic navigation with high resolution bathymetric data, and the drive to increase safety of navigation are now demanding time-sensitive data. IHO has identified the requirement for a Product Specification for dynamic tidal and water level data.

Tidal height information has traditionally been provided as high/low predictions; however, with increasing drafts and technology, there has been a move to hourly predictions with major ports providing real-time water level information to their pilots and web-sites.

There is now a requirement to supply tidal and water level data as a single point time-series and as a surface time series to manage critical depths and provide tidal windows.

1.1 Introduction

Tidal and water level predictions have been fundamental in route planning and entry to ports (SOLAS Chapter V). These have traditionally been supplied as a physical hard copy publication and recently as a separate software installation that may not be integrated with the ECDIS. To improve safety of navigation, this product specification will ensure that tidal and water level data supplied for dynamic capability is consistent by all approved authorities.

1.1.1 Data types

There is one data type that can be delivered to a ship and/or to an ECDIS:

1. A time series of water level height relative to a vertical datum and water level trend. The data can represent either a single point (that is, one geographic location) or for an array of points contained in a grid. Time and datum information are contained in the metadata. One purpose of this data type is to update water depths for under-keel clearance management.

1.1.2 Display

There are two different means of displaying water level data to support navigation, route planning, and route monitoring:

1. Display of water level at a single point. The portrayal options for this are:
   a. A symbol at the location of the water level data source;
   b. A text box containing information on the water level height, trend, etc;
   c. Graphic time series plot(s) showing water level height over time at one or more locations.
2. Display of a single point location from gridded data, where a mouse click on the chart area will display the information at that point from the nearest node in the grid. The display has the qualities as described in type (1) - display of water level at a single point.

1.1.3 Encoding

There is one encoding of water level data:

1. HDF5 (Hierarchical Data Format version 5) is used for encoding time series of water level heights and trends at a single point or at an array of points in a grid. HDF5 promotes compatible data exchange due to its common neutral encoding format. HDF5 is object oriented and suitable for many types of data and forms the basis of the Network Common Data Form (NetCDF), which is a set of software libraries and machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data. NetCDF is also a community standard for sharing scientific data.

Table 1-1 below summarises Clauses 1.1.1 through 1.1.3.

Table 1-1 – S-104 data variables, formats, encoding and display

Data Variable	Data Format	Encoding	Display
Water Level Height and Trend	Single Location, Single Time (for example, Obs.)	HDF5	Symbol (O), Text Box (O)
	Single Location, Time Series (for example, Astronomical Prediction)	HDF5	Symbol (O), Text Box (O), Graphic Plot (I)
	Multiple Locations, Time Series (for example, Gridded Forecast)	HDF5	Symbol (O), Text Box (O), Graphic Plot (I)

NOTE: O = Overlay: A layer superimposed on and georeferenced to a nautical chart. I = Inset: A graphic that can be placed anywhere on the screen.

1.2 Scope

This document describes an S-100 compliant Product Specification for the encapsulation and data transfer of tidal and water level data for use in an Electronic Chart Display and Information System (ECDIS) or any proposed dynamic tide application. This Product Specification includes the content model, the encoding, the feature catalogue and metadata. The water level product may be used either alone or combined with other S-100 compatible data.

1.3 References

1.3.1 Normative

M-3 *Resolutions of the International Hydrographic Organization, IHO Publication M-3,* 2nd Edition, 2010 (updated October 2020)

S-44 *IHO Standards for Hydrographic Surveys,* 5th Edition, February 2008

S-62 *List of Data Producer Codes* (online), URL: http://registry.iho.int/producercode/list.do

S-97 *IHO Guidelines for Creating S-100 Product Specifications*, June 2020

S-100 *IHO Universal Hydrographic Data Model*, Edition 4.0.0, December 2018

S-101 *IHO Electronic Navigational Chart Product Specification*, Edition 1.0.0, December 2018

S-102 *IHO Bathymetric Surface Product Specification*, Edition 2.0.0, October 2019

S-111 *IHO Surface Currents Product Specification*, Edition 1.0.0, December 2018

HDF5 *Hierarchical Data Format*, version 5 – www.hdfgroup.org

1.3.2 Informative

IALA G1143 *Unique Identifiers for Maritime Resources*, Edition 3.0. International Association of Marine Aids to Navigation and Lighthouse Authorities, June 2021.

ISO 8601:2004 *Data elements and interchange formats - Information interchange - Representation of dates and times*

ISO 3166-1:1997 *Country Codes*

ISO/TS 19103:2005 *Geographic information – Conceptual schema language*

ISO 19111:2003 *Geographic information – Spatial referencing by coordinates*

ISO 19115-1 *Geographic information – Metadata – Part 1 – Fundamentals*. As amended by Amendment 1, 2018.

ISO 19115-2:2009 *Geographic information – Metadata: Extensions for imagery and gridded data*

ISO 19115-3 *Geographic information – Metadata - XML schema implementation for fundamental concepts*. 2016.

ISO 19123:2005 *Geographic information – Schema for coverage geometry and functions*

ISO 19129:2009 *Geographic information – Imagery gridded and coverage data framework*

ISO 19131:2007 *Geographic information – Data product specifications*

ISO 19157:2013 *Geographic information – Data Quality.* As amended by Amendment 1, 2018.

ISO/IEC 19501-1 and 19505-2, *Information technology — Open Distributed Processing – Unified Modelling Language*, Version 2.4.1

netCDF *Network Common Data Form Unidata* - www.unidata.ucar.edu/software/netcdf

S-100WG5 Draft Minutes and Actions. Available at the S-100WG5 meeting documents page, URL: https://iho.int/en/s-100wg5-2020

S-100WG5-04.14. : Part 10c – CRS Attributes. Available at the S-100 WG5 meeting documents page, URL: https://iho.int/en/s-100wg5-2020

S-100WG5-04.18A. Part 10c – New dataCodingFormat. Available at the S-100 WG5 meeting documents page, URL: https://iho.int/en/s-100wg5-2020

XML Schema Part 2: Datatypes Second Edition, W3C Recommendation, 28 October 2004, URL: https://www.w3.org/TR/xmlschema-2/

1.4 Terms, definitions and abbreviations

1.4.1 Use of language

Within this document:

- "Must" indicates a mandatory requirement.
- "Should" indicates an optional requirement, that is the recommended process to be followed, but is not mandatory.
- "May" means "allowed to" or "could possibly", and is not mandatory.

1.4.2 Terms and Definitions

Terms and definitions have been taken from the normative references cited in Clause 1.3. Only those which are specific to this document have been included and modified where necessary. Additional terms are defined in this document.

Coordinate
One of a sequence of numbers designating the position of a point in N-dimensional space [ISO 19111]

Coordinate reference system
Coordinate system which is related to the real world by a datum [ISO 19111]

Coverage
Feature that acts as a **function** to return values from its **range** for any **direct position** within its spatial, temporal, or spatiotemporal **domain**

EXAMPLE: Examples include a raster **image**, polygon overlay, or digital elevation matrix.

NOTE: In other words, a **coverage** is a **feature** that has multiple values for each **attribute** type, where each **direct position** within the geometric representation of the **feature** has a single value for each **attribute** type [ISO 19123].

Coverage geometry
Configuration of the **domain** of a **coverage** described in terms of **coordinates** [ISO 19123]

Data product
Dataset or **dataset series** that conforms to a data Product Specification

NOTE: The S-104 data product consists of metadata and one or more sets of water level height and trend [ISO 19131].

Direct position
Position described by a single set of coordinates within a coordinate reference system [ISO 19107]

Domain
Well-defined set [ISO 19103]

NOTE: Domains are used to define the domain set and range set of operators and functions.

Elevation
The altitude of the ground level of an object, measured from a specified vertical datum [IHO S100 GFM]

Feature
Abstraction of real world phenomena [ISO 19101]

NOTE: A feature may occur as a type or an instance. Feature type or feature instance should be used when only one is meant.

Feature attribute
Characteristic of a feature

EXAMPLE 1: A **feature attribute** named *colour* may have an **attribute** value *green* which belongs to the **data type** *text*.

EXAMPLE 2: A **feature attribute** named *length* may have an **attribute** value *82.4* which belongs to the **data type** *real*.

NOTE 1: A **feature attribute** may occur as a **type** or an **instance**. **Feature attribute** type or **feature attribute** instance is used when only one is meant.

NOTE 2: A **feature attribute** type has a name, a **data type**, and a **domain** associated to it. A **feature attribute** instance has an **attribute** value taken from the **domain** of the **feature attribute** type.

NOTE 3: In a **feature catalogue**, a **feature attribute** may include a value **domain** but does not specify **attribute** values for **feature** instances. [ISO 19101, ISO 19109, ISO 19110, ISO 19117]

Height
Distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface [ISO 19111:2006]

NOTE: Height is distinguished from elevation in that it is a directional measurement.

Georeferenced grid
Grid for which cells can be located by the use of specific algorithms. See **ungeorectified grid**

Grid
Network composed of a set of elements, or cells, whose vertices, or nodes, have defined positions within a coordinate system. See also **georeferenced grid, regular grid, ungeorectified grid, node,** and **grid point** [ISO 19123]

NOTE 1: A rectangular grid has axes perpendicular to each other.

NOTE 2: A uniform rectangular grid has constant spacing in the X-direction and constant spacing in the Y-direction, although the two spacing values are not necessarily equal.

Grid cell
Element of a grid defined by its vertices, or **nodes**

Grid point
Point located at the intersection of two or more **grid cells** in a **grid.** Also called a **node** [ISO 19123]

Record
Finite, named collection of related items (objects or values) [ISO 19107]

NOTE: Logically, a record is a set of pairs <name,item>

Uncertainty
The interval (about a given value) that will contain the true value of the measurement at a specific confidence level [IHO S-44].

NOTE: Errors exist and are the differences between the measured value and the true value. Since the

true value is never known it follows that the error itself cannot be known. Uncertainty is a statistical assessment of the likely magnitude of this error.

Water level trend
Change of water level at a given time, such as 'increasing', 'decreasing', or 'steady'

When the average change of the water level over a one hour period is greater than or equal to a value set by the producing authority in metres it is considered "increasing". When it is less than or equal to -(value set by the producing authority in metres), it is "decreasing". When it is between the values set by the producing authority, it is "steady".

In areas of small water level range, for example Baltic Sea, use of "not available" is optional.

Ungeorectified grid
Grid with non-uniform point spacing in any coordinate system. Includes triangular irregular networks (TINs) and those curvilinear coordinate grids whose node positions cannot be calculated analytically.

1.4.3 Abbreviations

CRS	Coordinate Reference System
ECDIS	Electronic Chart Display Information System
EPSG	European Petroleum Survey Group
ENC	Electronic Navigational Chart
FC	Feature Catalogue
HDF	Hierarchical Data Format
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IHO	International Hydrographic Organization
IMO	International Maritime Organization
ISO	International Organization for Standardization
MRN	Maritime Resource Name
NetCDF	Network Common Data Form
PC	Portrayal Catalogue
SOLAS	International Convention for the Safety of Life at Sea
TIN	Triangulated Irregular Network
TWCWG	Tides, Water Level and Currents Working Group
UML	Unified Modelling Language
UTC	Coordinated Universal Time
W3C	World Wide Web Consortium
XML	eXtensible Markup Language

1.4.4 Notation

In this document Conceptual Schemas are presented in the Unified Modelling Language (UML). Several model elements used in this Schema are defined in ISO Standards developed by ISO TC 211, or in IHO S-100. In order to ensure that class names in the model are unique ISO TC/211 has adopted a convention of establishing a prefix to the names of classes that define the TC/211 defined UML package in which the UML class is defined. Since the IHO Standards and this Product Specification make use of classes derived directly from the ISO Standards this convention is also followed here. In the IHO Standards the class names are identified by the name of the Standard, such as "S100" as the prefix optionally followed by the bialpha prefix derived from ISO. For the classes defined in this Product Specification the prefix is *"S104".* In order to avoid having multiple classes instantiating the same root classes, the ISO classes and S-100 classes have been used where possible; however, a new instantiated class is required if there is a need to alter a class or relationship to prevent a reverse coupling between the model elements introduced in this document and those

defined in S-100 or the ISO model.

Table 1-2 – Sources of externally defined UML classes

Prefix	Standard	Package
CI	ISO 19115-1	Citation and Responsible Party
CV	ISO 19123	Coverage Core & Discrete Coverages
DQ	ISO 19157	Data Quality Information
DS	ISO 19115-1	Metadata Application Information
EX	ISO 19115-1	Metadata Extent information
IF	ISO 19129	Imagery Gridded and Coverage Data Framework
LI	ISO 19115-1	Linage Information
MD	ISO 19115-1	Metadata entity set information
MI	ISO 19115-2	Metadata entity set imagery
S100	IHO S-100	IHO Universal Hydrographic data Model
SC	ISO 19111	Spatial Referencing by Coordinates
SD	ISO 19130	Sensor Data
S101	IHO S-101	IHO Electronic Navigational Chart Product Specification
S102	IHO S-102	IHO Bathymetric Surface Product Specification
S111	IHO S-111	IHO Surface Currents Product Specification

1.5 General data product description

This clause provides general information regarding the data product.

Title: Water Level Information for Surface Navigation

Abstract: Encodes information and parameters for use in making a tidal and water level product.

Content: Describes the tidal and water level data contained in the product. The specific content is defined by the Feature Catalogue and Schema.

Spatial Extent: **Description:** Areas where tidal and water level information is available

East Bounding Longitude: 180

West Bounding Longitude: -180

North Bounding Latitude: 90

South Bounding Latitude: -90

Purpose: The data shall be used to produce a dataset to be used for dynamic water level applications, including an ECDIS.

1.6 Data Product Specification metadata

This information uniquely identifies this Product Specification and provides information about its creation and maintenance. For further information on dataset metadata see clause 12.

Title: Water Level Information for Surface Navigation

S-100 Version: 4.0.0

NOTE: Efforts were made to accommodate known S-100 Edition 5.0.0 draft

at time of publication.

S-104 Version: 1.0.0

Date: August 2021

Language: English

Classification: Unclassified

Contact: International Hydrographic Organization.
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URL: https://iho.int

Identifier: S-104

Maintenance: Changes to the Product Specification S-104 are coordinated by Tides, Water Level and Currents Working Group (TWCWG) of the IHO and made available via the IHO Publications website. Maintenance of the Product Specification must conform to IHO Technical Resolution 2/2007 (revised 2010). This Specification will be a standing agenda item for TWCWG meeting with clarifications, revisions and New Editions released as required. A New Edition will be released every 5-10 years depending on technological advances.

1.7 IHO Product Specification maintenance

1.7.1 Introduction

Changes to S-104 will be released by the IHO as a New Edition, revision, or clarification.

1.7.2 New Edition

New Editions of S-104 introduce significant changes. *New Editions* enable new concepts, such as the ability to support new functions or applications, or the introduction of new constructs or data types. *New Editions* are likely to have aRevision

1.7.3 Revision

Revisions are defined as substantive semantic changes to S-104. Typically, *revisions* will change S-104 to correct factual errors; introduce necessary changes that have become evident as a result of practical experience or changing circumstances. A *revision* must not be classified as a clarification. *Revisions* could have an impact on either existing users or future users of S-104. All cumulative clarifications must be included with the release of approved *revisions*.

Changes in a *revision* are minor and ensure backward compatibility with the previous versions within the same Edition. Newer *revisions*, for example, introduce new features and attributes. Within the same Edition, a dataset of one version could always be processed with a later version of the Feature and Portrayal Catalogues.

In most cases a new Feature or Portrayal Catalogue will result in a revision of S-104.

1.7.4 Clarification

Clarifications are non-substantive changes to S-104. Typically, *clarifications*: remove ambiguity; correct grammatical and spelling errors; amend or update cross references; insert improved graphics in spelling, punctuation and grammar. A *clarification* must not cause any substantive semantic change to S-104.

Changes in a *clarification* are minor and ensure backward compatibility with the previous versions within the same Edition. Within the same Edition, a dataset of one *clarification* version could always be processed with a later version of the Feature and Portrayal Catalogues, and a Portrayal Catalogue

can always rely on earlier versions of the Feature Catalogue.

Changes in a *clarification* are minor and ensure backward compatibility with the previous versions.

1.7.5 Version numbers

The associated version control numbering to identify changes (n) to S-104 must be as follows:

New Editions denoted as **n**.0.0

Revisions denoted as n.**n**.0

Clarifications denoted as n.n.**n**

2 Specification Scopes

This Product Specification outlines the types of water level products from the national Hydrographic Office (HO) or authorised producer, to the end user. The data may be historical observation, real-time observation, astronomical prediction, analysis or hybrid method, hindcast or forecast models. Requirements for data and metadata are provided. The data product is:

a) Time series product, including series of water level heights relative to a vertical datum and the water level trend (rising, falling, etc). The data products are:

i) Single point product – provision of water level information for a single point in the traditional graphic display mariners are familiar with from hard copy publications and digital tide tables; and

ii) Gridded data product – provision of water level information for a defined region as a surface, allowing any grid point to be queried as per a traditional single point.

Scope ID: Global

Level: 006- series

Level name: Water Level Dataset

3 Dataset Identification

Title: Water Level Data Product

Alternate Title: None

Abstract: This data product is a file containing water level data for a particular geographic region and set of times, along with the accompanying metadata describing the content, variables, applicable times, locations and structure of the data product. Water level data is the height of the water observed or mathematically-predicted. The data may consist of water level at a small set of points where observations or predictions are available or may consist of numerous points organised in a grid as from a hydrodynamic model forecast.

Topic Category: Producing authority to choose the most appropriate from the list below:

Concept Name	ISO 19115-1 Topic Category Number	ISO 19115-1 Topic Category Code	Definition
Elevation	006	elevation	Height above or below mean sea level Examples: Altitude, bathymetry, digital elevation models, slope, derived products

Inland Waters	012	inlandWaters	Inland water features, drainage systems and their characteristics Examples: Rivers and glaciers, salt lakes, water utilization plans, dams, currents, floods, water quality, hydrologic information
Oceans	014	oceans	Features and characteristics of salt water bodies (excluding inland waters) Examples: Tides, tsunamis, coastal information, reefs

Geographic Description: Areas specific to water navigation

Spatial Resolution: The spatial resolution, or the spatial dimension of the earth covered by the size of a grid matrix cell (nominal ground sample distance), varies according to the model adopted by the producer.

Purpose: Water level data is intended to be used as stand-alone data or as a layer in an ENC.

Language: English

Classification: Data can be classified as one of the following:
Unclassified
Restricted
Confidential
Secret
Top Secret
Sensitive but Unclassified
For Official Use Only
Protected
Limited Distribution

Spatial Representation Type: Coverage

Point of Contact: Producing Authority.

Use Limitation: Invalid over land

4 Data Content and Structure

4.1 Introduction

This section discusses the Application Schema, which is described in UML; the Feature Catalogue; dataset types, in which there is an extensive discussion of the water level data; dataset loading and unloading; and geometry.

Water level data consist of one basic type:

1. A time series of water level height and trend relative to a vertical datum. The data can be represented for either a single point (that is, one geographic location) or for an array of points contained in a grid. Time and datum information are contained in the metadata.

4.2 Application Schema

This Application Schema is expressed in UML. The single feature type, **WaterLevel**, is depicted in Figure 4-1 below. The details of the Application Schema are given in Annex C, which also describes its relation to the conceptual model of coverage data described in ISO 19123 and S-100 Part 8.

Figure 4-1 - Water Level Feature

4.3 Feature Catalogue

4.3.1 Introduction

The S-104 Feature Catalogue describes the feature types, information types, attributes, attribute values, associations and roles which may be used in the product. See Annex D – Feature Catalogue.

The S-104 Feature Catalogue is available in an XML document which conforms to the S-100 XML Feature Catalogue Schema and can be downloaded from the IHO website.

4.3.2 Feature types

4.3.2.1 Geographic

Geographic (geo) feature types form the principal content of S-104 and fully defined by their associated attributes.

4.3.2.2 Meta

Meta features contain information about other features within a data set. Information defined by meta features override the default metadata values defined by the data set descriptive records. Meta attribution on individual features overrides attribution on meta features.

4.3.3 Feature relationships

A feature relationship links instances of one feature type with instances of the same or a different feature type. There are three common types of feature relationship: Association; Aggregation; and Composition. In S-104 there are no relationships used.

4.3.4 Attributes

S-100 defines attributes as either simple or complex. S-104 uses three types of simple attributes, listed in Table 4-1 below. There are no complex attributes used in S-104.

Table 4-1 - Simple feature attribute types.

Type	Definition
Enumeration	A fixed list of valid identifiers of named literal values
Real	A signed Real (floating point) number consisting of a mantissa and an exponent
Date and Time	A DateTime is a combination of a date and a time type. Character encoding of a DateTime shall follow ISO 8601:1988 EXAMPLE 19850412T101530

4.3.5 Spatial Quality

Spatial quality attributes (Figure 4-2) are encoded as horizontal and vertical uncertainty values. In S-100 Edition 4.0.0 they are encoded at the feature type level (see Figure 4-2 and Table 12-4), which means they apply uniformly to all **WaterLevel** feature instances in the dataset and uniformly to all locations (grid points or station locations).

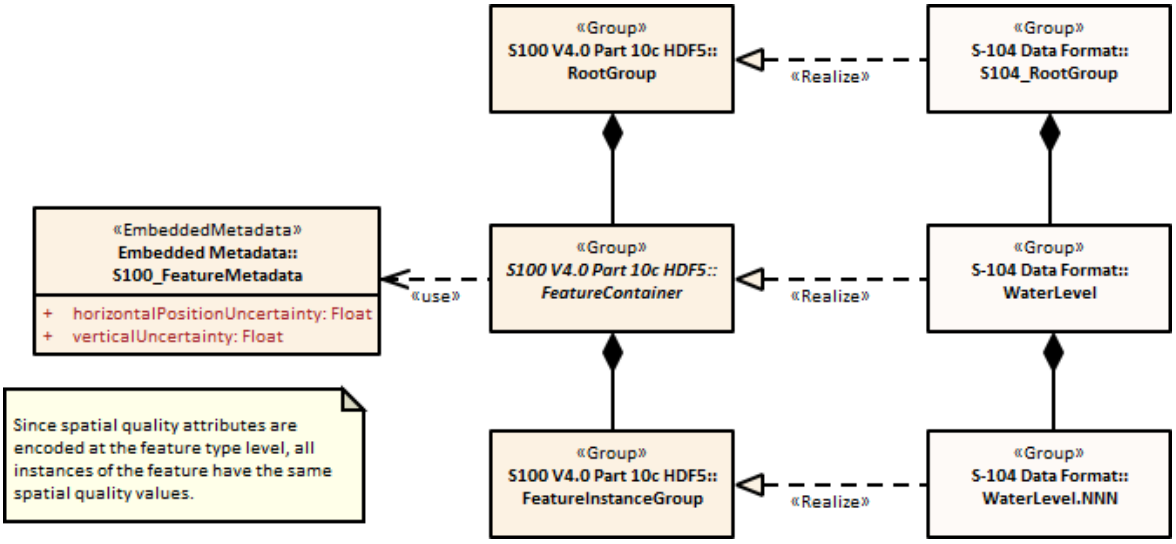


Figure 4.2 – Spatial Quality

Note that uncertainty in water levels pertains to the quality of data values, not to spatial quality as that term is used in S-100, and is encoded differently and at the instance level (see Table 10-2 and clause 10.2.2.4).

Water levels are usually defined at one or more individual locations, so spatial quality applies to these locations.

NOTE: The Spatial Quality information type used in S-101 and other products is not used in this Edition of S-104 even for station-based data formats. Complete specification and implementation of Spatial Quality information types will be addressed in a later Edition of S-104.

4.4 Dataset types

Datasets for S-104 include one basic type of dataset:

1. HDF5 files, which may contain:

   (a) Time series of predicted or observed water level heights and trends at one or more fixed stations; and

   (b) Gridded hydrodynamic model forecast fields.

4.5 Spatial Schema

4.5.1 Coverages

For an ECDIS, water level data are formatted in two ways: Arrays of points contained in a regular grid; and sets of points not described by a regular grid. Further details on the data products are given in clause 10 – Data Product Format.

Water level data are categorised as follows, based on the data source:

1. Observed, predicted, or forecasted values at a number of stationary locations;
2. Computed values (for example hindcast or forecast data from hydrodynamic models) arranged in a regular grid; and
3. Values at multiple locations but not in a regular grid.

The three categories of water level data have structures that can be described by three S-100 coverages: S100_PointCoverage; S100_GridCoverage; and S100_TINCoverage (S-100 Edition 4.0.0, clause 8-7.1). In addition the ISO 19123 class CV_ReferenceableGrid is used for ungeorectified

gridded data[1].

Grid Coverage: The class S100_GridCoverage represents a set of values assigned to the points in a two-dimensional grid. Attributes include *interpolationType*, *dimension*, *axisNames*, *origin*, *coordinateReferenceSystem*, *offsetVectors*, *origin*, *extent*, *sequencingRule*, *startSequence*, and *rangeType*.

Point Coverage: The class S100_PointCoverage represents a set of values, such as water level height and trend values, assigned to a set of arbitrary X,Y points. Each point is identified by a horizontal coordinate geometry pair (X,Y) and assigned one or more values as attribute values. These values are organised in a record for each point. Attributes include *domainExtent*, *rangeType*, *metadata*, *commonPointRule*, *geometry*, and *value*.

TIN Coverage: A TIN coverage is a type of CV_ContinousCoverage[2] as described in ISO 19123. The attribute values in the value record for each CV_GeometryValuePair represent values for each of the vertex corners of the triangle. Any additional attributes related to a TIN triangle may be described as attributes of CV_ValueTriangle.

The types of water level data and their corresponding coverages are shown in Table 4-2 below.

Table 4-2 - Water level data types and their coverages

Type of Data	Coverage
Time series data at one or more stationary locations at one or more times, organised by time	S100_PointCoverage
Time series data at one or more stationary locations at one or more times, organised by location	S100_PointCoverage
Regularly-gridded data at one or more times	S100_GridCoverage
Ungeorectified gridded data at one or more times	CV_ReferenceableGrid[1]
TIN coverage at one or more times	S100_TINCoverage

The spatial representations in S-104 are encoded using the implementation specification in S-100 Part 10c, which realises S-100 Part 8 and ISO 19123 conceptual models. The relationships are depicted in Figure 4-3 below.

[1] Ungeorectified gridded data is included in S-100 Edition 4.0.0 Part 8 (Clauses 8-7.2 and 8-8.1.4), but S-100 Part 8 does not define a corresponding S-100 class in its conceptual model.

[2] S-100 Edition 4.0.0, clause 8-7.1.3 incorrectly says it is a subtype of CV_ContinuousQuadrilatralGridCoverage, but Figure 8-22 in the same clause correctly depicts it as a subclass of CV_TINCoverage, which in turn is a subclass of CV_ContinuousCoverage.

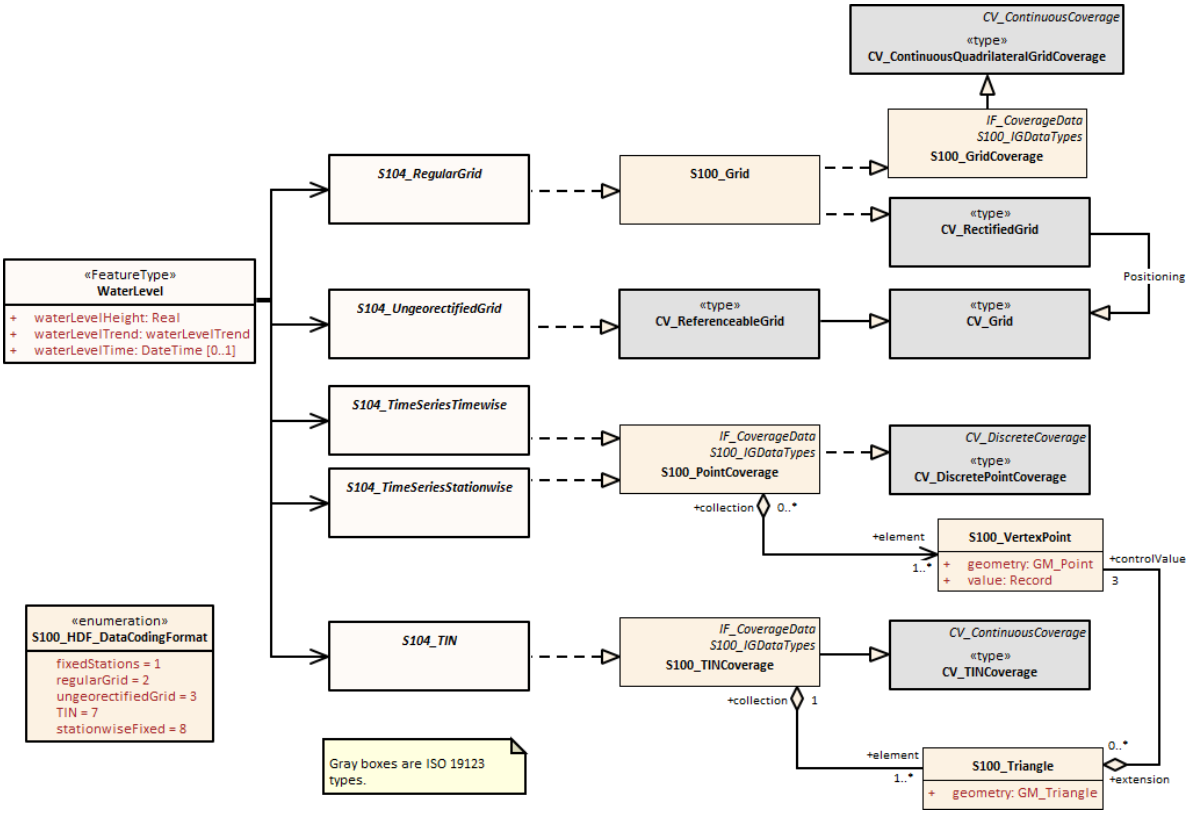


Figure 4-3 - Coverages and their realisation from S-100 Part 8 and ISO 19123

5 Coordinate Reference Systems (CRS)

To define the location of features using the S-100 Standard and Framework, one first needs to define a Coordinate Reference System (CRS). A Coordinate Reference System in two dimensions uses a coordinate pair, either X and Y for a Cartesian system or latitude and longitude for a geodetic/geographic system to define the location of a feature on a 2-D grid. However, if one wants to plot features in a 3-dimensional Coordinate Reference System, where we now want to include depths on a nautical chart or elevations on a map, one needs to assign the depth or elevation as the third component. For Cartesian systems, one would use X, Y, Z as the triplet; or for geodetic/geographic systems one would use latitude, longitude and height. The height can be the ellipsoid height or any of the other vertical references (see Vertical Reference System below). Geodetic/geographic coordinates are more intuitive for positioning and navigation applications on or near the Earth's surface while Cartesian coordinates are more appropriate if vectors are needed to accurately illustrate a graphical relationship between two or more points. If geodetic/geographic coordinates are specified, then the IHO recommends using the latest realisation of the World Geodetic System of 1984 (WGS 84).

5.1 Horizontal reference system

For products based on the S-100 Standard and Framework, including this standard for S-104 products, the geodetic/geographic coordinate reference system must be of the form EPSG:xxxx (WGS 84). The generic form/code for the WGS 84 frame is EPSG:4326 while the latest and most widely adopted realisation of the WGS 84 reference frame is EPSG:9057. The full reference to EPSG can be found at https://epsg.org/home.html and other EPSG references for recent WGS 84 realisations are given below:

WGS 84 (generic)	ESPG:4326	
WGS 84(G1762)	EPSG:9057	Valid epoch 2005.0
WGS 84(G1674)	EPSG:9056	Valid epoch 2005.0

WGS 84(G1150) EPSG:9055 Valid epoch 2001.0

Coordinate Reference System: EPSG:9057 (WGS 84) *latest

Datum: WGS 84 defined by NGA

Projection: None

Horizontal Units: Degrees, minutes and seconds or decimal degrees

Coordinate Reference System Registry: EPSG Geodetic Parameter Registry

Date type (according to ISO 19115-1): 002 - publication

Responsible party: International Association of Oil and Gas Producers (IOGP)

5.2 Vertical reference system

For positioning and navigation applications, it is desirable to accurately plot depths, bathymetry, elevations and terrain on nautical charts and maps using one or more vertical reference systems. To do so, a vertical datum is defined and serves as a reference surface for vertical positions. Vertical datums come in three categories: 1) Those based on Mean Sea Level (MSL); 2) Tidal datums; and 3) 3-D datums (ellipsoid), which are realised through space-based systems such as GPS. Vertical datums can be regional (geoid, tidal, chart) or global (ellipsoid) in nature. The vertical axis of a vertical reference system is defined upwards (away from the Earth's centre) from its origin (EPSG code 6499) or downwards (EPSG code 6498) and is perpendicular to the horizontal surface where the observations or measurements are taken. As an example, a positive value for the level of water above the vertical datum in a vertical reference system with upward orientation (EPSG code 6499) means that the water level is above the vertical reference surface. For nautical charts, depths and tides are measured relative to a chart datum such as Lowest Astronomical Tide (LAT) or Mean Lower Low Water (MLLW).

Coordinate reference system: Vertical component of a 3-D reference system

Datum: Chart, tidal, geoid, ellipsoid (WGS 84)

Projection: None

Horizontal Units: metres

Coordinate reference system registry: EPSG Geodetic Parameter Registry

Date type (according to ISO 19115-1): 002 - publication

Responsible party (vertical datums): National hydrographic and geodetic agencies

The vertical coordinate system is defined by four components. The first component defines the positive vertical direction (either an upward height or a downward depth). The second refers to the base or origin (that is, the zero value) of the vertical coordinate. If the base is a tidal datum, the specific datum is defined from either the S-100 list of vertical datums (for example, LAT, MLLW, MSL, etc) or the EPSG list. Finally, the specific datum number from the appropriate list is given. The components are summarised in Table 5-1 below.

Table 5-1 - Attributes describing the vertical coordinate system

Name	Remarks
Vertical Coordinate System	EPSG Code; Allowed Values • 6498 (Depth – Metres – Orientation Down) • 6499 (Height – Metres – Orientation Up)
Vertical Coordinate Base	1 - Sea Surface 2 - Vertical Datum 3 - Sea Bottom

Vertical Datum Reference	Only if verticalCoordinateBase = 2 1 – S-100 vertical datum 2 – EPSG
Vertical Datum	Only if verticalCoordinateBase = 2 If verticalDatumReference = 1 this is a value from S100_VerticalAndSoundingDatum If verticalDatumReference = 2 this is an EPSG code for vertical datum

The vertical datum must be consistent with the bathymetric CRS in S-102.

5.3 Temporal reference system

The temporal reference system is the Gregorian calendar for date and UTC for time. Time is measured by reference to TM_Calendar dates and TM_Clock time in accordance with ISO 19108:2002, Temporal Schema, clause 5.4.4. A date variable will have the following 8-character format: *yyyymmdd*. A time variable will have the following 7-character format: *hhmmssZ*. A date-time variable will have the following 16-character format: *yyyymmddThhmmssZ*

6 Data Quality

6.1 Introduction

Quality of water level data for navigation consists of quality of the observed/predicted/forecast data, quality of the positional data, and quality of the time stamp. Quality of the observed data depends on the accuracy of the water level gauges and their processing techniques; and is normally available in field survey reports or quality controlled analyses. Quality of predicted/forecast data depends on quality, timeliness and spatial coverage of the input data as well as the mathematical techniques. Temporal accuracy for observational data is normally available in field survey reports or quality controlled analyses. Temporal accuracy for predicted/forecast data is normally described in technical reports.

6.1.1 Data quality metadata (informative)

The data quality information will list the following:

For Single station data product:

1) Port Type- a) Standard/major or b) Secondary/minor;
2) Sigma confidence of predictions/models; or
3) Instrument measuring accuracy for observed.

For Gridded data product:

1) Sigma confidence of predictions/model.

6.1.2 Data quality elements and data quality measures

Data quality allows users and user systems to assess fitness for use of the provided data. Data quality measures and the associated evaluation are reported as metadata of a data product. This metadata improves interoperability with other data products and provides usage by user groups that the data product was not originally intended for. The secondary users can make assessments of the data product usefulness in their application based on the reported data quality measures.

For S-104 the following Data Quality Elements have been included:

- Conformance to this Product Specification;
- Intended purpose of the data product;
- Completeness of the data product in terms of coverage;
- Logical consistency;
- Positional uncertainty and accuracy;
- Thematic accuracy;

- Temporal quality;
- Aggregation measures;
- Validation checks or conformance checks including:
  - General tests for dataset integrity;
  - Specific tests for a specific data model.

Table 6-1 below indicates which of the data quality measures recommended in S-97 Part C have been identified as applicable to S-104. Columns 1-4 are taken as-is from S-97; the contents of column 5 are from S-97, annotated with whether the measure applies to S-104. Note that for attributes which allow fill values (see clause 10.2.2.2) the presence of a fill value is not counted as an error for the purposes of the data quality measures.

Table 6-1 - Quality measures applicable to S-104 (from S-97 Part C Clause 7)

Data quality measure	Definition	DQ measure / description	Evaluation scope	S104 applicability
Completeness / Commission	Excess data present in a dataset, as described by the scope.	numberOfExcessItems / This data quality measure indicates the number of items in the dataset, that should not have been present in the dataset.	dataset/data set series	Yes (All S-100 based PS)
Completeness / Commission	Excess data present in a dataset, as described by the scope.	numberOfDuplicateFeatureInstances / This data quality measure indicates the total number of exact duplications of feature instances within the data.	dataset/data set series	Yes (All S-100 based PS)
Completeness / Omission	Data absent from the dataset, as described by the scope.	numberOfMissingItems / This data quality measure is an indicator that shows that a specific item is missing in the data.	dataset/data set series / spatial object type	Yes (All S-100 based PS) See clause 6.2 below
Logical Consistency / Conceptual Consistency	Adherence to the rules of a conceptual schema.	numberOfInvalidSurfaceOverlaps / This data quality measure is a count of the total number of erroneous overlaps within the data. Which surfaces may overlap and which must not is application dependent. Not all overlapping surfaces are necessarily erroneous.	spatial object / spatial object type	No (S104 does not define vector surface features) (Applies to PS with geometric surfaces.)
Logical Consistency / Domain Consistency	Adherence of the values to the value domains.	numberOfNonconformantItems / This data quality measure is a count of all items in the dataset that are not in conformance with their value domain.	spatial object / spatial object type	Yes (All S-100 based PS)
Logical Consistency / Format Consistency	Degree to which data is stored in accordance with the physical structure of the data set, as described by the scope	physicalStructureConflictsNumber / This data quality measure is a count of all items in the dataset that are stored in conflict with the physical structure of the dataset.	dataset/data set series	Yes (All S-100 based PS)

Data quality measure	Definition	DQ measure / description	Evaluation scope	S104 applicability
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	rateOfFaultyPointCurveConnections / This data quality measure indicates the number of faulty link-node connections in relation to the number of supposed link-node connections. This data quality measure gives the erroneous point-curve connections in relation to the total number of point- curve connections.	spatial object / spatial object type	No (Applies only for PS with curves.)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfMissingConnectionsUnder shoots / This data quality measure is a count of items in the dataset within the parameter tolerance that are mismatched due to undershoots.	spatial object / spatial object type	No (Applies only for PS with curves.)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfMissingConnectionsOvers hoots / This data quality measure is a count of items in the dataset within the parameter tolerance that are mismatched due to overshoots.	spatial object / spatial object type	No (Applies only for PS with curves.)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfInvalidSlivers / This data quality measure is a count of all items in the dataset that are invalid sliver surfaces. A sliver is an unintended area that occurs when adjacent surfaces are not digitised properly. The borders of the adjacent surfaces may unintentionally gap or overlap to cause a topological error.	dataset/data set series	No (Applies to PS with geometric surfaces.)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfInvalidSelfIntersects / This data quality measure is a count of all items in the dataset that illegally intersect with themselves.	spatial object / spatial object type	No (Applies to PS with curves / geometric surfaces.)
Logical Consistency / Topological Consistency	Correctness of the explicitly encoded topological characteristics of the dataset, as described by the scope.	numberOfInvalidSelfOverlap / This data quality measure is a count of all items in the dataset that illegally self- overlap.	spatial object / spatial object type	No (Applies to PS with curves / geometric surfaces.)
Positional Accuracy / Absolute or External Accuracy	Closeness of reported coordinative values to values accepted as or being true.	Root Mean Square Error / Standard deviation, where the true value is not estimated from the observations but known a priori.	spatial object / spatial object type	Yes, for data coding formats 1 and 8. (PS with objects that have coordinative values associated.)

Data quality measure	Definition	DQ measure / description	Evaluation scope	S104 applicability
Positional Accuracy / Vertical Position Accuracy	Closeness of reported coordinative values to values accepted as or being true.	linearMapAccuracy2Sigma / Half length of the interval defined by an upper and lower limit in which the true value lies with probability 95%.	spatial object / spatial object type	Yes. (PS with objects that have a vertical coordinative values associated.)
Positional Accuracy / Horizontal Position Accuracy	Closeness of reported coordinative values to values accepted as or being true.	linearMapAccuracy2Sigma / Half length of the interval defined by an upper and lower limit in which the true value lies with probability 95%.	spatial object / spatial object type	Yes. (PS with objects that have a horizontal coordinative values associated.)
Positional Accuracy / Gridded Data Position Accuracy	Closeness of reported coordinative values to values accepted as or being true.	Root mean square error of planimetry / Radius of a circle around the given point, in which the true value lies with probability P.	spatial object / spatial object type	Yes, for data coding formats 2, 3. (Applies to PS with objects that have a gridded coordinative values associated.)
Temporal Quality / Temporal Consistency	Consistency with time.	Correctness of ordered events or sequences, if reported.	dataset/data set series / spatial object type	Yes, for time series features. (Applies to PS with objects that have a time value associated.)
Thematic Accuracy / ThematicClassificationCorrectness	Comparison of the classes assigned to features or their attributes to a universe of discourse.	miscalculationRate / This data quality measure indicates the number of incorrectly classified features in relation to the number of features that are supposed to be there. [Adapted from ISO 19157] This is a RATE which is a ratio, and is expressed as a REAL number representing the rational fraction corresponding to the numerator and denominator of the ratio. For example, if there are 1 items that are classified incorrectly and there are 100 of the items in the dataset then the ratio is 1/100 and the reported rate = 0.01.	dataset/data set series / spatial object type	Yes (All S-100 based PS.)
Aggregation Measures / AggregationMeasures	In a data Product Specification, several requirements are set up for a product to conform to the Specification.	DataProductSpecificationPassed / This data quality measure is a boolean indicating that all requirements in the referred data Product Specification are fulfilled.	dataset/data set series / spatial object type	Yes (PS that require a complete pass of all elements of a dataset/dataset series / spatial object types.)

Data quality measure	Definition	DQ measure / description	Evaluation scope	S104 applicability
Aggregation Measures / AggregationMeasures	In a data Product Specification, several requirements are set up for a product to conform to the specification.	DataProductSpecificationFailRate / This data quality measure is a number indicating the number of data Product Specification requirements that are not fulfilled by the current product/dataset in relation to the total number of data Product Specification requirements.	dataset/data set series / spatial object type	Yes (PS that require a complete pass of all elements of a dataset/dataset series / spatial object types.)

6.2 Completeness

A time series is complete when there is a value or a null indicator at every time in the series. A water level coverage data set is complete when the grid or point set coverage value matrix contains height value or fill (missing) value for every vertex point defined in the grid; and when all of the mandatory associated metadata is provided. See Annex F – Validation Checks.

6.3 Assessment of data quality

The prescribed precision (see Annex A – Data Classification and Encoding Guide) of water level (0.01 m) is close to the perceived accuracy of the data.

Important factors in the quality of water level information for navigation consists of the quality of:

- The observed data;
- The predicted/forecast data;
- The positional data; and
- The time stamp.

Factors determining the accuracy of the data are shown in Table 6-2 below. Information of the quality of the components of the data is normally available in field survey reports, Quality Control analyses or other technical reports.

Table 6.2 - Data types and accuracy factors

Type of Data	Factors Influencing Accuracy
Observed water level	Accuracy of the sensors Processing techniques
Predicted/forecast Water level	Quality of input data Timeliness of input data Mathematical modelling techniques Accuracy of harmonic constants
Horizontal Position	Accuracy of geolocation techniques Model grid accuracy
Vertical Position	Accuracy of vertical datum
Time stamp	Sensor accuracy Data time tagging accuracy

Data quality measures for the entire data set are described in Table 12-4. These include, *horizontalPositionUncertainty*, *verticalUncertainty*, and *timeUncertainty*. The additional data quality measure for uncertainty in *waterLevelHeight* is described in clause 10.2.2.4.

6.4 Validation checks

Validation checks (in development) are intended for production systems designed to produce S-104 Water Level Information datasets. The checks can be administered at any time during the production phase. They can also be applied downstream in the distribution and end user systems to test the conformance of a dataset to the format rules specified in S-100 Part 10c and the S-104 Product Specification.

For example, checks will be made for: Inclusion of mandated variables; variable values being within accepted ranges; inclusion of optional values when required; matches between number of array elements and array dimension specifications; timeliness of data, etc. Error severity may be, for example, that the dataset is unusable; that the dataset is of degraded utility but otherwise safe to use; or that dataset has one or more small and inconsequential inconsistencies.

Fill values must be considered as allowed values for attributes which allow them (see clause 10.2.2.2), even though the fill value will be outside the allowed range in the Feature Catalogue.

7 Data Capture and Classification

The water level product contains data processed from sensors or derived from the output from mathematical models. In most cases, the data collected by the Producing Authority must be translated, sub-setted, reorganised, or otherwise processed to restructure into a usable data format.

7.1 Data sources for water levels

Water level data comes primarily from a few specific sources: observations, astronomical predictions, analyses, and forecast models. When such data are produced and quality-controlled by an approved Producing Authority (IHO Resolutions A6.3 & A6.9, S-62), they are suitable for inclusion in the Water Level data product.

Observational Data: Observational water level data comes initially from *in situ* sensors in the field (for example, tide gauges deployed along a channel) and are monitored by the data collecting authority. After data acquisition, the data are quality controlled and stored by the Producing Authority. Some of the observed data may be available for distribution within minutes of being collected and are described as being “in real time”. Other data may be days or years old, and are called historical data.

Astronomical Predictions: Astronomical predictions are produced when a sufficiently long time series of observed water level has been obtained and the data has been harmonically analysed by the Producing Authority to produce a set of amplitude and phase constants. The harmonic values can then be used to predict the astronomical component of the water level as a time series covering any desired time interval. Astronomical predictions can also be produced by other proven methods of tidal analysis. Data available for single stations or numerous, may be arranged by the Producing Authority into a gridded field.

Analysed and Hybrid Values: Analysed water level values may be derived from sea-surface topography, data assimilation, statistical correlations or other means. A hybrid method combines two of or more approaches.

Hindcast and Forecast Data: Hydrodynamic models numerically solve a set of fluid dynamic equations in two or three dimensions; and rely on observational data, including water levels and winds, to supply boundary conditions. Model grids may be either regular or irregular. Such models are often run several times per day and can be a hindcast or a forecast. The hindcast is a model simulation that attempts to recreate present conditions by using the most recent observational data, while a forecast is a simulation made for many hours into the future using predicted winds, water levels, etc. The results are saved for a limited number of times, and are stored as arrays that derive from the model’s grid. These models and methods are developed, run and monitored by the Hydrographic Office.

These descriptions are summarised in Table 7-1 below.

Table 7-1 - Types of water level data, based on the source of the data

Type	Name	Description
1	Historical observation	Observation made hours, days, etc, in the past
2	Real-time observation	Observation no more than a few minutes old
3	Astronomical prediction	Value computed using harmonic analysis or other proven method of tidal analysis
4	Analysis or hybrid method	Calculation by tatistical or other indirect methods, or a combination of methods
5	Hindcast	Gridded data from a two- or three-dimensional dynamic simulation of past conditions using only observed data for boundary forcing, via statistical method or combination
6	Forecast	Gridded data from a two- or three-dimensional dynamic simulation of future conditions using predicted data for boundary forcing, via statistical method or combination

7.2 The Production Process

Nearly all available information on water level from the Producer must be reformatted to meet the standards of this Product Specification (Figure 10-1 - the S-104 format). This means:

(a) Populating the carrier metadata block (clause 12.3) and values group attributes (Table 12-6) with the relevant metadata; and

(b) Reorganizing the water level data when using the encoding rules (see clause 10 and Annex E–HDF5 Encoding for Gridded Data).

7.2.1 Metadata

Metadata is derivable from the information available from the approved authority. The following variables will require additional processing:

- The bounding rectangle is computable from either the distribution of stations or nodes, or from grid parameters. Note that the bounding box is encoded in both carrier metadata at the root group level and in the discovery metadata block (attribute *dataCoverage*) in the Exchange Catalogue, and must be the same in both places.
- Position uncertainties may be available from the approved authority's metadata;
- Water level uncertainty may be available from the prediction or forecast model, specification of the water level gauge or calculated from observations;
- If a previously issued data file is being cancelled or replaced, the *replacedData* and/or *dataReplacement* attributes in the Exchange Catalogue must be populated;
- The metadata file name in carrier metadata (attribute *metadata* in Table 12-3) must be populated with the name of the ISO 19115-1 metadata file;

NOTE: Exchange Sets to S-104 Edition 1.0.0 may not include an ISO metadata file, in which case the attribute *metadata* in Table 12-3 may be encoded as the empty string. Alternatively, a minimally populated ISO metadata file may be included in the Exchange Set. The discovery metadata block in the Exchange Catalogue should also reference this file as provided in the S-100 XML Schema for the Exchange Catalogue.

All mandatory metadata in carrier metadata (clause 12.3) must be populated with appropriate values. In cases where the attribute is mandatory but inapplicable, the appropriate fill or null value described in clause 12.3 must be used.

Similarly, when the Exchange Set is being compiled, all mandatory metadata or information fields in the discovery metadata and Exchange Catalogue (clauses 12.1 and 12.2) must be populated. In cases where the attribute is mandatory but inapplicable, or the value is unknown or not included in the relevant enumeration list, the appropriate fill or null value described must be used.

NOTE (informative): Running the validation checks (Annex F) should detect missing metadata, but in Edition 1.0.0 the checks are yet to be defined and automated; and visual checking of metadata may be necessary. The Tables in clauses 12.2 and 12.3 describe the mandatory requirements and allowed values.

7.2.2 Water level data

Observational water level and tidal water level predictions at a single location and gridded forecast data must normally be reformatted to fit the S-104 Standard. The following may require additional calculations:

- For gridded data. If a land mask array is included, the mask value is substituted into the gridded values as appropriate (see Annex A, clause A.2.1).
- Time stamps must be encoded as UTC.

7.2.3 Validation (informative)

Dataset and Exchange Set validation tests must be passed before the Exchange Set is published.

For numeric attributes, the fill value will be outside the allowed range of values specified in the Feature Catalogue, if any. Similarly, for enumerations, the fill value will not be a member of the enumeration as listed in the Feature Catalogue. Validation checks for datasets must allow for the presence of fill values.

NOTE: Validation checks are not an essential component at S-100 Readiness Level 1 and are not described in S-104 Edition 1.0.0, for which reason this sub-clause is designated “informative” in this Edition.

7.3 Guidance for chunking and compression (informative)

Chunking affects both dataset size and optimised data retrieval, the latter in the sense of how an ECDIS would most efficiently retrieve relevant chunks of a dataset when a user pans and zooms.

Product Specification developers may desire to assess typical profiles and volumes of data for their datasets and develop guidance for the use of chunking and compression in their data products. Common practice is provided below. Product teams should assess its applicability to their own products and use, omit, and adapt it accordingly.

The development of guidance on how to optimally and correctly do chunking and compression is ongoing; however, current best practice is:

- For gridded data with 2 dimensions, for example dataCodingFormat = 2 (regular grids), choosing roughly-square rectangular chunk sizes will result in better performance when reading subsets of the data, and will probably result in better compression (one reason being that because NoData areas tend to be clustered together geographically, geographically-tiled chunks will compress out all those repetitive values).
- Producers may use "auto-chunking", where this functionality is available (for example, in the production toolset’s HDF5 library). Auto-chunking will choose chunk sizes automatically.
- Choosing the right chunk sizes depends on the type of data and what the use of chunking is trying to accomplish. Auto chunking is more ideal for compression and is less ideal for time-critical access patterns.

Auto-chunking means different datasets may be chunked differently, and the chunking HDF5 attributes in S-100 Part 10c will not apply if the HDF5 file contains different HDF5 datasets. Applications cannot expect a standardised chunk size and will have to handle whatever chunk sizes they encounter in datasets.

If auto-chunking is used, the related mandatory chunking attribute in Group_F (see S-100 Edition 4.0.0 Part 10c. Table 10c-8; and clause 10.2.2.2 in this Product Specification) must be coded with chunk size as the string ‘varies’ (without quotes).

Data producers should note experiences from preliminary testing:

- 2D arrays - Need to be chunked based on how the data is read. If applications need to hold the entire grid in memory, use no chunking, otherwise estimate a reasonable size for data extraction. It is probably better to have the chunking set a little smaller than to make it too big,

for I/O purposes.

- 1D arrays – Do not chunk unless they are enormous (for S-104 this is not an issue since clause 11.2.1 limits datasets to well below the size where chunking matters).
- Given the relatively small sizes of datasets for S-104 (for example, 10 MB limit guidelines in clause 11.2.1) chunking will not be of great benefit in read performance for S-104.

Producers should determine the compression scheme that is optimal for their own use case, as needed.

8 Maintenance

Maintenance and Update Frequency: Water level is always moving, so more-or-less- continual revision or updating of the data is essential. For real-time observations, new values are periodically collected (for example, every 6 minutes). For a forecast, the entire field of water levels is created one or more times per day. New issues of real-time observations or forecasts should be considered updates.

Water level harmonic constant data are updated much less often, typically on an annual basis. Table 8-1 below summarises this information.

Table 8-1 - Typical update/revision intervals and related information for S-104 products produced by a single Producer.

Data types	Interval	Number of spatial locations	Number of time values per location
Astronomical Predictions	1 year	100 to 1,000	52560 (10 minute data) or 8,760 (hourly data)
Model Forecasts	6 hr	100,000 to 1,000,000	1 to 24
Real-time Observations	0.1 hr	1 to 10	1 to 240

Data Source: Data is produced by the Producing Authority through the collection of observed values, predicting astronomical tides, or running analysis or hindcast/forecast. This data is typically quality-controlled and reformatted to conform to file size limitations and the S-104 standard encoding.

Production Process: S-104 datasets, including the metadata and the coverages for water level, are updated by replacement of the entire data product. Producers routinely collect observational data and maintain an analysis and/or forecast capability. When new data becomes available (often several times per day), the data is reformatted and made available for dissemination.

9 Portrayal

9.1 Introduction

This section describes means of displaying water level data to support navigation, route planning and route monitoring. Three types of data are discussed in depth. The first is point data, which would apply to historical data, astronomical predictions, forecast/hindcast, and real-time data. The second is regularly gridded data, which would apply to analyses, hindcasts and forecasts. For gridded or point set data, the water level portrayal characteristics used for single-point data can be adapted to the display of data at multiple points.

For example, a point portrayal may be provided to display water level at significant locations such as where real-time observations are available. A gridded portrayal may be provided for voyage planning where a mariner's selection of routes may be influenced by water level at certain way points. Note that not all portrayal categories (point and gridded) may be available for all types of water level data (historical observations, real-time observations, astronomical predictions, and forecast total water level).

All recommended sizes are given assuming a minimum size ECDIS display of 270 by 270 mm or 864 by 864 pixels.

Three portrayal options are provided because of the different types of information that could be supplied.

The options listed below allow Data Producers to cater for the information that they have available for their countries. The intent is that the Mariner will want to use the data for route planning and real-time navigation.

NOTE: No XML Portrayal Catalogue is provided in S-104 Edition 1.0.0, and implementation of portrayal is not expected for S-104 Edition 1.0.0.

9.2 Display of Water Level at a Single Point

Portrayal of water level using single point data should be used in instances where the data source is a water level (for example, a historical or real-time water level measuring device) at a single geographic location. All text and line colour will be in black unless stated otherwise. The portrayal options are (1) a symbol at the location of the water level data source, (2) a text box containing information on the height, trend, etc, and (3) a graphic plot showing the height over time.

NOTE: All text and line colour will be in black unless stated otherwise.

9.2.1 Symbol

The water level point will be represented by symbol entered in the IHO Geospatial Information (GI) Registry (see Table 9-1).

Table 9-1 - Beta version of the tide station symbol in the IHO GI Registry

Symbol	Name	Definition
	TIDEHT01	Point for which tide height information is available

9.2.2 Text Box

The information displayed within a window (minimum of 100 x 100 pixels. See Figure 9-1 below) will be dependent on water level information type. See Table 9-2 for a breakdown of information.

Table 9-2 - Numerical information displayed at the location of a water level

Water Level Type	Information Displayed
All types	Station name, date and time stamp (Ship time zone), water level, trend, water level type, additional information (link to create pick report)

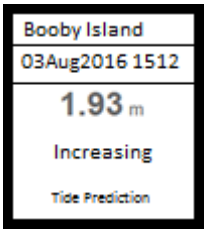


Figure 9.1 - Sample text box for a single water level station.

The numerical value of the water level is a number in metres in black text on white background (or the inverse for night vision). This display should be made available when the cursor is held over the data point.

If available, “Additional information” will be supplied on a priority level or possibly via “Pick Report”. See Table 9-3 below.

Table 9-3 - Priority for additional information

Priority level	Additional information
1	Only that listed in Table 9-2
2	Data Source, Latitude, Longitude, Graphic plot display

3	Uncertainty in water level, uncertainty in horizontal position, uncertainty in vertical position, uncertainty in time

9.2.3 Graphic time series plot

The availability of the graphic plot display (605 x 650 pixels), should be indicated by a link in the window mentioned in clause 9.2.2 that creates another window/tab displaying up to 7 days of water level. The Mariner will have the option to change between 3 hours, 6 hours, 12 hours, 1 day, 3, 5 or 7 day display. The display will have the option to display two plots within the one window; a primary plot and a secondary plot. The number of plots shown will depend on dataset availability for the area in question.

When Portrayal Catalogues use an area fill to depict water level information from an S-104 feature, the fill colour should have transparency set so that background colours, lines and symbols of features from other products can be perceived through a coverage area fill shade (for example, depth contours and traffic separation schemes should show through a gridded or TIN water level coverage area fill). Line and text transparency must be similar to those of hover boxes. The colours to be used for lines are shown in Table 9-4 below. Text colour is black.

Table 9-4 - Data type colours for graphic plot window

Data type	Plot colour
Primary plot	
Observed	Magenta
Predicted	Black
Analysis	Green
Forecast	Blue
Hindcast	Cyan
Secondary plot	
Observed minus Predicted	Black
Observed minus Analysis	Green
Observed minus Forecast	Blue
Observed minus Hindcast	Cyan
Forecast minus Predicted	Red

See clause 7.1 for definitions of “predicted” and “forecast”.

A maximum limit of five lines in total are to be plotted; for example, Observed, Predicted (astronomical) and Forecast, and Observed minus Predicted and Observed minus Forecast. The following must be included in the plot space: (1) Station name and the water level type; (2) date and time information; (3) height scale; and (4) vertical datum reference. A sample plot for one station is shown in Figure 9-2 below.

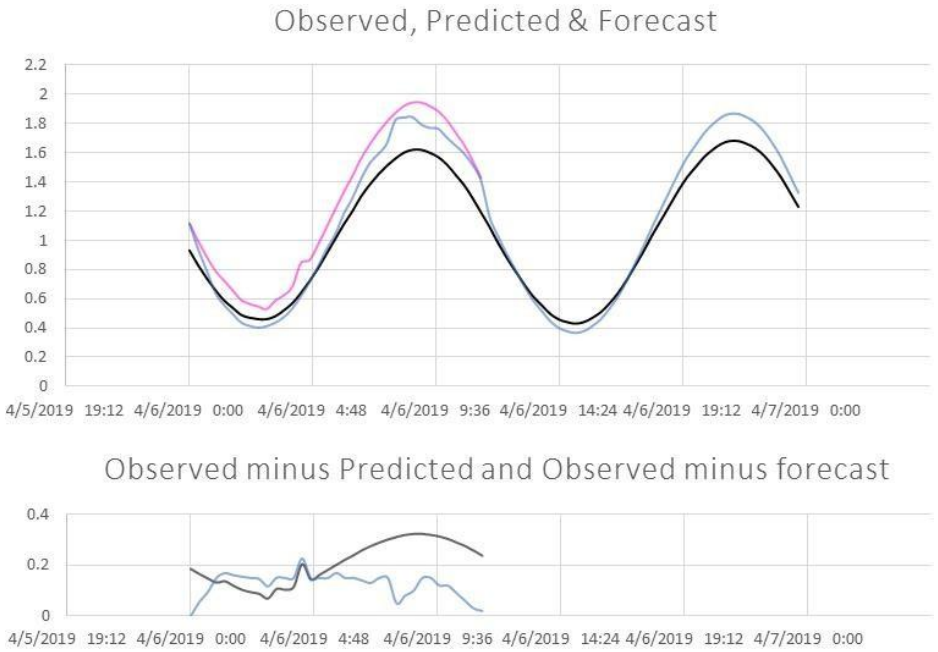


Figure 9-2 - Sample one-day plot of a time series of observed, predicted, forecast, observed minus predicted, and observed minus forecast water level heights

NOTE: This sample plot does not include station name and vertical datum reference.

Multiple lines can be plotted on the graphic plot window at the same time and the colours are used to differentiate the data type. Data types with the same colours are plotted on different plots. Note that other ECDIS Standards will define when this graphic plot can be displayed, due to the size of the window covering the screen size. Note also that the use of dashed lines was considered but discounted by the viewers who indicated difficulty following lines on a small plot window.

The colour of the curve could be used for the words in the title of the graph (Observed, Predicted, Forecast, etc.), to allow the user to know directly which data is in which colour.

9.3 Display of gridded data

The display of gridded data depicts water level surface information at each individual point having the qualities described in clause 9.2. As with single point water level data, a mouse click on the chart area will display the information from the grid node nearest to that point.

NOTE 1: There is no adjustment of bathymetry data because this option is outside the scope of this Product Specification.

NOTE 2: There are no specifications for the display of a water surface from gridded data in this Product Specification Edition.

9.4 Treatment of missing values

For “abnormal” missing values for real-time observations (no data sent for that time stamp, at a location where data is otherwise available), manufacturers must default to predicted/modelled information on ECDIS, with an annotation indicating that such substitution has been used.

9.5 Temporal considerations

The time selected for display (that is, past, present or future) of the water level by the system will typically not correspond exactly to the timestamp of the input data. For data with only a single record

(that is, the timestamp of the earliest values equals that of the latest value) such as real-time data, the water level values are displayed only if the absolute difference between the display time and the data timestamp is less than a discrimination interval (for example, 5 minutes). For a single record, the variable *timeRecordInterval* (see clause 12.3) can be used to set the discrimination interval. This is related to real-time delivery of water level, to flag missing real-time data and to revert to prediction data. If no prediction data is available, retain last provided water level reading.

For data with multiple times, if selected display time is later than the first timestamp and earlier than the last timestamp, then the closest two timestamps (that is, one earlier and one later) in the data are found and the water level values are linearly interpolated. However, if the selected display time is earlier than the first timestamp or later than the last timestamp, the water level values at the closest time are displayed only if the absolute time difference between the display time and the data time stamp is less than a discrimination interval (for example, half the value of the variable *timeRecordInterval*).

9.6 Interoperability

Interoperability principles determine priority in display of elements so that important image elements, such as depth numerals, are not obscured by water level values. Water level portrayal will conform to interoperability Rules when they are established.

9.7 Construction and packaging of Portrayal Catalogues

The Portrayal Catalogue must be constructed as a main Portrayal Catalogue XML file (see S-100 Part 9, clause 9-13) and other files in subfolders. The structure is described in S-100 Part 9, clause 9-13.2. The main Portrayal Catalogue XML file and portrayal subfolders described in S-100 must be placed in a single subfolder named 104_1_0_0_PC/YYYYMMDD. When distributed within an exchange set, the entire Portrayal Catalogue must be packaged as a zip archive named 104_1_0_0_PC_YYYYMMDD.ZIP. The YYYYMMDD component in the folder and archive names denotes a “build date” and allows distinguishing Portrayal Catalogues corresponding to the same version of the S-104 Product Specification (for example, correcting a discrepancy between a portrayal rule and a stable version of the S-104 Product Specification).

10 Data Product Format (Encoding)

10.1 Introduction

The Water Level Data Products must be encoded using one of the listed formats. The structure of the data product is discussed in the next Section. There is only one format allowed to encode data:

a) HDF5 for water level height and trend data.

Character Set: MD_CharacterSetCode (ISO19115-1) should be set to utf8

Specification: S-100 profile of HDF5

10.2 HDF5 product structure for time series and gridded data

The key idea at the core of the structure is this: The organisation of the information is substantially the same for each of the various types of data, but the information itself will be interpreted differently.

10.2.1 Data Type Definition

HDF5 will be used for all water level data types.

Format Name: HDF5

Character Set: MD_CharacterSetCode (ISO 19115-1)

Specification: S-100 profile of HDF5

This product format is designed to be flexible enough to apply to water level values in the form of:

(a) data at one or more times for one or more individual, fixed stations, organised by time or station;

(b) regularly-gridded data for one or more times;

(c) ungeorectified gridded data for one or more times; and

(d) TIN data.

This approach contains, for each type, data in a similar format but which is interpreted differently. Since each type of data will be interpreted differently, the type of data must be identified by the variable *dataCodingFormat,* as shown in Table 10-1 below. (The letters in parentheses in the second column reference the types listed earlier in this paragraph.)

Table 10-1 - S-104 data types and values of the variable *dataCodingFormat* (see S-100 Edition 4.0.0, Table 10c-4)

dataCodingFormat	Type of Data
1	Time series data at one or more fixed stations (organised by time) - type (a)
2	Regularly-gridded data at one or more times - type (b)
3	Ungeorectified gridded data or point set data at one or more times - type (c)
7	TIN data - type (d)
8	Stationwise time series at one or more fixed stations (organised by station) - type (a)

For the use of HDF5, the following key concepts (S-100 Part 10c, clause 10c-5.1) are important:

- *File* - a contiguous string of bytes in a computer store (memory, disk, etc), and the bytes represent zero or more objects of the model;
- *Group* - a collection of objects (including groups);
- *Dataset* - a multidimensional array of data elements with attributes and other metadata;
- *Dataspace* - a description of the dimensions of a multidimensional array;
- *Datatype* - a description of a specific class of data element including its storage layout as a pattern of bits;
- *Attribute* - a named data value associated with a group, dataset, or named datatype;
- *Property List* - a collection of parameters (some permanent and some transient) controlling options in the library;
- *Link* - the way objects are connected.

In addition, a dataset may have one, two, or more dimensions, and each element in the dataset may be a compound. That is, each element may itself be an array of possibly different datatypes (float, integer, string, etc).

For all data types, the product structure in HDF5 includes:

(a) A metadata block; which is followed by

(b) one or more Groups which contain the actual water level data.

The water level information is saved in arrays that hold either gridded data or a time series.

10.2.2 Product structure

The structure of the data product follows the form given in S-100 Part 10c – HDF5 Data Model and File Format. The general structure, which was designed for several S-100 products, not just water levels, is given in Figure 10-1 below.

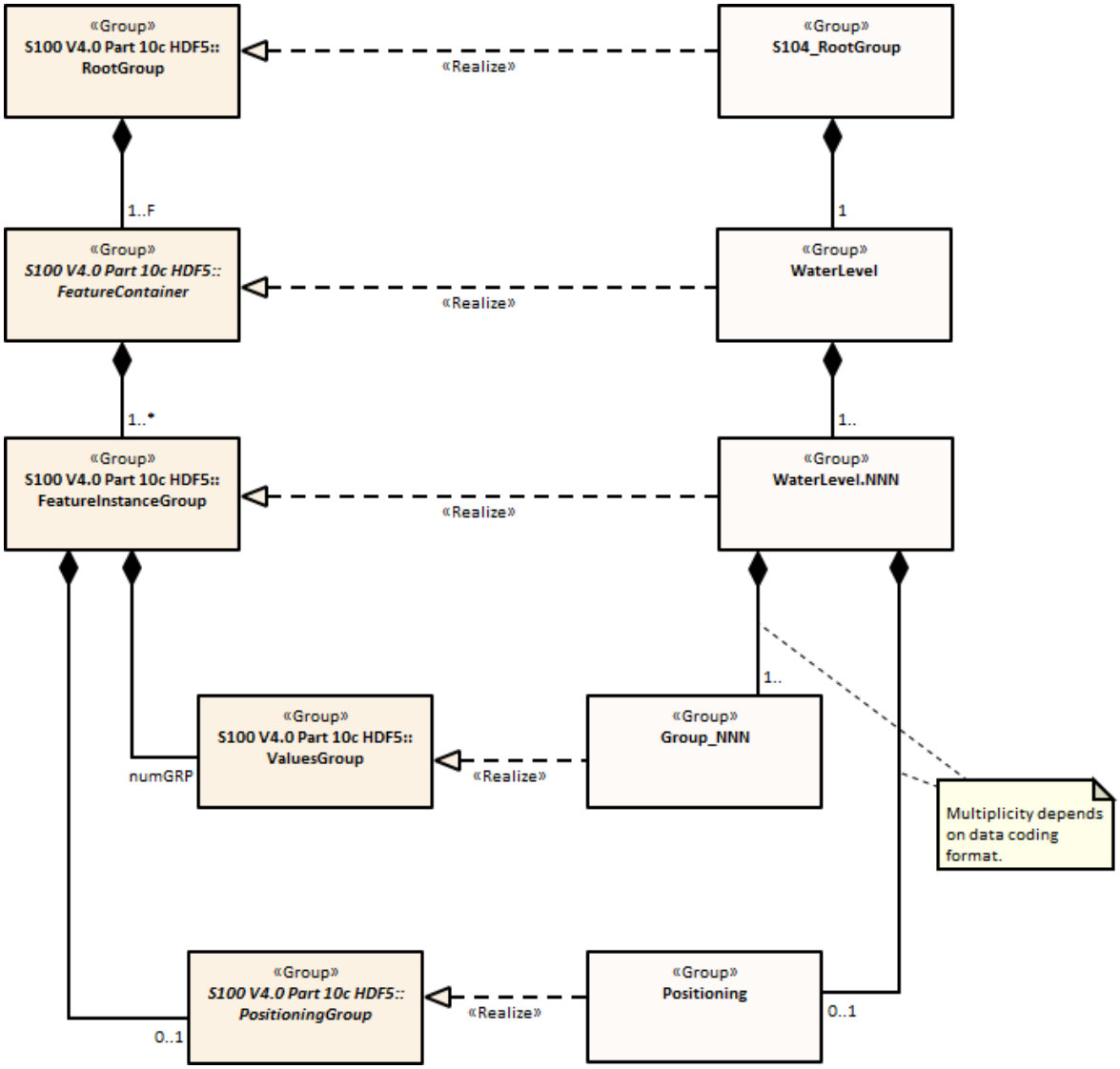


Figure 10.1 - Outline of the data file structure for S-104 data files, showing the realisation of S-104 structure from the generic structure described in S-100 (see Part 10c – Figure 10c-7)

In Figure 10.1 there are four Levels:

Level 1: At the top Level lies the Root Group; it contains the Root Metadata (Table 12-3) and two subsidiary groups. The Root Metadata applies to all S-100 type products.

Level 2: The next Level contains the Feature Information Group and the Feature Container Group. The Feature Information Group contains two datasets: The featureCode, which has the name of the S-100 feature (here WaterLevel); and the feature information dataset (WaterLevel) which contains a compound array with eight parameters for each S-100 feature attribute (height, trend, and time). The Feature Container Group contains the Feature Metadata (Table 12-4) and one or more Feature Instance Groups. The Feature Metadata is common to all water level products.

Level 3: This Level contains one or more Feature Instances. A Feature Instance is, for example, a time series of gridded data for a single region, or a time series of astronomical predictions for a set of stations.

Level 4: This Level contains the actual data for the feature. S-104 uses only the Values Group and, for only some data, the Positioning Group.

The basic structure of the S-104 data product is shown in Table 10-2 below. Levels refer to HDF5 structuring. (See S-100 Part 10c, Figure 10c-9). Naming in each box below header line is as follows: **Generic name**; S-100 or S-104 name; and (*HDF5 type*) group, attribute or attribute list, or dataset.

Table 10-2 – Overview of an S-104 data product

LEVEL 1 (ROOT) CONTENT	LEVEL 2 CONTENT	LEVEL 3 CONTENT	LEVEL 4 CONTENT
General Metadata (see Table 12-3) *(h5_attribute)*			
Feature Codes Group_F (*h5_group)*	**Feature Name** WaterLevel *(h5_dataset)*		
	Feature Codes featureCode *(h5_dataset)*		
Feature Type WaterLevel *(h5_group)*	**Type Metadata** (see Table 12-4) *(h5_attribute)*		
	Horz. & vert. Axis Names axisNames *(h5_dataset)*		
	First Feature Instance WaterLevel.01 *(h5_group)*	**Instance Metadata** (see Table 12-5) *(h5_attribute)*	
		Location Data Positioning *(h5_group)*	**Lon+lat Array** geometryValues *(h5_dataset)*
		Uncertainty Data uncertainty *(h5_dataset)*	
		First data group Group_001 *(h5_group)*	**Time Attribute** timePoint *(h5_attribute)*
			Height+trend Array values *(h5_dataset)*
		Second data group Group_002 *(h5_group)*	**Time Attribute** timePoint *(h5_attribute)*
			Height+trend Array values *(h5_dataset)*
		Third data group Group_003 *(h5_group)*	**Time Attribute** timePoint *(h5_attribute)*
			Height+trend Array values *(h5_dataset)*
	Second Feature Instance WaterLevel.02 *(h5_group)*	**Instance Metadata** (see Table 12-5) *(h5_attribute)*	

The following sections explain entries in Table 10-2 in more detail.

10.2.2.1 Root group

The Root Group contains the Feature Codes group, the Feature Type group, and the simple attributes shown in Table 12-3.

10.2.2.2 Feature codes (Group_F)

This group specifies the S-100 feature to which the data applies. The group has no attributes and consists of two components:

featureCode – A dataset with the name(s) of the S-100 feature(s) contained in the data product. For S-104, the dataset has a single element, the string “WaterLevel”.

WaterLevel – This is a dataset with the name contained in the **featureCode** dataset. The dataset contains a one-dimensional compound array of length 3 (one for each of the three water level attributes: height, trend, and time). Each of the three elements of string values has 8 values, as shown in Table

10-3 below.

NOTE 1: This dataset has a single attribute, named *chunking*, which is a string containing the HDF5 chunking values used in creating the values arrays (for example '0,0'). These chunking values can be overridden at the feature instance level by the attribute *instanceChunking* (see Table 12-4).

NOTE 2: Values provided in Table 10-3 are required.

Table 10-3 – Contents of the one-dimensional compound array (length = 3, compound elements = 8) WaterLevel. All values are strings

N	Name	Explanation	S-100 Attribute 1	S-100 Attribute 2	S-100 Attribute 3
1	code	Camel Case Name	waterLevelHeight	waterLevelTrend	waterLevelTime
2	name	plain text	Water level height	Water level trend	Water level time
3	uom.name	Units of Measurement	metres		DateTime
4	fillValue	Denotes missing data	-9999.0	0	
5	datatype	HDF5 datatype	H5T_FLOAT	H5T_ENUM	H5T_STRING
6	lower	Lower bound on attribute	-99.99		19000101T000000Z
7	upper	Upper bound on attribute	99.99		21500101T000000Z
8	closure	Open or Closed data interval. See S100_IntervalType in Part 1	closedInterval		closedInterval

NOTE: The specification can still be used for providing water level information outside the 1900-2149 date range but it will fail validation checks pertaining to dates and must be considered "not for navigation" data.

10.2.2.3 Type group (WaterLevel)

This group contains a dataset called *axisNames* and one or more instances of the single feature WaterLevel. A single instance may contain a gridded forecast at multiple hours, or a set of time series predictions or observations at several stations. This group has the simple attributes shown in Table 12-4. For S-104, *axisNames* consists of two elements, the strings 'longitude' and 'latitude' (EPSG:4326 axis names). The contents of the *axisNames* array must be exactly the same as the axis names used by the appropriate Registry entry for the coordinate system specified in the metadata; for EPSG, the axis names in the corresponding EPSG registry entry must be used.

10.2.2.4 Instance group (WaterLevel.nn)

This group contains a single instance of the feature (see clause 10.2.2.3). The groups are numbered from 01 to 99. This group has the simple attributes shown in Table 12-5, as well as the (water level, trend, and time) values groups, the (conditional) positioning group, and a dataset called 'uncertainty'.

Uncertainty Dataset – The (optional) uncertainty data is contained in a compound HDF5 dataset named 'uncertainty'. There is a name and an uncertainty value for water level height, which is *waterLevelHeight*. The units of height uncertainty are metres. The default, denoting a missing value, is -1.0.

10.2.2.5 Value groups (Group_nnn)

These groups each contain an attribute (the date-time stamp), and the compound data arrays containing water level height and trend, and optionally water level time. These groups have the simple attributes shown in Table 12-6. These components are explained below.

Date-Time Stamp - The date-time stamp is an attribute named *timePoint* with a single (string) value. For gridded (regular, ungeorectified, and TINs: *dataCodingFormat* = 2, 3, or 7), the time stamp is the time of validity for all points in the grid. For a time series at fixed stations (*dataCodingFormat* = 1), the time stamp is valid for all stations in that Value group.

Value Arrays - The height and trend values (waterLevelHeight and waterLevelTrend) are stored in arrays named *values,* with a prescribed number of rows (*numROWS*) and, if two-dimensional, columns (*numCOLS*).

For a time series of fixed stations (*dataCodingFormat* = 1 and 8), the height and trend values will be for times in the series as determined by the starting date-time and the data time interval. If the time intervals are non-uniform (only for *dataCodingFormat* = 8), then the time for each height and trend value is given by waterLevelTime.

For a regular grid (*dataCodingFormat* = 2), the height and trend values will be for each point in the grid, the data array *values* is two-dimensional, and the time for all points in the grid is given by the date-time stamp.

For an ungeorectified grid and TINs (*dataCodingFormat* = 3 and 7, respectively), the height and trend values will be for each point in the grid, the data array *values* is one-dimensional, and the time for all points in the grid is given by the date-time stamp.

10.2.2.6 Conditional geography group (Positioning)

The group named **Positioning** contains all the locations (longitude and latitude values) that have associated data values. This group has no attributes. In S-104, this group is present in the data product only for *dataCodingFormat* values of 1, 3, 7, or 8.

The geographic values are stored in the single, one-dimensional compound array named *geometryValues*, of size *numPOS*. Each element in the compound array *geometryValues* contains the pair of float values (longitude, latitude). The value of *numPOS* and the interpretation of the kinds of locations depends on the *dataCodingFormat* as well. The values and number of stations (respectively) for each data type are explained in Table 10-4 below.

For *dataCodingFormat* = 7 (TIN), the **Positioning** group also contains the required *triangles* and optional *adjacency* arrays. Each row in the *triangles* array encodes a triangle as the indexes of 3 coordinates in the *geometryValues* dataset. Each row in the *adjacency* array encodes the triangles adjacent to any given triangle by specifying their indexes in the *triangles* dataset. Elements for edges without adjacent triangles are filled with the value -1. See S-100 Part 10c, Table 10c-16 for the encoding format. S-100 Part 8, clause 8-6.2.7 explains the structure of TINs and their use for describing coverage data.

For *dataCodingFormat* = 2 (regular grid), location data for grid points can be computed from the grid origin and number of grid points in each dimension, which are encoded as HDF5 attributes. The attribute *numPOS* is not needed since the grid data is stored as a two-dimensional array with the number of rows and columns given by the numbers of grid points in each dimension. See S-100 Part 10c, clause 10c-9.3 for more information.

NOTE: the variable names in this Group (longitude, latitude) must match in case and spelling those in *axisNames*.

Table 10-4 – Values of *numPOS* for the group *Positioning*

Data Coding Format	Data Type	Location Data	Array Size: Value of numPOS
1	Time series at fixed stations	Position of stations	*numberOfStations*
2	Regular grid	(Not applicable)	(Not applicable)
3	Ungeorectified gridded data	Location of the grid nodes	*numberOfNodes*
7	TINs	Location of the grid nodes	*numberOfNodes*
8	Stationwise time series at fixed stations	Position of stations	*numberOfStations*

10.2.2.7 Summary of generalised dimensions

To summarise, for non-regularly gridded data only, there is an initial Positioning Group with X and Y position, stored in one-dimensional arrays of size *numPOS*. Following that, there are data Groups containing water level and trend data, which are stored in either one-dimensional arrays of size *numROWS* or two-dimensional arrays of size *numROWS* by *numCOLS*. The total number of data Groups is *numGRP*.

The four variables that determine the array sizes (*numROWS*, *numCOLS*. *numPOS,* and *numGRP)* are different, depending upon which data coding format is used. Their descriptions are given in Table 10-5

below.

Table 10-5 – The array dimensions used in the data product

Data Coding Format	Data Type	Positioning	Data Values		
		numPOS	**numCOLS**	**numROWS**	**numGRP**
1	Fixed Stations	numberOfStations	1	numberOfStations	numberOfTimes
2	Regular Grid	(not used)	numPointsLongitudinal	numPointsLatitudinal	numberOfTimes
3	Ungeorectified Grid	numberOfNodes	1	numberOfNodes	numberOfTimes
7	TIN	numberOfNodes	1	numberOfNodes	numberOfTimes
8	Fixed Stations (Stationwise)	numberOfStations	1	numberOfTimes	numberOfStations

10.2.2.8 Mandatory naming conventions

The following group and dataset names are mandatory in S-100: 'Group_F', 'featureCode', and (for S-104) 'WaterLevel', 'axisNames', 'Positioning', (for S-104) 'WaterLevel.nn', and 'Group_nnn' (n is an integer from 0 to 9). Attribute names shown in clause 12.3 are also mandatory.

10.2.2.9 Summary of product structure

For regularly gridded data, the water level array is two dimensional, with dimensions *numPointsLongitudinal* and *numPointsLatitudinal*. These attributes are part of instance metadata described in Table 12-5 and S-100 Part 10c, Table 10c-12. By knowing the grid origin and the grid spacings, the position of every point in the grid can be computed by simple formulae.

However, for time series data, TINs, and ungeorectified gridded data (that is, when *dataCodingFormat* is 1, 3, 7, or 8), the location of each point must be specified individually. This is accomplished by the data in Positioning Group, which gives the individual longitude (X) and latitude (Y) for each location. For time series data, the X and Y values are the positions of the stations; the number of stations is *numberOfStations.* For TINs and ungeorectified-gridded data, the X and Y values are the positions of each point in the grid; the number of grid points is *numberOfNodes*.

NOTE: If *dataCodingFormat* is 2, the Positioning Group is not present.

The remaining Groups each contain a title, a date-time value (attribute *timePoint*, except for *dataCodingFormat* = 8), and the water level array. The title can be used to identify each individual station with time-series data. For *dataCodingFormat* = 2 or 3, the date-time is for the entire grid. The water level array is two dimensional, with a number of columns (*numCOLS*) and rows (*numROWS*). For a time series, the water level value will be for each time in the series. For a grid, the water value will be for each point in the grid.

The format allows features encoding data stationwise (*dataCodingFormat* = 8) to be encoded with either uniform or non-uniform time intervals.

- For non-uniform time intervals, each record has a date-time encoded in the water level array.
- For uniform time intervals, the time interval is encoded as an attribute of the values group. In this case, the date-time of individual records is omitted from the water level array.

The Groups are numbered 1, 2, etc., up to the maximum number of Groups, *numGRP*. For fixed station stationwise data (*dataCodingFormat* = 8), the number of Groups is the number of stations. For regular and ungeorectified grids and TINs (*dataCodingFormat* = 2, 3, and 7), and for fixed station timewise data (*dataCodingFormat* = 1) the number of Groups is the number of time records.

The overall structure of the water level data product is created by assembling the data and metadata. The product structure is compliant with the HDF5 data architecture, which allows multi-dimensional arrays of data to be grouped with metadata. The format of the data product (see Figure 10-1) described above is portrayed in Figure 10-2 below. The Carrier Metadata is discussed in clause 12.3 (Tables 12-3 – 12-5), and the Values Group attributes are discussed in clause 12.3 (Table 12-6).

NOTE: The name of each Group is the ‘Group_nnn‘, where nnn is numbered from 1 to *numGRP*.

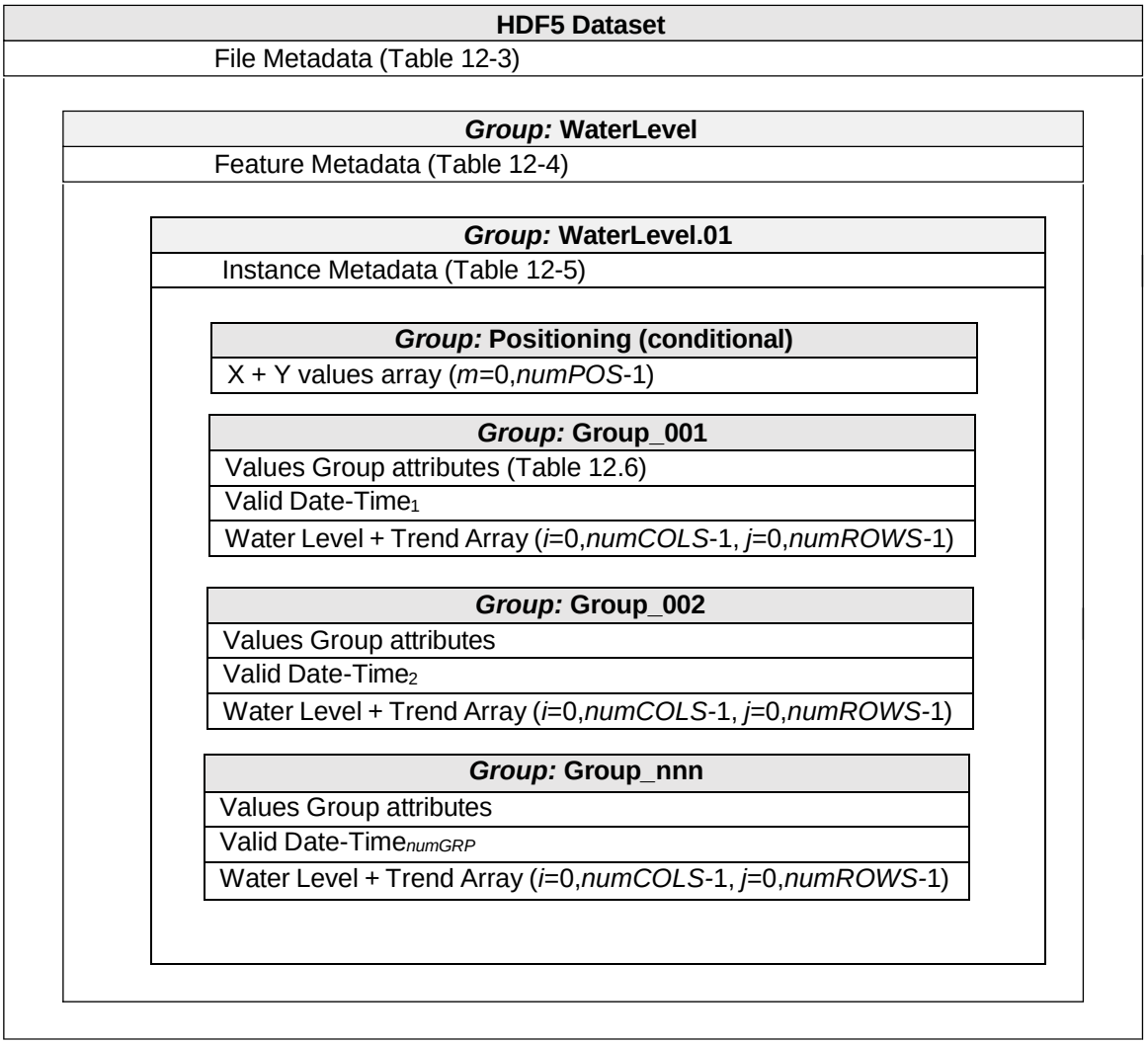


Figure 10-2 – Schematic of the S-104 HDF5 data product structure

The four parameters *numPOS*, *numCOLS*, *numROWS*, and *numGRP* are explained in Table 10-5.

Group ‘Positioning’ appears only for *dataCodingFormat* = 1, 3, 7, or 8 (Table 10-5).

Valid Date-Time$_{1,2,...numGRP}$ have different meanings and encodings for *dataCodingFormat*=1, 2, 3 and 7 compared to *dataCodingFormat*=8 (see Table 12-6).

10.2.2.10 Digital certification block

Information here is used to certify the validity or integrity of the data.

[Digital signatures and encryption are not a requirement for Edition 1.0.0 (S-100 Readiness Level 1). This clause is reserved for future development.]

10.3 Sample HDF5 encoding

The product structure has been designed for compatibility with the HDF5 capabilities. The HDF5 encoding of the data set is discussed in Annex E – Sample HDF5 Encoding.

11 Data Product Delivery

11.1 Introduction

This section describes how the water level data product is to be packaged by the Producer.

Due to the cost of transmitting data via the internet, it is desirable to limit file size and updating frequency whenever possible. The exchange data file size, as created by the Producer and after compression, is recommended to be limited to 10 MB. Another quantity to be aware of is the total MB to be transferred per year. S-100 (Part 15, clause 15-5.2) allows one data compression scheme: Zip. In addition, the file may be encrypted.

Updating of files typically means issuing a new forecast, or disseminating the latest observed water level for a specific geographic region. This may occur several times per day. Therefore, all files must contain a date-time of issuance of the product. Because of the potentially high frequency (that is, hourly or less) availability of new datasets, the ECDIS system must check for new data at a similar frequency.

11.2 HDF5

The HDF5-formatted datasets are packaged with metadata and an Exchange Catalogue; and then combined into an Exchange Set. HDF5 files for time series or gridded water level data may require access to the Internet, since they change several or more times a day.

11.2.1 Exchange Sets

Exchange Sets, or data products, produced by the Producer consist of files containing both the Exchange Catalogue and one or more data products (of possibly different S-100 types), with each product covering a specific geographic region and specific period of time (Figure 11-1). The Exchange Catalogue lists the products and contains the discovery metadata.

The name of the Exchange Set must be derived from the Catalogue identifier, which in turn must be globally unique. See clause 12.2.2 for the rules determining how the Catalogue identifier is constructed. An extension appropriate to the packaging method must be suffixed. For example:

- If the Catalogue identifier is 104ABCDXYZ_1_20_20210420 and the Exchange Set is packaged as a Zip file, the name of the Zip file must be 104ABCDXYZ_1_20_20210420.zip or 104ABCDXYZ_1_20_20210420.ZIP.
- If the Catalogue identifier is 104ABCDXYZ_1_20_20210420 and the Exchange Set is distributed as a folder on compact disc media, the folder name must be 104ABCDXYZ_1_20_20210420.

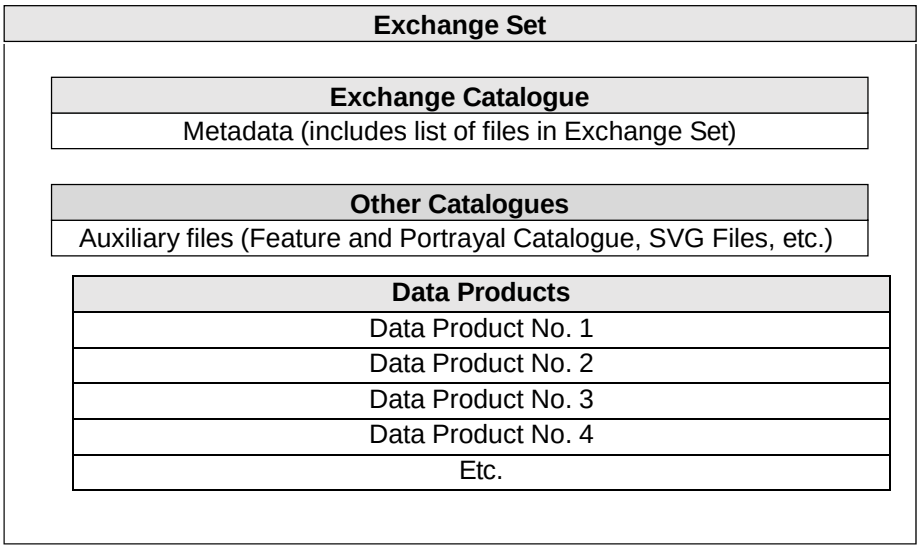


Figure 11-1 – Schematic diagram of the Exchange Set

The Exchange Set size is limited to 10 MB. The size of datasets (HDF5 data files) can vary widely, depending on the data. Using the sample HDF5 files (see Annex E), a file containing, along with

metadata, a single water level height array and a single water level trend array, each with 100,000 grid points would have a size of approximately 0.21 MB. Exchange files may be compressed using zip methodology. Doing so can reduce file size by 80% or more.

11.2.1.1 Recommended Exchange Set structure (informative)

The structure of an S-104 Exchange Set should be according to the structure described below, which is depicted in Figure 11-2.

1) All content must be placed inside a top root folder named S100_ROOT. This is the only top level root folder in an Exchange Set containing only S-100 products.
2) The S100_ROOT folder must contain a subfolder for S-104 which holds content specific to S-104.
3) An S-104 Exchange Set must contain an Exchange Set Catalogue, CATALOG.XML; its digital signature CATALOG.SIG; and may contain any number of S-104 conformant dataset files and Catalogue files.
4) The S-104 subfolder must contain subfolders for the component dataset files (DATASET_FILES) and Catalogues (CATALOGUES) as required:
   a. The DATASET_FILES subfolder is required if and only if the Exchange Set contains an S-104 HDF5 dataset.
   b. The CATALOGUES subfolder is required if and only if the Exchange Set contains a Feature or Portrayal Catalogue.
5) The DATASET_FILES folder must contain a subfolder named after the producer code. Individual data files must be placed under the producer subfolder. Multiple data files are allowed in a producer folder.
6) An Exchange Set may carry Feature and Portrayal Catalogues in different versions, which should also be grouped together in the CATALOGUES folder.
7) If a Portrayal Catalogue is included in the Exchange Set, it must be packaged as a ZIP archive containing all Portrayal Catalogue files, including the main PC XML file (file 104_1_0_0_PC.XML in Figure 11-2) and other portrayal files. Guidance on packaging Portrayal Catalogues is provided in clause 9.7. Figure 11-2 depicts an example of a Portrayal Catalogue archive (104_1_0_0_PC_20220101.ZIP) for a hypothetical S-104 Edition 1.0.0 Portrayal Catalogue built on 01 January 2022.
8) The zipped Portrayal Catalogue must be unpacked into the CATALOGUES folder, maintaining the folder structure and file and folder names in the Zip archive. If the guidelines in clause 9.7 are followed, this means the main Portrayal Catalogue file (file 104_1_0_0_PC.XML in Figure 11-2) will be placed directly under the CATALOGUES/*<PR_ROOT>/<YYYYMMDD>* folder (where <PR_ROOT> is the name of the portrayal root folder containing all the Portrayal Catalogues for this edition of S-104), <YYYYMMDD> is the subfolder for this build of the Portrayal Catalogue, and other Portrayal Catalogue files and folders will be placed as files or folders under the CATALOGUES/*<PR_ROOT>/<YYYYMMDD>* folder, according to the folder structure in the Zip archive. For convenience, the system may relocate an unpacked Portrayal Catalogue to a central location common to all S-104 datasets, maintaining the relative locations of the 104_X_X_X_PC.XML file and the sub-folders *AreaFills*, etc, since these sub-folder names and their contents are encoded in the 104_X_X_X_PC.XML file.
9) Except for the signature of the Exchange Catalogue file (CATALOG.XML), which is in the CATALOG.SIG file, all digital signatures are included within their corresponding resource metadata records in CATALOG.XML.
10) Dataset and Catalogue file and/or folder names should be such as to avoid inadvertent overwriting of files.
11) Digital signatures and Portrayal Catalogues may be omitted for Exchange Sets conforming to Edition 1.0.0 of S-104.
12) It is not necessary for an Exchange Set to contain more than one build of a Feature or Portrayal Catalogue for the same version of a Product Specification. For example, an Exchange Set will not contain both 104_1_0_0_FC/20210630/ and 104_1_0_0_FC/20220101/ folders for

Edition 1.0.0 Feature Catalogues. The presence of both in Figure 11-2 is only for illustrative purposes.

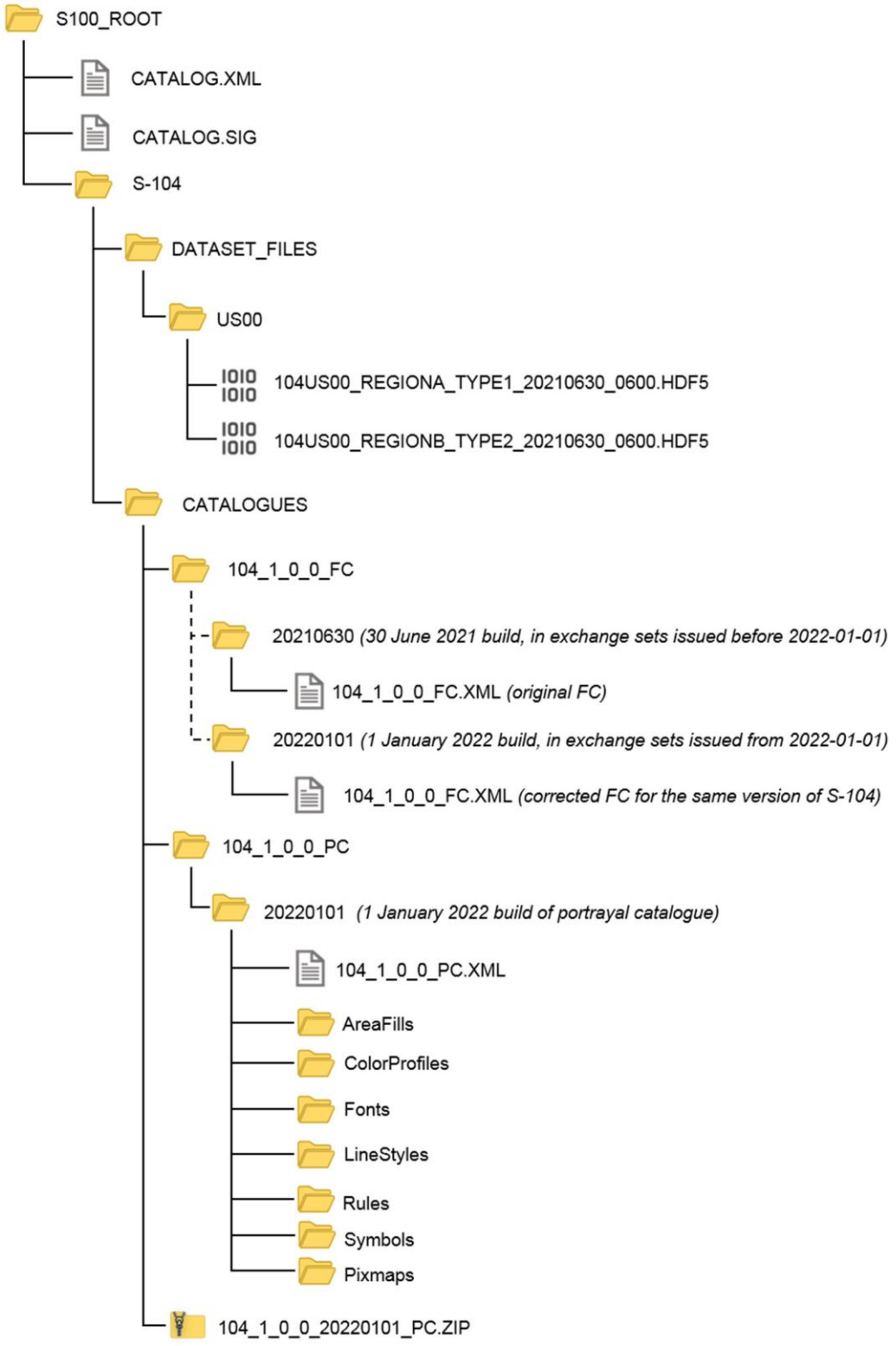


Figure 11-2 – Recommended Exchange Set structure

General guidelines for Exchange Set structure are under development and are expected to be included in S-100 Edition 5.0.0, after which the guidelines for S-104 will be finalised.

Note that the names and locations of files are coded within the CATALOG.XML or Portrayal

Catalogue files, and therefore files and folders should not be renamed or relocated by Producers or End-User systems unless these references can be updated. Portrayal and Feature Catalogues can be relocated to a common system location if their internal structure is maintained.

11.2.2 Exchange Catalogue

The Exchange Catalogue normally in XML format acts as the table of contents for the exchange set. The catalogue file of the exchange set must be named CATALOG.XML[3]; no other file in the Exchange Set may have the same name. The contents of the Exchange Catalogue are described in clause 12.

The Exchange Catalogue Schemas may be downloaded from the IHO S-100 Working Group GitHub site: https://github.com/IHO-S100WG/S100-Schemas. The S-104 Exchange Catalogue Schemas reference the generic S-100 Schemas, which are also available from the same location. Installation instructions will be included in the Schema package.

11.2.3 Dataset file naming

The dataset file contains both metadata and one or more sets of height and trend arrays (see clause 10 – Data Product Format). The dataset name must begin with the three-character Product Specification number, followed by the four-character producer code (CCCC). Where the producer code in the IHO GI registry is in a 2- or 3-character format, it must be right-padded with two or one zeroes. For example, the two-character code “AA” is encoded as “AA00”. Thus water level files begin with the seven-character string ‘104CCCC’. The unrestricted characters may be used to denote geographical region, valid time, source of the data, version numbers, and/or any other relevant information. Characters may be lower or upper case. For real-time and forecast data, it is recommended that the dateTime of the first record be part of the dataset name, to help distinguish the most recent files.

The filename extension for HDF5 (for example, .h5 or .hdf5) must be used to denote the file format.

EXAMPLE 1: 104US00_CHES_TYPE1_20210630_0600.HDF5 for observational data (TYPE1 – see clause 12.2.18) produced by NOAA (producer code US00) for Chesapeake Bay (CHES), observations beginning from 06:00 UTC on 30 June 2021.

EXAMPLE 2: 104US00_ches_dcf8_20190703T00Z.h5 for a dataset produced by NOAA (US00) containing data for NOAA fixed stations in the Chesapeake Bay (ches) organised stationwise (dcf8) beginning from midnight at the beginning of 3 July 2019.

Each Producer should adopt a naming scheme that is consistent across its entire S-104 product line. While the examples above are hypothetical, they illustrate how the principles of this clause can be applied by producers.

11.2.4 Support files

This Data Product requires no support files.

12 Metadata

12.1 Introduction

For information exchange, there are several categories of metadata required:

- Discovery metadata about each of the datasets contained in the Catalogue; and
- Discovery metadata about the support files that make up the package.

The discovery metadata classes have numerous attributes which enable important information about the datasets and accompanying support files to be examined without the need to process the data; for example, decrypt, decompress, load, etc. Other Catalogues can be included in the Exchange Set in support of the datasets such as feature, portrayal, coordinate reference systems, codelists, etc. The attribute “purpose” of the support file metadata provides a mechanism to update support files more easily.

NOTE: S-104 Edition 1.0.0 datasets do not reference support files. The support files in the Exchange

[3] After S-100 Edition 5.0.0 is published, Producers may use the naming rule in S-100 Edition 5.0.0 instead. This also applies to the signature file.

Set are for Feature and Portrayal Catalogues, when these are contained within S-104 Exchange Sets.

Discovery metadata is given in XML files accompanying the HDF5 file that contains the data, and can be accessed without opening the HDF5 file. In addition to discovery metadata, S-104 also provides for carrier metadata that is embedded within the HDF5 file, which provides information needed to process and display the data. Discovery metadata is described in clause 12.2; carrier metadata in clause 12.3.

This clause defines the mandatory and optional metadata needed for S-104. In some cases the metadata may be repeated in a language other than English.

12.1.1 Structure of Exchange Set

This clause describes the structure of the Exchange Set in terms of UML diagrams derived from the formal UML model in S-100 Part 4a. The structure is the same as informally described in clause 11.2.1.

Figure 12-1 below depicts the realisation of the ISO 19115-1 and ISO 19115-3 classes which form the foundation of an S-104 Exchange Set. This Figure is derived from Figure 4a-D-1 in S-100 Edition 4.0.0, with relationships not applicable to S-104 omitted. Note that the only support files in S-104 are the Feature and Portrayal Catalogue files, which are described by **S100_CatalogueMetadata** elements. The classes for **S100_SupportFile** and **MX_SupportFile** in S-100 Figure 4a-D-1 are therefore omitted from Figure 12-1.

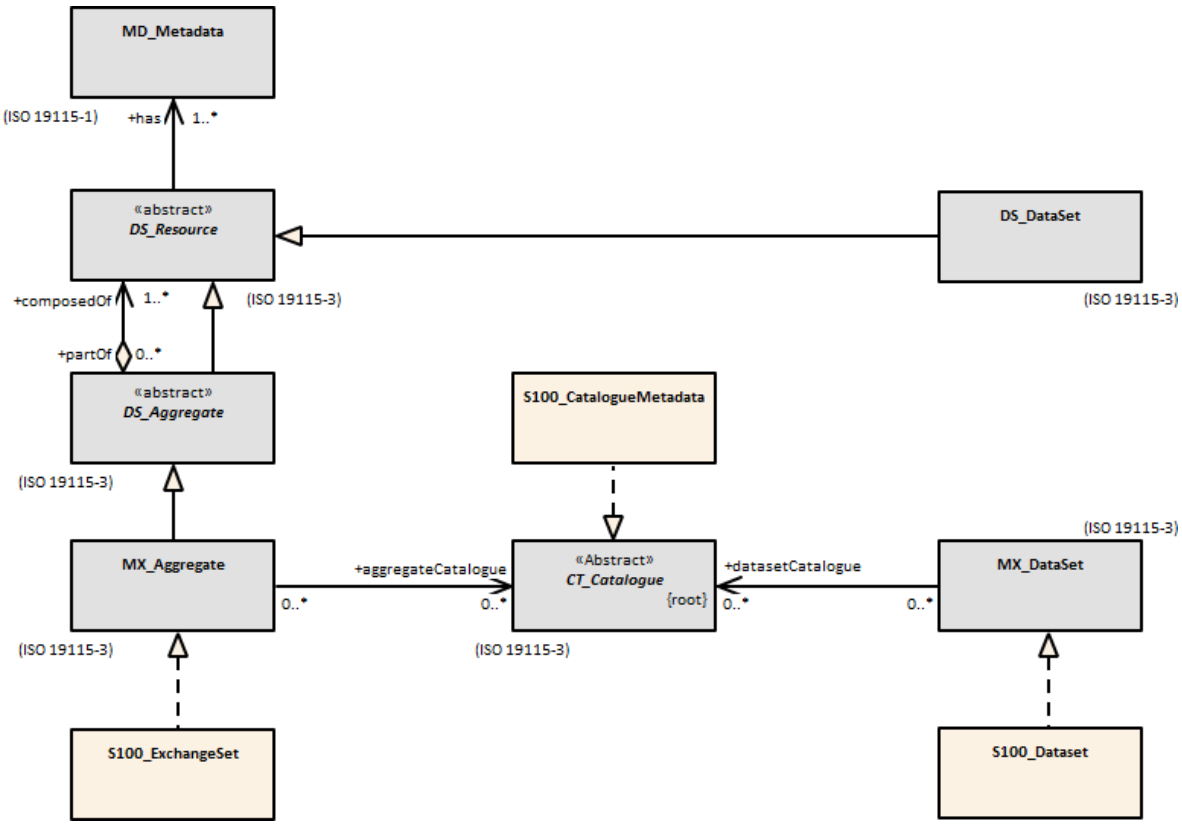


Figure 12-1 – Realisation of the Exchange Set classes (extract from S-100 4.0.0 Figure 4a-D-1)

12.1.2 Metadata in the Exchange Set

Figure 12-2 below depicts the relationships of Exchange Set "core" elements (datasets and Feature/Portrayal Catalogues) and Exchange Set metadata. This Figure is derived from Figure 4a-D-3 in S-100 Edition 4.0.0. Here too, elements and relationships not applicable to S-104 have been omitted (specifically, the classes representing support files and support file discovery metadata and the *MultiAggregation* self- relationship for **S100_ExchangeSet** are omitted). Note also that the link between **S100_Dataset** and **S100_CatalogueMetadata** is implicit by means of the S-104 version to which the Feature Catalogue, Portrayal Catalogue and dataset conform, which must have the same Edition and revision components. Further, S-104 extends S-100 dataset discovery metadata by

adding extra product-specific metadata attributes, in the **S104_DatasetDiscoveryMetadata** class, which is described in detail in clause 12.2.15.

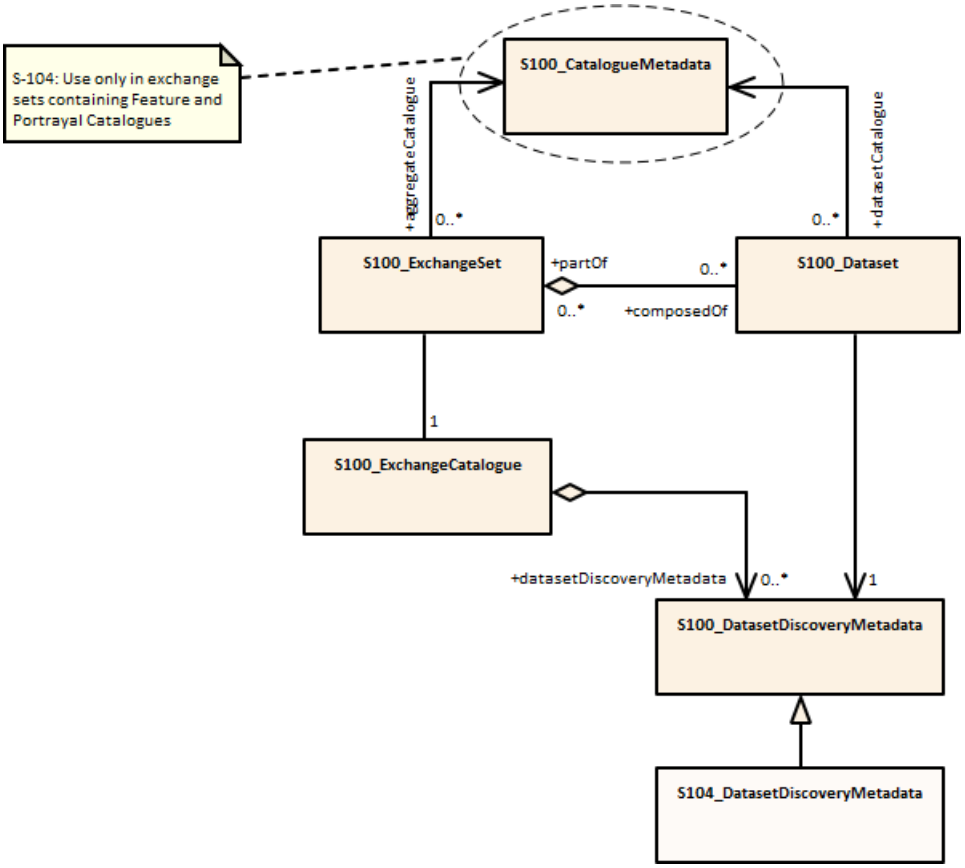


Figure 12-2 – Components and associated metadata for the S-104 Exchange Set (from S-100 Edition 4.0.0 Figure 4a-D-3).

Every Exchange Set must contain an Exchange Catalogue. Dataset discovery metadata (class **S104_DatasetDiscoveryMetadata**) must accompany every S-104 dataset in an Exchange Set. (Being a specialisation of **S100_DatasetDiscoveryMetadata**, it inherits the necessary S-100 dataset discovery metadata attributes.) Similarly, Catalogue metadata must accompany any Feature and Portrayal Catalogues included in the Exchange Set.

Since S-104 does not add product-specific metadata attributes to Catalogue metadata, the S-100 class for Catalogue metadata is used in S-104 Exchange Sets without extension.

Documentation tables for **S100_ExchangeSet** and **S100_Dataset** follow. The tangible representations of these two classes in actual Exchange Sets are the digital files and/or folders containing the Exchange Set and dataset(s) respectively. The tangible representations of their roles are the presences of the respective components within the Exchange Set.

The other classes in Figure 12-2 are represented by XML files or XML blocks and are documented in clause 12.2.

12.1.2.1 S100_ExchangeSet

S-104 Exchange Sets conform to S-100 Exchange Set structure but do not contain support files for datasets. Feature and Portrayal Catalogues may optionally be included.

Table 12-1 – Exchange Set components and relationships

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_ExchangeSet	Aggregation of the elements comprising an Exchange Set for the transfer of data	-	-	See Note 1

Role	composedOf	Collection of datasets which are part of the Exchange Set	0..*	-	See Note 2
Role	aggregateCatalogue	Collection of catalogues	0..*	-	For Feature and Portrayal Catalogues
Role	--	An Exchange Set must have an associated Exchange Catalogue	1	-	See Note 3

NOTES:

(1) The *aggregateFile* association is not used because S-104 Exchange Sets do not contain support files referenced in datasets. The *superSet* and *subSet* associations are not used because S- 104 Exchange Sets do not contain other Exchange Sets.

(2) Correction to S-100, which has “partOf”, contradicting the Figure.

(3) Added in S-104 to document the link to S100_ExchangeCatalogue, which exists in S-100 but is not documented in the S100_ExchangeSet Table in S-100 Edition 4.0.0.

12.1.2.2 S100_Dataset

S-104 datasets have the same place in the S-104 Exchange Set as described in S-100 Edition 4.0.0.

Table 12-2 – Dataset relationships within Exchange Set

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_Dataset		-	-	-
Role	partOf	An Exchange Set is composed of 0 or more datasets	0..*	-	Correction to S-100 4.0.0, which contradicts Figure 4a-D-3 in the S- 100 Table
Role	datasetCatalogue	Catalogue which is related to this dataset	0..*	-	Implicitly linked via version number.

12.2 Discovery Metadata

An outline of the overall concept of an S-104 Exchange Set for the interchange of geospatial data and its relevant metadata is explained in clauses 11.2.1 and 12.1.1. The place of metadata in the Exchange Set is summarised in clause 12.1.2.

Figure 12-3 below depicts the structure of the Exchange Catalogue and its component discovery metadata blocks. The structure is the same as in S-100 Appendix 4a-D with the following extension and restrictions:

- S-104 defines a specialised class for S-104 discovery metadata because S-104 extends S-100 generic discovery metadata with additional product-specific attributes. This specialisation is used in place of **S100_DatasetDiscoveryMetadata**.
- In contrast to S-100 Figure 4a-D-2, support file discovery metadata is not shown because S-104 datasets do not reference support files.

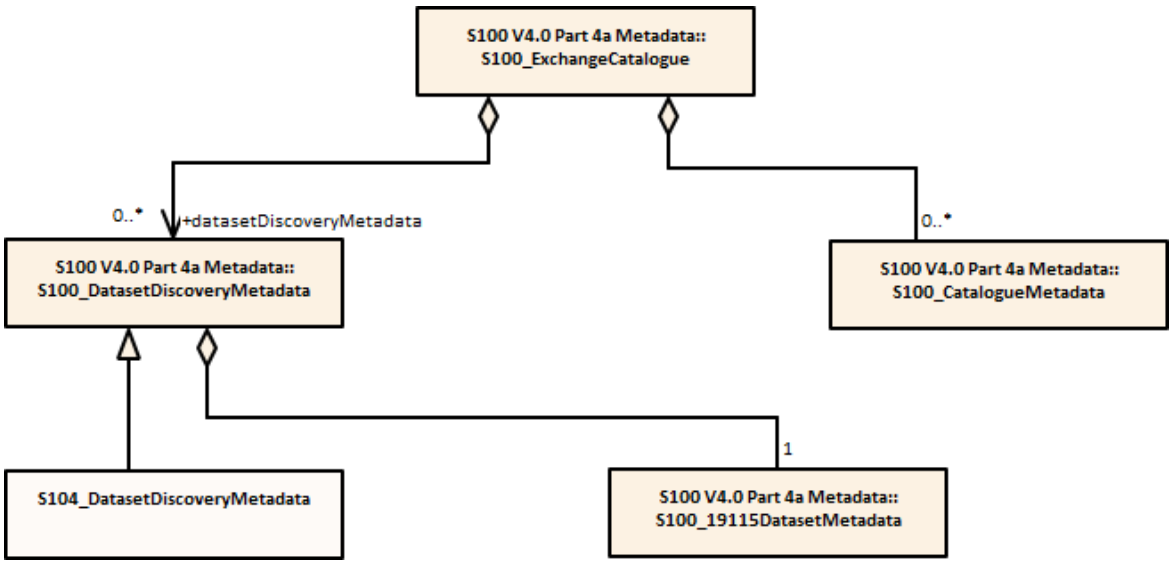


Figure 12-3 – Relationship between Exchange Catalogue, discovery metadata, and dataset (from S- 100 Edition 4.0.0 Figures 4a-D-2 and 4a-D-4).

The detailed structure of the S-104 Exchange Catalogue is depicted in Figure 12-4 below. This Figure is derived from Figure 4a-D-4 in S-100 Edition 4.0.0, with the following extensions and restrictions that are specific to S-104:

- The specialised **S104_DatasetDiscoveryMetadata** class mentioned earlier is added and contains the S-104-specific metadata attributes to the generic S-100 dataset discovery metadata defined in S-100 Part 4a, Appendix 4a-D.
- Elements that are optional in the generic S-100 Catalogue model but not used in S-104 are not shown; for example, the *updateNumber* and *updateApplicationDate* attributes in the dataset discovery class are not used in S-104.
- Constraints that are specific to S-104 are summarised in a diagram note. Details about constraints are provided in the documentation tables following the diagram.

More detailed information about the various classes and textual descriptions are in the Tables in clauses 12.2.1 – 12.2.19 following Figure 12-4.

The file represented by the class **S100_19115DatasetMetadata** is an XML file conforming to ISO 19115-3 format as specified in the ISO 19115-3 XML Schemas supplied by the ISO. This file may repeat metadata elements in the S-100 classes. In S-104 this file is included pro-forma because S-100 Figure 4a-D-2 depicts it as being mandatory for each dataset in the Exchange Set. However, since prototype S-100 viewers do not currently use ISO-format metadata, the ISO metadata file need not be completely populated for S-104 Edition 1.0.0 Exchange Sets.

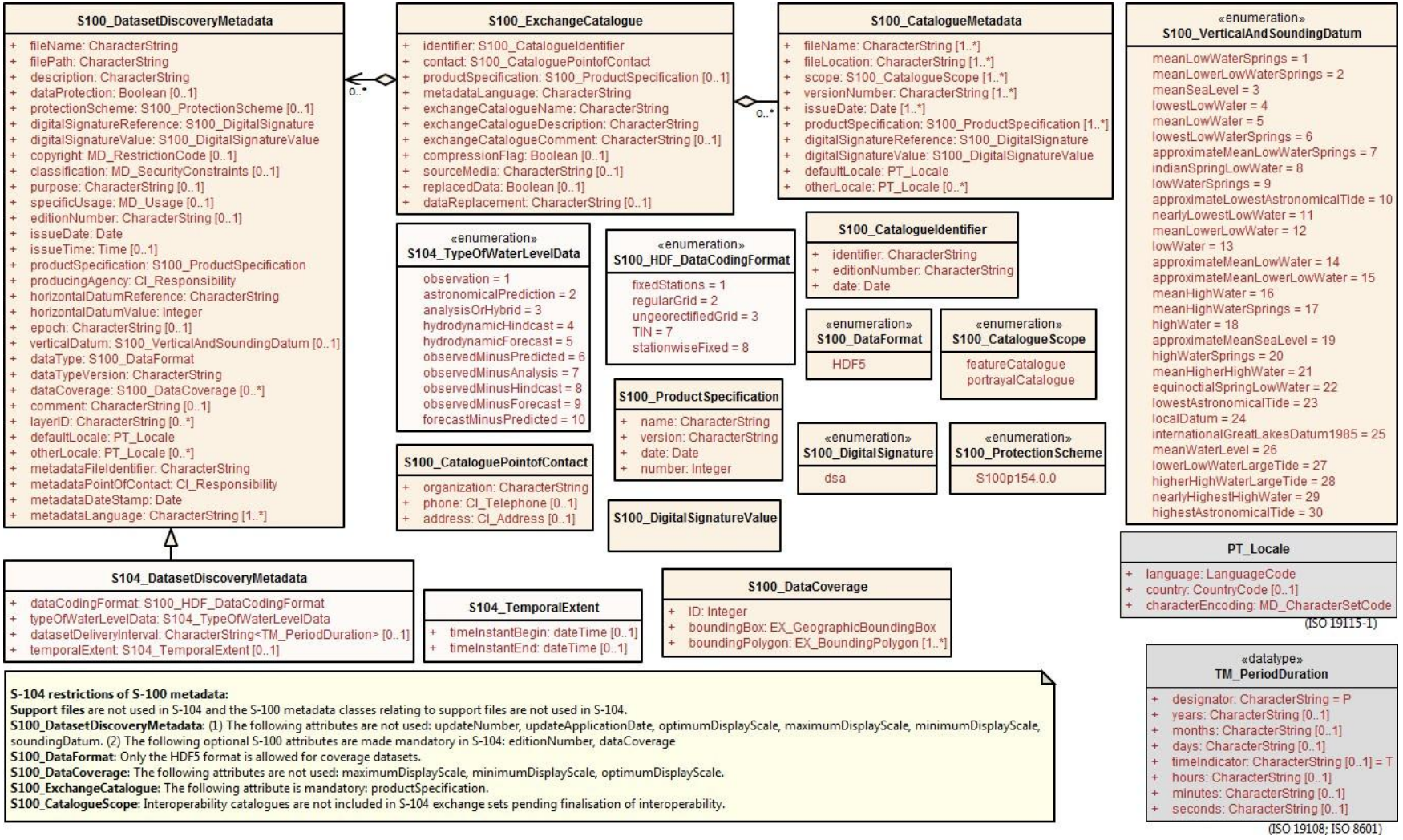


Figure 12-4 – Details of Exchange Set Catalogue classes. Based on S-100 Edition 4.0.0 Figure 4a-D-4.

In S-104 Edition 1.0.0 only Feature and Portrayal Catalogues are allowed. The language used for the metadata is English.

Time reference for all data will be UTC.

All water level values to be given in metres (up to two decimal places for real values).

12.2.1 S100_ExchangeCatalogue

Each Exchange Set has a single S100_ExchangeCatalogue which is an XML file that contains meta information for the data in the Exchange Set. S-104 restricts the S-100 class by omitting the support file metadata classes and, consequently, the S-100 role for their containment or references.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_ExchangeCatalogue	An Exchange Catalogue contains the discovery metadata about the Exchange datasets and support files	-	-	S-104 does not use the aggregation to support file discovery metadata because support files are not used
Attribute	identifier	Uniquely identifies this Exchange Catalogue	1	S100_CatalogueIdentifier	
Attribute	contact	Details about the issuer of this Exchange Catalogue	1	S100_CataloguePointOfContact	
Attribute	productSpecification	Details about the Product Specifications used for the datasets contained in the Exchange Catalogue	1	S100_ProductSpecification	Mandatory in S-104.
Attribute	metadataLanguage	Details about the language	1	CharacterString	Language name from ISO 693-2; for example, “English”.
Attribute	exchangeCatalogueName	Catalogue filename	1	CharacterString	In S-104 it would be CATALOG.XML
Attribute	exchangeCatalogueDescription	Description of what the Exchange Catalogue contains	1	CharacterString	
Attribute	exchangeCatalogueComment	Any additional Information	0..1	CharacterString	
Attribute	compressionFlag	Is the data compressed	0..1	Boolean	Yes or No
Attribute	sourceMedia	Distribution media	0..1	CharacterString	

Attribute	replacedData	If a data file is cancelled is it replaced by another data file	0..1	Boolean	1 if the Exchange Set cancels and replaces a previously issued dataset
Attribute	dataReplacement	Cell name	0..1	CharacterString	
Role	datasetDiscoveryMetadata	Exchange catalogues may include or reference discovery metadata for the datasets in the exchange set	0..*	Aggregation S100_DatasetDiscoveryMetadata	
Role	--	Metadata for catalogue	0..*	Aggregation S100_CatalogueMetadata	Metadata for the feature, portrayal, and interoperability catalogues, if any

12.2.2 S100_CatalogueIdentifier

S-104 uses **S100_CatalogueIdentifier** without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_CatalogueIdentifier	An Exchange Catalogue contains the discovery metadata about the Exchange datasets and support files	-	-	-
Attribute	identifier	Uniquely identifies this Exchange Catalogue	1	CharacterString	See Note 1 for the naming convention
Attribute	editionNumber	The Edition number of this Exchange Catalogue	1	CharacterString	See Note 2
Attribute	date	Creation date of the Exchange Catalogue	1	Date	XML date format

NOTES:

(1) Use the file name component of the dataset according to the convention in clause 11.2.3. For example, if the dataset file is named 104ABCDXYZ_1_20_20210420.HDF5 the metadata identifier should be 104ABCDXYZ_1_20_20210420. In the event of an Exchange Set containing multiple datasets, use the name of the dataset of largest extent with a “+N” suffix (without quotes), where N is the number of additional datasets in the Exchange Set. If the Exchange Set contains only Feature and/or Portrayal Catalogues, use 104ABCD+N where “ABCD” is the 4-character code of the producer of the Feature or Portrayal Catalogue.

(2) The Edition number must be the same as the Edition number of the dataset of largest extent contained in this Exchange Set. A “.n” suffix (*n* being successive positive integers) may be added if necessary to distinguish from Exchange Catalogues in previously issued Exchange Sets (this is theoretically possible if an Exchange Set is being reissued; for example, with a change to only a minor dataset or to a Feature or Portrayal Catalogue).

12.2.3 S100_CataloguePointofContact

S-104 uses **S100_CataloguePointOfContact** without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_CataloguePointOfContact	Contact details of the issuer of this Exchange Catalogue	-	-	-
Attribute	organization	The organization distributing this Exchange Catalogue	1	CharacterString	This could be an individual Producer, value added reseller, etc
Attribute	phone	The phone number of the organization	0..1	CI_Telephone	
Attribute	address	The address of the organization	0..1	CI_Address	

12.2.4 S100_DatasetDiscoveryMetadata

Data in the Discovery Metadata are used to identify the relevance of the dataset to the particular application. S-104 restricts the multiplicity and contents of **S100_DatasetDiscoveryMetadata** as described in the Remarks column.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_DatasetDiscoveryMetadata	Metadata about the individual datasets in the Exchange Catalogue	-	-	S-104 does not use the following optional S-100 attributes: updateNumber, updateApplicationDate, optimumDisplayScale, maximumDisplayScale, minimumDisplayScale, soundingDatum S-104 does not use the aggregation to support file discovery metadata because support files are not referenced in S-104 datasets
Attribute	fileName	Dataset file name	1	CharacterString	
Attribute	filePath	Full path from the Exchange Set root directory	1	CharacterString	Path relative to the root directory of the Exchange Set. The location of the file after the Exchange Set is unpacked into directory <EXCH_ROOT> will be <EXCH_ROOT>/<filePath>/<filename>
Attribute	description	Short description giving the area or location covered by the dataset	1	CharacterString	For example, a harbour or port name, between two named locations etc
Attribute	dataProtection	Indicates if the data is encrypted	0..1	Boolean	0. indicates an unencrypted dataset 1. indicates an encrypted dataset

Role Name	Name	Description	Mult	Type	Remarks
Attribute	protectionScheme	Specification or method used for data protection	0..1	S100_ProtectionScheme	In S-100 Edition 4.0.0 the only allowed value is “S100p154.0.0”.
Attribute	digitalSignatureReference	Indicates if the data has a digital signature	0..1	S100_DigitalSignature	Specifies the algorithm used to compute digitalSignatureValue
Attribute	digitalSignatureValue	Digital signature	0..1	S100_DigitalSignatureValue	The value resulting from application of digitalSignatureReference Implemented as the digital signature format specified in S-100 Part 15
Attribute	copyright	Indicates if the dataset is copyrighted	0..1	MD_LegalConstraints> MD_RestrictionCode <copyright> (ISO 19115-1)	If copyrighted, use the code “copyright”
Attribute	classification	Indicates the security classification of the dataset	0..1	MD_SecurityConstraints> MD_ClassificationCode (codelist)	1. unclassified 2. restricted 3. confidential 4. secret 5. top secret 6. sensitive but unclassified 7. for official use only 8. protected 9. limited distribution
Attribute	purpose	The purpose for which the dataset has been issued	1	MD_Identification>purpose CharacterString	For example, new, re-issue, new edition, update etc. The allowed string values and their definitions are given below: **String value** **Definition** newDataset New dataset newEdition New edition of the dataset update Dataset update reissue Dataset that has been re-issued cancellation Dataset that has been cancelled
Attribute	specificUsage	The use for which the dataset is intended	1	MD_USAGE>specificUsage (character string)	For example, in the case of ENCs this would be a navigation purpose classification. The string *Not For Navigation* must be encoded when dates are outside the range specified in Table 10-3.

Role Name	Name	Description	Mult	Type	Remarks
Attribute	editionNumber	The Edition number of the dataset	1	CharacterString	When a data set is initially created, the Edition number 1 is assigned to it. The Edition number is increased by 1 at each New Edition. Edition number remains the same for a re-issue Mandatory in S-104
Attribute	issueDate	Date on which the data was made available by the Data Producer	1	Date	
Attribute	issueTime	Time of day at which the data was made available by the Data Producer	0..1	Time	The S-100 datatype Time in XML format
Attribute	productSpecification	The product specification used to create this dataset	1	S100_ProductSpecification	
Attribute	producingAgency	Agency responsible for producing the data	1	CI_ResponsibleParty	
Attribute	horizontalDatumReference	Reference to the register from which the horizontal datum value is taken	1	CharacterString	EPSG
Attribute	horizontalDatumValue	Horizontal Datum of the entire dataset	1	Integer	4326
Attribute	epoch	Code denoting the epoch of the geodetic datum used by the CRS	0..1	CharacterString	For example, 2005.0 to represent the 2005 realization of WGS84 (the base CRS for EPSG 4326). (This recommendation differs from the remark) in S-100 Edition 4.0.0 which uses the GPS week number, but ISO standards use xxxx.y)
Attribute	verticalDatum	Vertical Datum of the entire dataset	0..1	S100_VerticalAndSoundingDatum	Must be encoded if the vertical datum is listed in S100_VerticalAndSoundingDatum, in the IHO GI registry, or the EPSG Registry See the Table of vertical datums and the note in clause 12.2.10 for allowed values and format
Attribute	dataType	The encoding format of the dataset	1	S100_DataFormat	
Attribute	dataTypeVersion	The version number of the dataType.	1	CharacterString	
Attribute	dataCoverage	Area covered by the dataset	1	S100_DataCoverage	Mandatory in S-104
Attribute	comment	Any additional information	0..1	CharacterString	

Role Name	Name	Description	Mult	Type	Remarks
Attribute	layerID	Identifies other layers with which this dataset is intended to be used or portrayed	0..*	CharacterString	For example, a Marine Protected Area dataset needs an ENC dataset to portray as intended in an ECDIS
Attribute	defaultLocale	Default language and character set used in the Exchange Catalogue	1	PT_Locale	
Attribute	otherLocale	Other languages and character sets used in the Exchange Catalogue	0..*	PT_Locale	
Attribute	metadataFileIdentifier	Identifier for metadata file	1	CharacterString	For example, for ISO 19115-3 metadata file
Attribute	metadataPointOfContact	Point of contact for metadata	1	CI_Responsibility > CI_Individual or CI_Responsibility > CI_Organisation	
Attribute	metadataDateStamp	Date stamp for metadata	1	Date	May or may not be the issue date of the dataset
Attribute	metadataLanguage	Language(s) in which the metadata is provided	1..*	CharacterString	Language name from ISO 693-2; for example, “English”

12.2.5 S100_DataCoverage

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_DataCoverage		-	-	The attributes optimumDisplayScale, minimumDisplayScale, and maximumDisplayScale are not used
Attribute	ID	Uniquely identifies the coverage	1	Integer	-
Attribute	boundingBox	The extent of the dataset limits	1	EX_GeographicBoundingBox	-
Attribute	boundingPolygon	A polygon which defines the actual data limit	1..*	EX_BoundingPolygon	May be encoded with an appropriate nilReason code if unavailable. The codes are in the S-100 schemas For example: <S100XC:boundingPolygon> <gex:polygon gco:nilReason=”unknown”/> </S100XC:boundingPolygon>

12.2.6 S100_DigitalSignature

S-104 uses S100_DigitalSignature without modification.

Role Name	Name	Description	Code	Remarks
Enumeration	S100_DigitalSignature	Algorithm used to compute the digital signature	-	-
Value	dsa	Digital Signature Algorithm	-	FIPS 186-4 (2013)

12.2.7 S100_DigitalSignatureValue

S-104 uses S100_DigitalSignatureValue without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_DigitalSignatureValue	Signed Public Key plus the digital signature	-		Data type for digital signature values. See S-100 Part 15 for content and format

12.2.8 EX_GeographicBoundingBox

From ISO 19115-1.

Role Name	Name	Description	Mult	Type	Remarks
Class	EX_GeographicBoundingBox	Geographic position of the dataset	-	-	Defined in ISO 19115-1: Geographic position of the resource
Attribute	westBoundLongitude	Western-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east)	1	Real	Arc degrees
Attribute	eastBoundLongitude	Eastern-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east)	1	Real	Arc degrees
Attribute	southBoundLatitude	Southern-most coordinate of the limit of the dataset extent, expressed in latitude in decimal degrees (positive north)	1	Real	Arc degrees
Attribute	northBoundLatitude	Northern-most, coordinate of the limit of the dataset extent expressed in latitude in decimal degrees (positive north)	1	Real	Arc degrees

NOTE (from ISO 19115-1): This is only an approximate reference so specifying the coordinate reference system is unnecessary and need only be provided with a precision of up to two decimal places.

12.2.9 EX_BoundingPolygon

From ISO 19115-1.

Role Name	Name	Description	Mult	Type	Remarks
Class	EX_BoundingPolygon	Boundary enclosing the dataset, expressed as the closed set of (x,y) coordinates of the polygon (last point replicates first point)	-	-	Defined in ISO 19115-1: Enclosing geometric object which locates the resource, expressed as a set of (x,y) coordinate(s)
Attribute	polygon	Sets of points defining the bounding polygon	1	GM_Object	Must be a GM_Polygon (See S-100 Part 7, ISO 19107, ISO 19136)

NOTE (from ISO 19115-1): If a polygon is used it should be closed (last point replicates first point).

12.2.10 S100_VerticalAndSoundingDatum

S-104 uses the same enumeration as S-100 and adds a convention about how to encode datums not in the S-100 enumeration (see the Note below the table).

Role Name	Name	Description	Code	Remarks
Enumeration	S100_VerticalAndSoundingDatum	Allowable vertical and sounding datums	-	-
Value	meanLowWaterSprings		1	(MLWS)
Value	meanLowerLowWaterSprings		2	-
Value	meanSeaLevel		3	(MSL)
Value	lowestLowWater		4	-
Value	meanLowWater		5	(MLW)
Value	lowestLowWaterSprings		6	-
Value	approximateMeanLowWaterSprings		7	-
Value	indianSpringLowWater		8	-
Value	lowWaterSprings		9	-
Value	approximateLowestAstronomicalTide		10	-
Value	nearlyLowestLowWater		11	-
Value	meanLowerLowWater		12	(MLLW)
Value	lowWater		13	(LW)
Value	approximateMeanLowWater		14	-

Value	approximateMeanLowerLowWater		15	-
Value	meanHighWater		16	(MHW)
Value	meanHighWaterSprings		17	(MHWS)
Value	highWater		18	(HW)
Value	approximateMeanSeaLevel		19	-
Value	highWaterSprings		20	-
Value	meanHigherHighWater		21	(MHHW)
Value	equinoctialSpringLowWater		22	-
Value	lowestAstronomicalTide		23	(LAT)
Value	localDatum		24	-
Value	internationalGreatLakesDatum1985		25	-
Value	meanWaterLevel		26	-
Value	lowerLowWaterLargeTide		27	-
Value	higherHighWaterLargeTide		28	-
Value	nearlyHighestHighWater		29	-
Value	highestAstronomicalTide		30	(HAT)

NOTE: S-100 Edition 4.0.0 lists only the 30 datums in this table. As a temporary measure for S-104 Edition 1.0.0 pending a resolution to this issue in S-100 Edition 5.0.0, the following rules are defined for encoding of datums:

- If the datum is one of the listed values in the vertical datum enumeration in the table above, it must be encoded as the listed value.
- Otherwise, if the datum is one of the listed values for vertical datum in the “Data Dictionary Register” of the IHO GI Registry, that IHO GI Registry entry must be used.
- If the datum is not listed in the enumeration or the ISO GI Registry, but is listed in the EPSG Registry, the EPSG entry must be used.
- Datums not included in the S-100 enumeration may be encoded using the “other: …” form permitted by the S-100 Edition 4.0.0 Exchange Catalogue format (see the Exchange Catalogue XML Schemas for S-100).
- For datums from the IHO GI Registry, the “camel case code” in the registry must be used in the “other: …” element. For datums from the EPSG Registry, the form should be “other: EPSG_NNNN”.
  - For example, the Baltic Sea Chart Datum 2000 is in the IHO GI Registry and must be encoded as:

    ```
    <S100XC:verticalDatum xsi:nil=”true” gco:nilReason=”other: balticSeaChartDatum2000”/>
    ```

    Where “balticSeaChartDatum2000” is the code given for the “Baltic Sea Chart Datum 2000” listed value in the vertical datum enumeration in the data dictionary register of the IHO GI registry.

- If the datum is not listed in the Table above, the IHO GI Registry or the EPSG Registry, producers should determine a suitable special code in consultation with the appropriate IHO Working Group(s) and the IHO GI Registry authority.
- The use of datums that are neither in the enumeration above, nor in the IHO GI Registry, nor the EPSG Registry is discouraged. Producers who need to use a datum not listed in the S-100 enumeration should propose its addition to the IHO GI Registry and/or this enumeration by means of an S-100 Maintenance Proposal.

Note that application software is not required to process information encoded in "other: …" form, meaning that ECDIS software, for example, is not required to recognise any datum encoded as "other: …" and will therefore be unable to adjust ENC depth information with water level data from the corresponding S-104 dataset, and may warn or reject the S-104 dataset as being incompatible with S-101 ENCs.

12.2.11 S100_DataFormat

Role Name	Name	Description	Code	Remarks
Enumeration	S100_DataFormat	Encoding format	-	The S-100 values ISO/IEC 8211 and GML are allowed only for metafeature files, if included in the exchange set (not allowed in S-104 Edition 1.0.0). The S-100 value 'undefined' is not used
Value	HDF5	The HDF5 data format as defined in Part 10c	-	-

12.2.12 S100_ProductSpecification

S-104 uses S100_ProductSpecification without modification.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_ProductSpecification	The Product Specification contains the information needed to build the specified product	-	-	-
Attribute	name	The name of the Product Specification used to create the datasets	1	CharacterString	The name in the Product Specification Register, in the IHO Geospatial Information Registry
Attribute	version	The version number of the Product Specification	1	CharacterString	For example, 1.0.0 for S-104 Edition 1.0.0
Attribute	date	The version date of the Product Specification	1	Date	
Attribute	number	The number (Registry index) used to lookup the product in the Product Specification Register of the IHO GI Registry	1	Integer	From the Product Specification Register, in the IHO Geospatial Information Registry

12.2.13 S100_CatalogueMetadata

S-104 uses S100_CatalogueMetadata without modification. This class is used to provide metadata about Feature and Portrayal Catalogues.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_CatalogueMetadata		-	-	-
Attribute	filename	The name for the Catalogue	1..*	CharacterString	
Attribute	fileLocation	Full location from the Exchange Set root directory	1..*	CharacterString	Path relative to the root directory of the Exchange Set. The location of the file after the Exchange Set is unpacked into directory <EXCH_ROOT> will be <EXCH_ROOT>/<filePath>/<filename>
Attribute	scope	Subject domain of the Catalogue	1..*	S100_CatalogueScope	
Attribute	versionNumber	The version number of the Product Specification	1..*	CharacterString	
Attribute	issueDate	The version date of the Product Specification	1..*	Date	
Attribute	productSpecification	The Product Specification used to create this file	1..*	S100_ProductSpecification	
Attribute	digitalSignatureReference	Digital signature of the file	1	CharacterString	Reference to the appropriate digital signature algorithm
Attribute	digitalSignatureValue	Value derived from the digital signature	1	CharacterString	

12.2.14 S100_CatalogueScope

Role Name	Name	Description	Code	Remarks
Enumeration	S100_CatalogueScope	The scope of the Catalogue	-	S-104 1.0.0 datasets do not contain Interoperability Catalogues and the value *interoperabilityCatalogue* is removed
Value	featureCatalogue	S-100 Feature Catalogue	-	
Value	portrayalCatalogue	S-100 Portrayal Ctalogue		

12.2.15 S104_DatasetDiscoveryMetadata

The class S104_DatasetDiscoveryMetadata is an extension of S100_DatasetDiscoveryMetadata and inherits the attributes and constraints of that class which are described in clause 12.2.4.

Role Name	Name	Description	Mult	Type	Remarks
Class	S104_DatasetDiscoveryMetadata	S-104 extension of generic S-100 dataset discovery metadata	-	-	Extension of S100_DatasetDiscoveryMetadata
Attribute	typeOfWaterLevelData	Type or source of water level data (Table 7-1)	1	S104_TypeOfWaterLevelData	See clause 12.2.18
Attribute	dataCodingFormat	Data organization index, used to read the data (Table 10-1)	1	S100_HDF_DataCodingFormat	See clause 12.2.17 Only the values listed in Clause 12.2.17 are allowed in S-104. Other values which may be defined in S-100 Part 10c are not allowed
Attribute	datasetDeliveryInterval	The expected time interval between availability of successive datasets for time-varying data	0..1	CharacterString <TM_PeriodDuration>	Allowed only if dataCodingFormat is 1 or 8, and optional even if dataCodingFormat = 1 or 8 Format: PnYnMnDTnHnMnS (XML built-in type for ISO 8601 *duration*). See Note
Attribute	temporalExtent	Specification of the temporal extent of the dataset	0..1	S104_TemporalExtent	The temporal extent is encoded as the date/time of the earliest and latest records in the dataset. If there is more than one feature in a dataset, the earliest and latest time values of records in all features are used, which means the earliest and latest values may be from different features This attribute is encoded if and only if at least one of the start and end of the temporal extent is known
	(Attributes inherited from S100_DatasetDiscoveryMetadata (clause 12.2.4)				

NOTE: The format for *datasetDeliveryInterval* is given by the XML built-in datatype *duration*, which can be validated by off-the-shelf XML parsers. See "*XML Schema Part 2: Datatypes (2nd edition) - Clause 3.2.6 duration*" (extracts below):

*The lexical representation for **duration** is the ISO 8601 extended format PnYnMnDTnHnMnS, where nY represents the number of years, nM the number of months, nD the number of days, 'T' is the date/time separator, nH the number of hours, nM the number of minutes and nS the number of seconds. The number of seconds can include decimal digits to arbitrary precision.*

The values of the Year, Month, Day, Hour and Minutes components are not restricted but allow an arbitrary unsigned integer, i.e., an integer that conforms to the pattern [0-9]+.. Similarly, the value of the Seconds component allows an arbitrary unsigned decimal. Following ISO 8601, at least one digit must follow the decimal point if it appears.

Reduced precision and truncated representations of this format are allowed provided they conform to the following:

- *If the number of years, months, days, hours, minutes, or seconds in any expression equals zero, the number and its corresponding designator ·may· be omitted. However, at least one number and its designator ·must· be present.*
- *The seconds part ·may· have a decimal fraction.*
- *The designator 'T' must be absent if and only if all of the time items are absent. The designator 'P' must always be present.*

S-104 restricts the ISO 8601/XML format by disallowing negative values.

S-104 recommends (but does not require) using 2 digits for the months, days, hours, minutes, components, when they are present. If the seconds component is encoded, two digits are recommended for the number of whole seconds (for example, encode 0.5 seconds as PT00.5S; encode 100 seconds as PT01M40S).

EXAMPLE 1: P3DT10H30M and P0Y0M3DT10H30M both indicate an interval of 3 days, 10 hours, and 30 minutes.

EXAMPLE 2: P0Y0M0DT06H00M00S, PT6H, PT06H00M00S, PT6H0.00S all indicate an interval of exactly 6 hours.

EXAMPLE 3: P30M indicates an interval of 30 months, not 30 minutes. PT30M indicates an interval of 30 minutes.

EXAMPLE 4: P6H, P30S, and P30M10S are invalid (they contain time components but lack the ‘T’ designator).

EXAMPLE 5: PT30m is invalid (‘m’ should be upper-case).

EXAMPLE 6: PT12:30 and P3DT10H 30M are invalid (the ‘:’ or space separators are not allowed, only the separators specified by the XML Schema datatypes specification for *duration* are allowed).

12.2.16 PT_Locale

Role Name	Name	Description	Mult	Type	Remarks
Class	PT_Locale	Description of a locale	-	-	From ISO 19115-1
Attribute	language	Designation of the locale language	1	LanguageCode	ISO 639-2 3-letter language codes
Attribute	country	Designation of the specific country of the locale language	0..1	CountryCode	ISO 3166-2 2-letter country codes
Attribute	characterEncoding	Designation of the character set to be used to encode the textual value of the locale	1	MD_CharacterSetCode	Use (the “Name” from the) IANA Character Set register: (ISO 19115-1 B.3.14) For example, UTF-8

LanguageCode, *CountryCode*, and *MD_CharacterSetCode* are codelists which are defined in resource files within the S-100 XML Schemas package and described in the documentation for the S-100 XML Schemas.

12.2.17 S100_HDF_DataCodingFormat

Item	Name	Description	Code	Remarks
Enumeration	S100_HDF_DataCodingFormat	Data coding formats for S-100 HDF5 data	-	S-104 does not use movingPlatform, irregularGrid, or variableCellSize data coding formats
Value	fixedStations	Data at multiple discrete fixed point locations	1	
Value	regularGrid	Data at grid points forming a regular grid with constant cell spacing	2	Regular grids are commonly composed of perpendicularly crossing lines of equal spacing on each dimension, creating square or rectangular cells
Value	ungeorectifiedGrid	Data that does not include any information that can be used to determine a cell's geographic coordinate values, or in which cell spacing is variable, and there is no predefined association between one cell's location and that of another	3	For example, a digital perspective aerial photograph without georectification information included
Value	TIN	Triangulated irregular network	7	A TIN is a representation of a continuous surface consisting entirely of triangular facets. The vertices at the corners of each triangle are shared with the adjacent triangle. These vertices form the control points of the coverage function
Value	stationwiseFixed	Time series at fixed stations (stationwise)	8	Data at multiple discrete fixed point locations organized by station

12.2.18 S104_TypeOfWaterLevelData

See clause 7.1 for detailed descriptions of the types of water level data based on source.

Item	Name	Description	Code	Remarks
Enumeration	S104_TypeOfWaterLevelData	Type of water level data	-	
Value	observation	Values from in-situ sensor(s); may be quality controlled and stored after collection	1	Includes both historical and real-time observations Sensors (for example, tide gauges deployed along a channel) are monitored by the data collecting authority. After data acquisition, the data are quality controlled and stored by the producing authority
Value	astronomicalPrediction	Values computed using harmonic analysis or other proven method of tidal analysis	2	
Value	analysisOrHybrid	Values calculated by statistical or other indirect methods, or a combination of methods	3	A hybrid method combines two or more approaches
Value	hydrodynamicHindcast	Values calculated from a two- or three-dimensional dynamic simulation of past conditions using only observed data for boundary forcing, via statistical method or combination	4	A hindcast is a model simulation that attempts to recreate present conditions by using the most recent observational data

Value	hydrodynamicForecast	Values calculated from a two- or three-dimensional dynamic simulation of future conditions using predicted data for boundary forcing, via statistical method or combination	5	A forecast is a simulation made for many hours into the future using predicted winds, water levels, etc
Value	observedMinusPredicted	Values computed as observed minus predicted values	6	Observation minus astronomical prediction
Value	observedMinusAnalysis	Values computed as observed minus analysis values	7	Observation minus analysis or hybrid
Value	observedMinusHindcast	Values computed as observed minus hindcast values	8	Observation minus hydrodynamic hindcast
Value	observedMinusForecast	Values computed as observed minus forecast values	9	Observation minus hydrodynamic forecast
Value	forecastMinusPredicted	Values computed as forecast minus predicted values	10	Hydrodynamic forecast minus astronomical prediction

12.2.19 S104_TemporalExtent

Role Name	Name	Description	Mult	Type	Remarks
Class	S104_TemporalExtent	Temporal extent	-		At least one of the timeInstantBegin and timeInstantEnd attributes must be populated; if both are known, both must be populated
Attribute	timeInstantBegin	The instant at which the temporal extent begins	0..1	dateTime	Must be a UTC dateTime value in XML Schema dateTime format. For example, 2021-08-03T06:00:00Z for 6am UTC on August 3, 2021
Attribute	timeInstantEnd	The instant at which the temporal extent ends	0..1	dateTime	Must be a UTC dateTime value in XML Schema dateTime format. For example, 2021-08-03T06:00:00Z for 6am UTC on August 3, 2021

12.3 Carrier metadata

The metadata for the S-104 product is divided in three sections, corresponding to the General Metadata (Table 12-3), the Feature Metadata (Table 12-4), and the Instance Metadata (Table 12-5 and Table 12-6). The Instance Metadata is subdivided into metadata attached to the instance as a whole (Table 12-5) and metadata attached to individual values groups (Table 12-6). Since these values do not reside in the Metadata blocks in the Exchange Catalogue, but are in the HDF5 files, they are referred to as Carrier Metadata. The Carrier Metadata consists of the data and parameters needed to read and interpret the information in the Water Level product even if the other S-104 metadata files are unavailable.

Note that in Tables 12-3 – 12-6, some of the metadata variables have restrictions on their core values (that is, whether they are optional or mandatory, the specific values allowed, etc) that are not imposed in S-100. These are grouped under the heading '*Additional restrictions on core metadata for S-104*'.

It is suggested for any enumeration in S-104, to use unsigned integer types (preferably standard integer type H5T_STD_U8LE) for the base type of the numeric code when creating the enumeration[4].

Figures 12-5 through 12-9 depict the carrier metadata at each level of the structural hierarchy in a HDF5 dataset. The elements (groups and metadata) defined in S-100 are distinguished from those defined in S-104 by prefix and shade. Figure 12-5 below is a summary diagram depicting all levels of the structural and their associated metadata components for all the coverage types used in S-104. Figures 12-6 through 12-9 show the details for each structural level and each coverage type.

The same information as in Figures 12-6 through 12-9 is depicted in Annex C (Figures C-6 through C-10) but organised by type of coverage instead of levels in the HDF5 structural hierarchy.

[4] See the guidance on HDF5 datatypes (https://support.hdfgroup.org/HDF5/Tutor/datatypes.html, retrieved 20 August 2021) for more information on the use of standard vs. native types when creating a dataset and for memory operations (read/write).

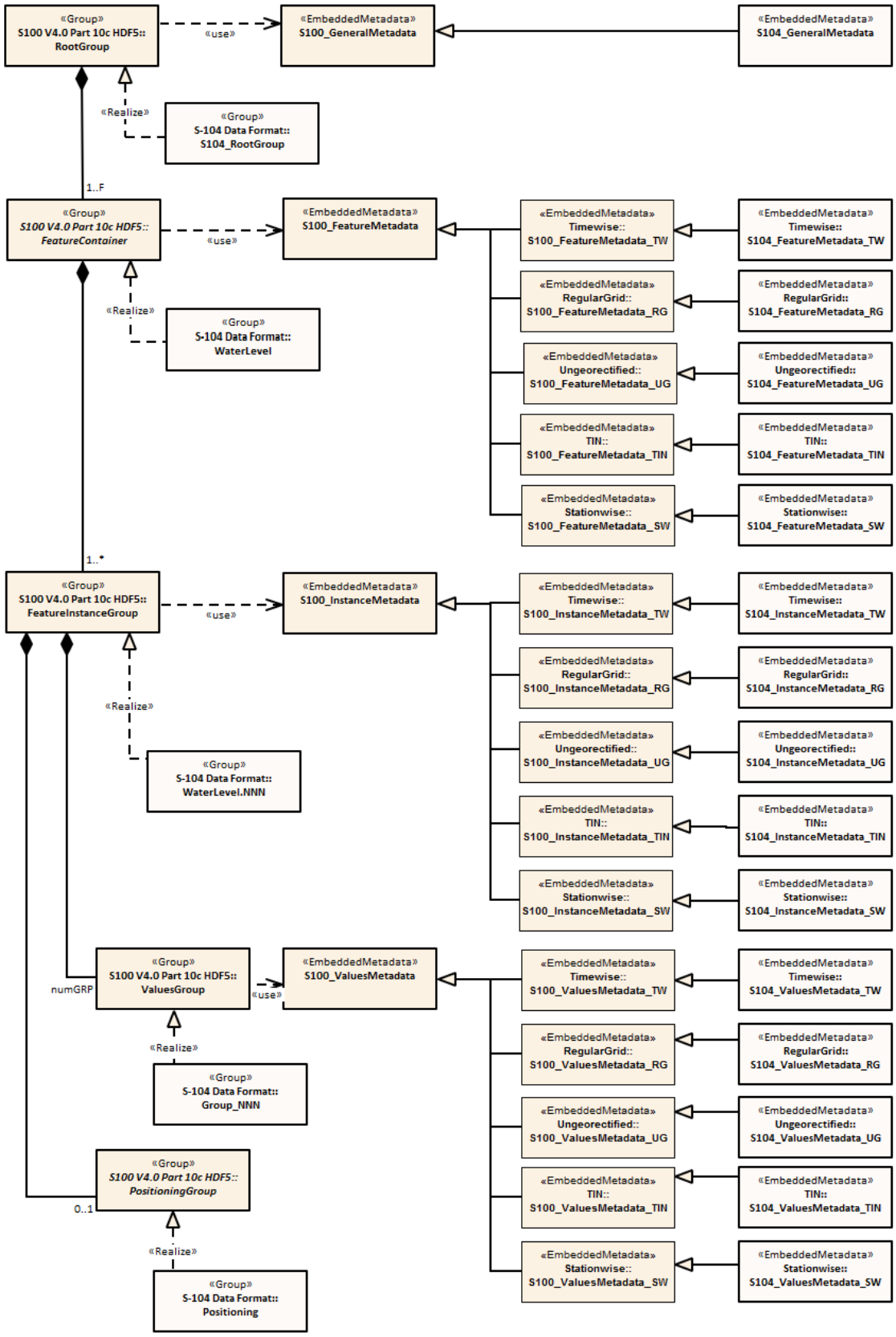


Figure 12-5 – Carrier Metadata for the S-104 HDF5 group hierarchy

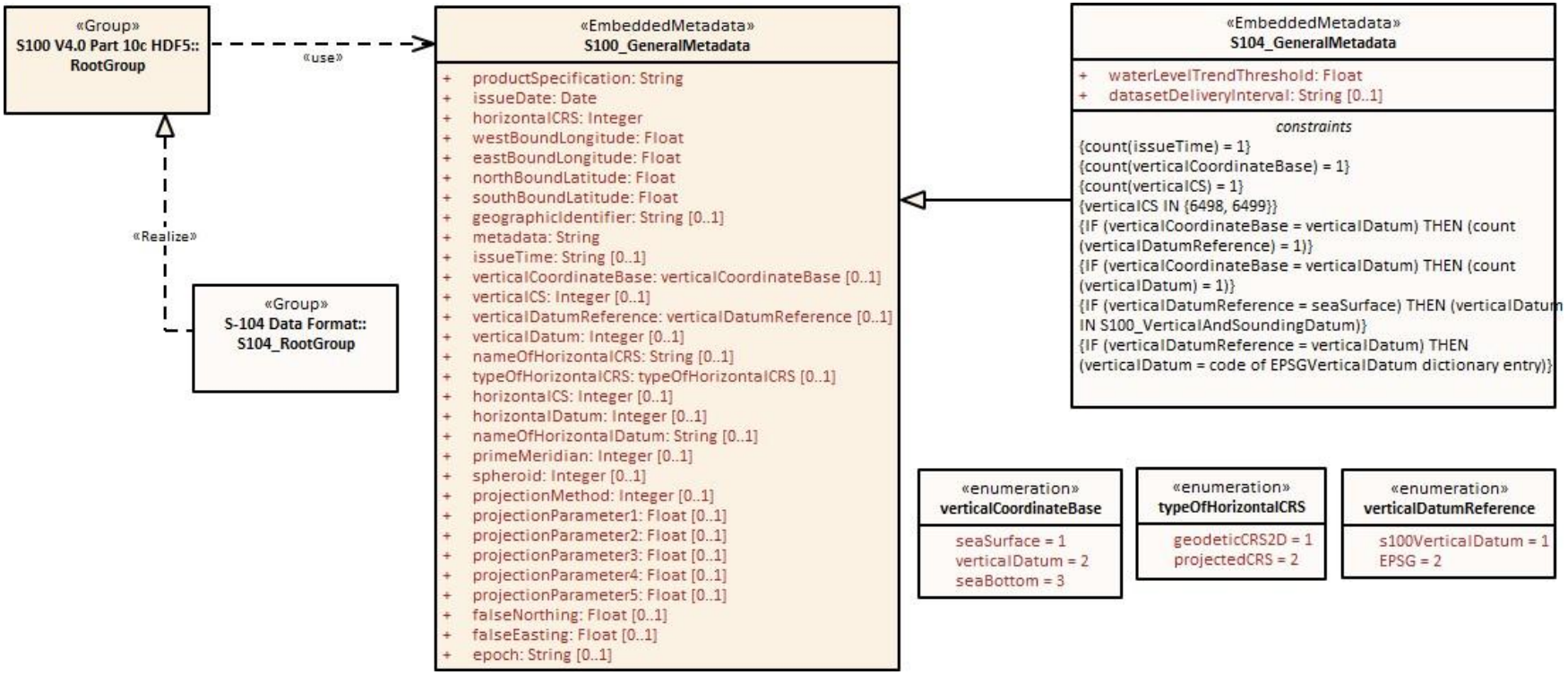


Figure 12-6 – General Metadata – Carrier Metadata for the root group

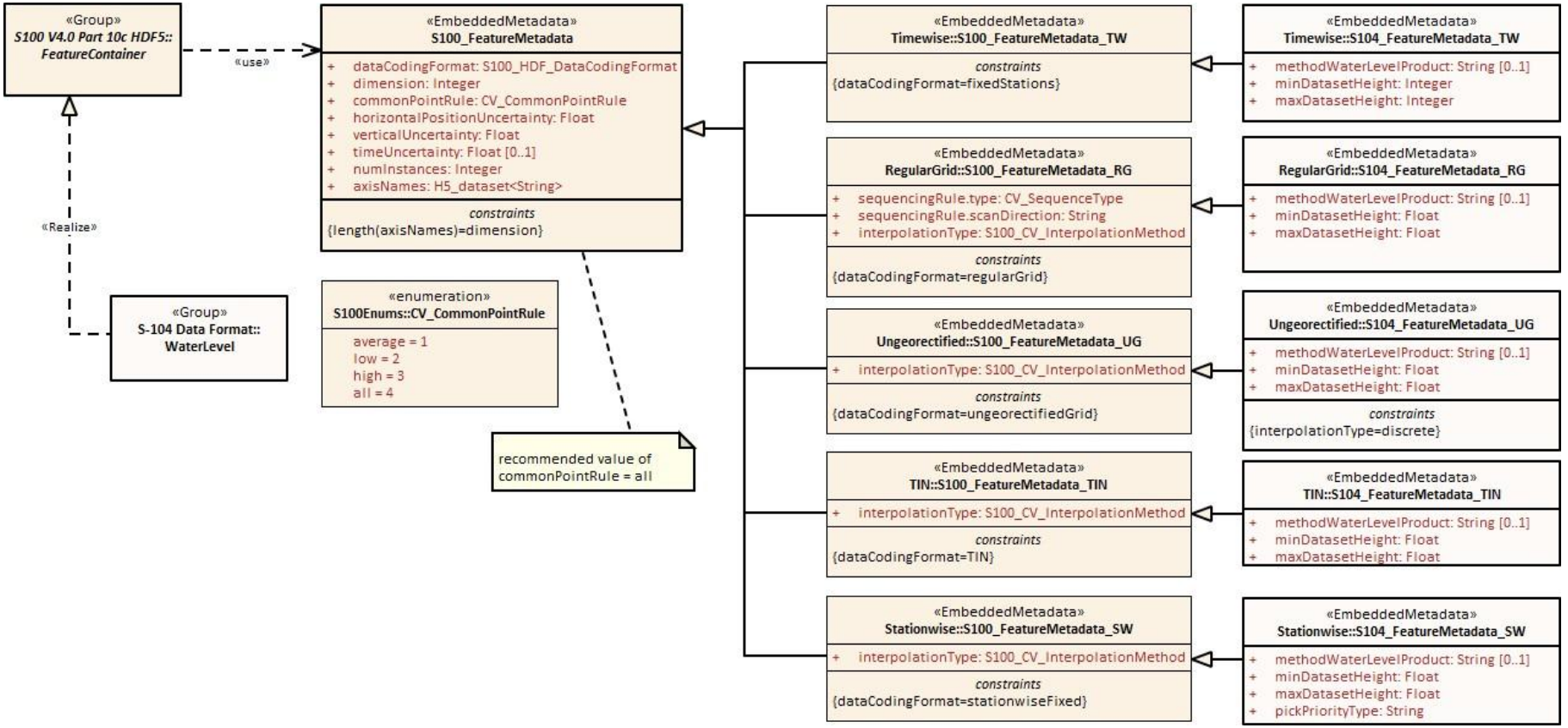


Figure 12-7 – Type Metadata – Carrier Metadata for the Feature Container group

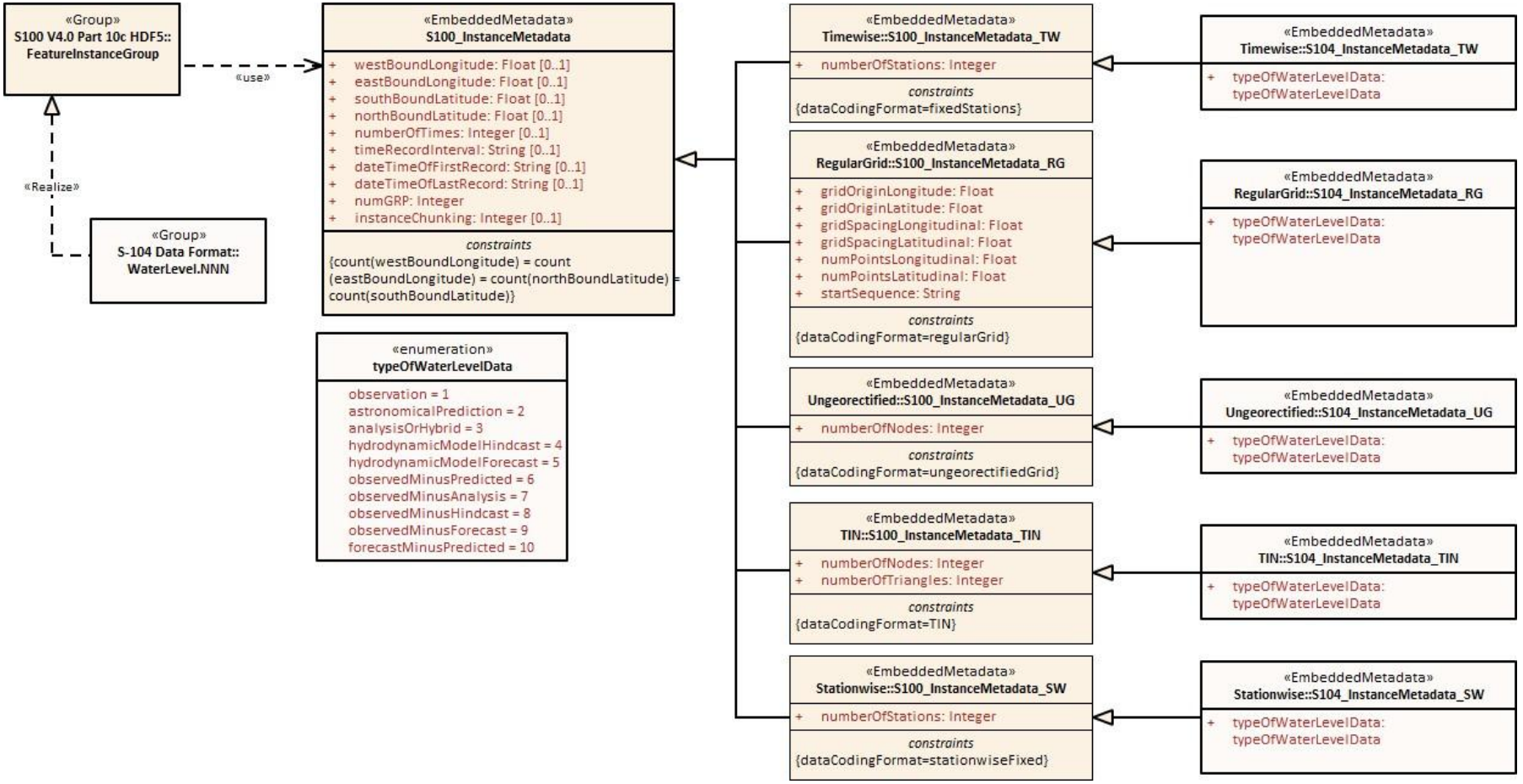


Figure 12-8 – Instance metadata – Carrier Metadata for the Feature Instance group

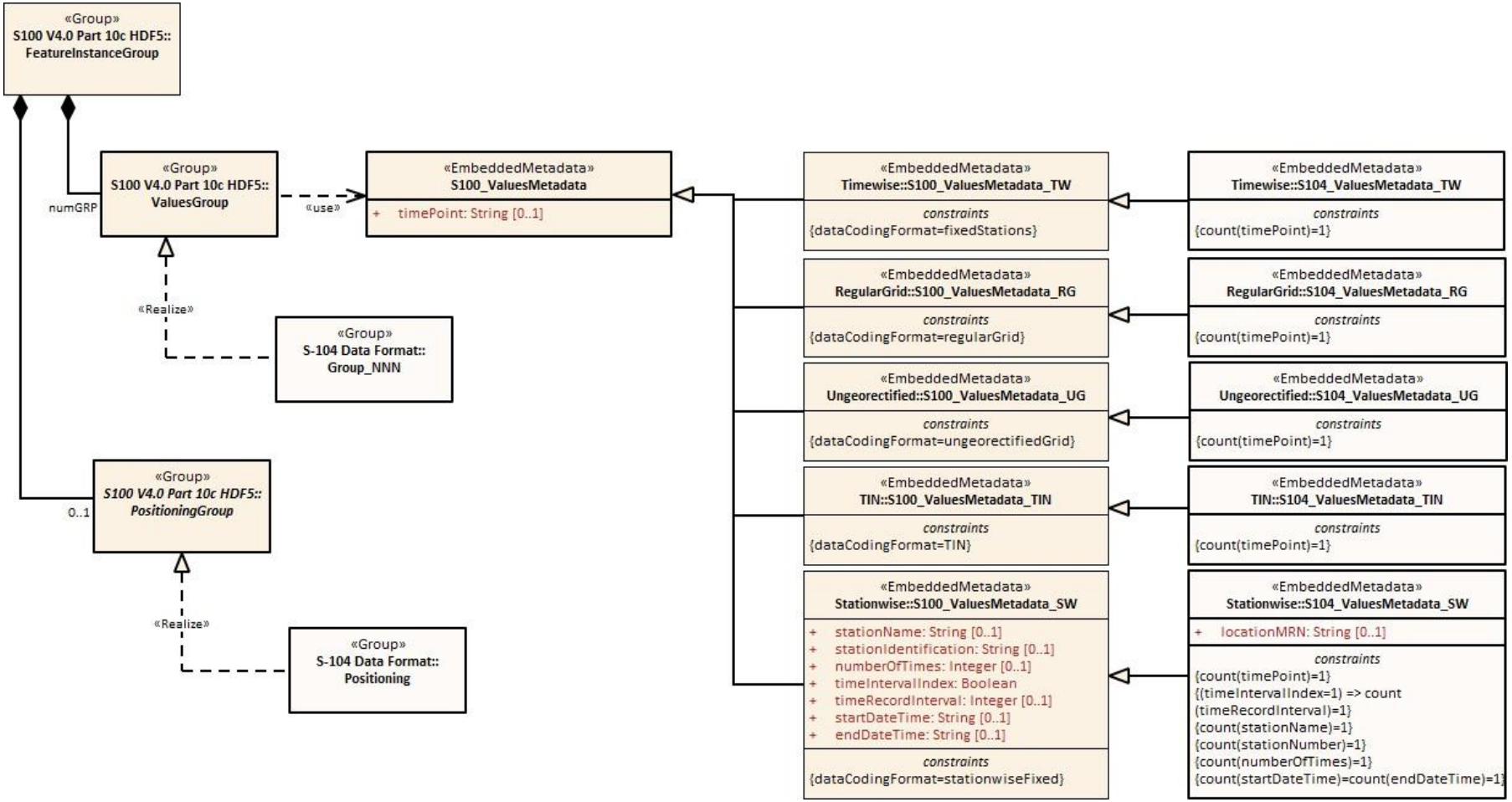


Figure 12-9 – Instance Metadata – Carrier Metadata for the Values group in each Feature Instance group

For all carrier metadata, latitude and longitude values are precise to 10^{-7} deg. except where noted. All times are in UTC format.

Table 12-3 – General Metadata, related to the entire HDF5 file (see S-100 Table 10c-6[5]). All times are in UTC format

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
1	Product specification number and version	productSpecification	1	String	This must be encoded as 'INT.IHO.S-104.X.Y', with X representing the Edition number and Y the revision number
2	Date of data product issue	issueDate	1	String	Date must be consistent with issueDate in discovery metadata
3	Horizontal Coord. Ref. Sys.	horizontalCRS	1	Integer	EPSG code or -1 if user defined. EXAMPLE 1: 4326 (for WGS84) See https://spatialreference.org/ref/epsg/?page=1 EXAMPLE 2: EPSG:9057 is WGS 84 (G1762) realization with valid epoch 2005.0
4	Bounding box	westBoundLongitude	1	Float	Area encompassing all feature instances Units are Decimal Degrees in the EPSG 4326 CS. In accordance with ISO 19115-1 these coordinates need be accurate only to two decimal places
5		eastBoundLongitude	1	Float	
6		southBoundLatitude	1	Float	
7		northBoundLatitude	1	Float	
8	Geographic location of the resource (by description)	geographicIdentifier	0..1	String	Description, or location code from list agreed by data producers (In S-100: EX_Extent > EX_GeographicDescription.geographicIdentifier > MD_Identifier.code)
9	Metadata file name	metadata	1	String	Name of XML metadata file for the HDF5 file Form: MD_<hdf file name>.XML
10	Name of the horizontal CRS	nameOfHorizontalCRS	0..1	String	Mandatory if horizontalCRS = -1
11	Type of the horizontal CRS	typeOfHorizontalCRS	0..1	Enumeration	Mandatory if horizontalCRS = -1. See Table 12-7
12	Horizontal coordinate system	horizontalCS	0..1	Integer	Mandatory if horizontalCRS = -1 Allowed values if typeOfHorizontalCRS = 1 (Geodetic CRS 2D): • 6422 (Lat, Lon – degree) Allowed values if typeOfHorizontalCRS = 2 (Projected CRS): • 4400 (Easting, Northing – metres) • 4500 (Northing, Easting – metres)
13	Horizontal datum	horizontalDatum	0..1	Integer	Mandatory if horizontalCRS = -1 EPSG code or -1 if user defined
14	Name of horizontal datum	nameOfHorizontalDatum	0..1	String	Mandatory if horizontalDatum = -1
15	Prime meridian	primeMeridian	0..1	Integer	Mandatory if horizontalDatum = -1; EPSG Code
16	Spheroid	spheroid	0..1	Integer	Mandatory if horizontalDatum = -1; EPSG Code
17	Projection method	projectionMethod	0..1	Integer	Mandatory if typeOfHorizontalCRS = 2; EPSG Code, see Table 12-10

[5] As amended by the revisions to S-100 Part 10c approved by the S-100 WG at S-100 WG5 (S-100 WG5 Draft.

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
18	Projection parameter 1	projectionParameter1	0..1	Float	Only if projectionMethod is used. See Table 12-10
19	Projection parameter 2	projectionParameter2	0..1	Float	Only if projectionMethod is used. See Table 12-10
20	Projection parameter 3	projectionParameter3	0..1	Float	Only if projectionMethod is used. See Table 12-10
21	Projection parameter 4	projectionParameter4	0..1	Float	Only if projectionMethod is used. See Table 12-10
22	Projection parameter 5	projectionParameter5	0..1	Float	Only if projectionMethod is used. See Table 12-10
23	False northing	falseNorthing	0..1	Float	Only if projectionMethod is used. To be applied to the coordinates at axis Northing. [m]
24	False easting	falseEasting	0..1	Float	Only if projectionMethod is used. To be applied to the coordinates at axis Easting. [m]
25	Epoch of realization	epoch	0..1	String	Code denoting the epoch of the geodetic datum used by the CRS. For example, 2005.0 for the G1762 realization of the geodetic datum for WGS84. Must match epoch denoted by horizontalCRS
Additional metadata for S-104					
26	Water level trend threshold	waterLevelTrendThreshold	1	Float	Critical value used to determine steady water level trend. Units are metres/hour (m/hr). For example, 0.2. See Annex A (DCEG)
27	Dataset delivery interval	datasetDeliveryInterval	0..1	String	The expected time interval between availability of successive datasets for time-varying data. Must be formatted as PnYnMnDTnHnMnS (ISO 8601 duration). See clause 12.2.15)
Additional restrictions on core general metadata for S-104					
28	Time of data product issue	issueTime	1	String	Mandatory for S-104. S-100 Time format. All times are in UTC. For example, 123000Z
29	Vertical coordinate system	verticalCS	1	Integer	Mandatory for S-104. EPSG Code; Allowed Values • 6498 (Depth– Metres–Orientation Down) • 6499 (Height– Metres–Orientation Up)
30	Vertical coordinate base	verticalCoordinateBase	1	Enumeration	Mandatory for S-104. For S-104, use 2: Vertical Datum. 1: Sea Surface 2: Vertical Datum 3: Sea Bottom
31	Vertical datum reference	verticalDatumReference	0..1	Enumeration	Mandatory for S-104 only if verticalCoordinateBase = 2. 1: S-100 vertical datum 2: EPSG
32	Vertical datum	verticalDatum	0..1	Integer	Mandatory for S-104 only if verticalCoordinateBase = 2. If verticalDatumReference = 1 this is a value from S100_VerticalAndSoundingDatum. If verticalDatumReference = 2 this is an EPSG code for vertical datum

NOTES:

1) If the CRS is user defined only the following coordinate systems are supported:
   - Geodetic CS (Latitude, Longitude) – Degrees; and
   - Cartesian CS (Northing, Easting or Easting, Northing) – Metres.
2) For the horizontal Datum all EPSG predefined Datums are allowed or any combination of predefined Prime Meridians or predefined Spheroids.
3) The projection methods are limited to those given in S-100 Edition 5.0.0 Table 10c-26[6] (in preparation).
4) If the horizontal CRS is defined by the EPSG code, the defined CRS should not use any other elements than the one allowed for user defined CRSs; (for example, no projection method that is not in the Table).
5) The bounding box is the data set bounding box; the coverage data feature instances may or may not cover the entire bounding box. If there is only a single coverage feature, its extent may or may not be the same as the data set.

Table 12-4 – Feature Metadata, pertaining to the Water Level feature (see S-100 Table 10c-10)

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
1	Data organization index (Used to read the data. See Table 10-1 and clause 12.2.17)	dataCodingFormat	1	Enumeration	See clause 12.2.17. The allowed values are: 1: Time series at fixed stations 2: Regularly-gridded arrays 3: Ungeorectified gridded arrays 7: TIN 8: Time series at fixed stations (stationwise) This Product Specification allows the use of only 1-3 and 7-8
2	Dimension	dimension	1	Integer	The (spatial) dimension of the feature instances. For water levels, use 2
3	Common Point Rule	commonPointRule	1	Enumeration	The procedure used for evaluating the coverage at a position that falls on the boundary or in an area of overlap between geometric objects 1: average 2: low 3: high 4: all (recommended)
4	Horizontal position uncertainty	horizontalPositionUncertainty	1	Float	-1.0 (unknown) or positive value (m)
5	Vertical position uncertainty	verticalUncertainty	1	Float	-1.0 (unknown) or positive value (m)
6	Time uncertainty	timeUncertainty	0..1	Float	-1.0 (unknown) or positive value (s)
7	Number of feature instances	numInstances	1	Integer	
Additional metadata for S-104					
8	Methodology	methodWaterLevelProduct	0..1	String	Brief description of tide gauge type, forecast method or model, etc
9	Min. water level height in dataset	minDatasetHeight	1	Float	Height in verticalCS in Table 12-3
10	Max. water level height in dataset	maxDatasetHeight	1	Float	Height in verticalCS in Table 12-3

[6] The new Table 10c-26 (Projection methods and their parameters) was approved for S-100 Ed. 5.0.0 by the S-100WG at S-100WG5. See S-100WG5 Draft Actions and Minutes - Agenda item 4.14 and S-100WG5-4.14.

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
dataCodingFormat = 1 (fixed stations) [No format-specific attributes]					
dataCodingFormat = 2 (regular Grid)					
11	Sequencing Rule	sequencingRule.type	1	Enumeration	Method to be used to assign values from the sequence of values to the grid coordinates. Components: type: Enumeration CV_SequenceType For example 1 (for 'linear')
12		sequencingRule.scanDirection	1	String	scanDirection: String <axisNames entry> (comma-separated). For example "latitude,longitude"
13	Interpolation Type	interpolationType	1	Enumeration	Interpolation method recommended for evaluation of the S100_GridCoverage Values: S100_CV_InterpolationMethod (ISO 19123)
dataCodingFormat = 3 (ungeorectified Grid)					
Additional restrictions on core feature metadata for S-104 for dataCodingFormat = 3					
11	Interpolation Type	interpolationType	1	Enumeration	Interpolation method recommended for evaluation of the S100_GridCoverage Values: S100_CV_InterpolationMethod (ISO 19123). For S-104 dataCodingFormat = 3, use 10 (for 'discrete')
dataCodingFormat = 7 (TIN)					
11	Interpolation Type	interpolationType	1	Enumeration	Interpolation method recommended for evaluation of the S100_GridCoverage Values: S100_CV_InterpolationMethod (ISO 19123)
dataCodingFormat = 8 (fixed stations, stationwise)					
Additional metadata for S-104 for dataCodingFormat = 8					
11	Order of series in pick report	pickPriorityType	1	String	Default priority of series for Pick Report. Use "0" for differences (*typeOfWaterLevelData* = 6, 7, 8, 9, 10) For example, "2,1,4,5,3,0,0,0,0,0" (without quotes). See Table 12-5. Total numbers (here 10) must be equal to numInstances

Table 12-5 – Instance Metadata, pertaining to the feature instance (see S-100 Table 10c-12). All times are in UTC format

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
1	Bounding box	westBoundLongitude	0..1	Float	Area of grid, set of stations, etc. Units are decimal degrees These are used if the feature instance has a bounding box different from the bounding box of the whole dataset This may happen, for example, if there is more than one feature instance in the dataset
2		eastBoundLongitude	0..1	Float	
3		southBoundLatitude	0..1	Float	
4		northBoundLatitude	0..1	Float	
5	Number of time records	numberOfTimes	0..1	Integer	The total number of time records. For dataCodingFormat = 8, this variable may be overridden by the corresponding one in the values group attributes (Table 12-6)

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
6	Time interval	timeRecordInterval	0..1	Integer	The interval between time records. Units: Seconds. For dataCodingFormat = 8, this variable may be overridden by the corresponding one in the values group attributes (Table 12-6).
7	Valid time of earliest value	dateTimeOfFirstRecord	0..1	String	DateTime format. First record in the Instance. All times are in UTC
8	Valid time of latest value	dateTimeOfLastRecord	0..1	String	DateTime format
9	Number of values groups	numGRP	1	Integer	Number of Values Groups. For dataCodingFormat = 1, 2, 3, and 7, equals the number of time points. For dataCodingFormat = 8, equals the number of stations
10	Instance chunking value	instanceChunking	0..1	String	For example “1,256” (without quotes). If present, overrides attribute value in Group_F
Additional metadata for S-104					
11	Type of water level data	typeOfWaterLevelData	1	Enumeration	See clause 12.2.18. The allowed values are: 1: Observation 2: Astronomical prediction 3: Analysis or hybrid method 4: Hydrodynamic model hindcast 5: Hydrodynamic model forecast 6: Observed minus predicted 7: Observed minus analysis 8: Observed minus hindcast 9: Observed minus forecast 10: Forecast minus predicted Note: if a difference is provided (6-10), suggested to also provide the other two series
dataCodingFormat = 1 (fixed stations)					
12	Number of fixed stations	numberOfStations	1	Integer	Number of individual fixed stations in this instance
dataCodingFormat = 2 (regular Grid)					
12	Longitude of grid origin	gridOriginLongitude	1	Float-Double	Degrees
13	Latitude of grid origin	gridOriginLatitude	1	Float-Double	Degrees
14	Grid spacing, long.	gridSpacingLongitudinal	1	Float-Double	Degrees
15	Grid spacing, lat.	gridSpacingLatitudinal	1	Float-Double	Degrees
16	Number of points, long.	numPointsLongitudinal	1	Integer	numCOLS
17	Number of points, lat.	numPointsLatitudinal	1	Integer	numROWS
18	Start sequence	startSequence	1	String	For example, “0,0” (without quotes) for scans starting at lower left corner i=0, j=0. For upper left, “0,n”, where n is the value of numROWS-1. First character represents first axis in sequencingRule.scanDirection. (Table 12-4), which here is latitude
dataCodingFormat = 3 (ungeorectified grid)					
12	Number of nodes	numberOfNodes	1	Integer	The total number of grid points
dataCodingFormat = 7 (TIN)					

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
12	Number of nodes	numberOfNodes	1	Integer	The total number of grid points
13	Number of triangles	numberOfTriangles	1	Integer	The total number of triangles in the TIN
dataCodingFormat = 8 (fixed stations, stationwise)					
12	Number of fixed stations	numberOfStations	1	Integer	Number of individual fixed stations in this instance

An expanded new metadata block is required for the Values Groups (Table 12-6). The variables *stationName* and *stationIdentification* have been added for both identification and possibly for inclusion in the text of the graph. Note that additional variables such as station category (for example, high or long-term, medium, or low) can be added here. The series start and end times, number of records, and time interval index are included since they may differ for each series.

NOTE: These attributes will be incorporated in S-100 Ed 5.0.0[7].

Table 12-6 – Values Group attributes (see S-100 Table 10c-18). All times are in UTC format

No	Name	Camel Case	Mult	Data Type	Remarks and/or Units
dataCodingFormat = 1 (fixed stations), 2 (regular grid), 3 (ungeorectified grid), or 7 (TIN)					
1	Time stamp	timePoint	1	String	DateTime. All times are in UTC
dataCodingFormat = 8 (fixed stations, stationwise)					
2	Index for time interval	timeIntervalIndex	1	(Integer)	1 (TRUE) denotes uniform time interval; interval provided by *timeRecordInterval* 0 (FALSE) denotes non-uniform time interval This is a boolean data type implemented as described in S-100 Table 10c-1
3	Time interval	timeRecordInterval	0..1	Integer	Only if *timeIntervalIndex* = 1 The uniform interval between time records. Units: Seconds. Value here overrides corresponding value at Instance level
Additional restrictions on core values group metadata for S-104 for dataCodingFormat = 8 (fixed stations, stationwise)					
4	Name of the station	stationName	1	String	Mandatory for S-104 For example, a geographic description or 'Not Available'
5	Station identification	stationIdentification	1	String	Mandatory for S-104 For example, a letter-number combination for the station or 'Not Available'
6	Number of time records	numberOfTimes	1	Integer	Mandatory for S-104 Value here overrides corresponding value at Instance level
7	Valid time of earliest value	startDateTime	1	String	Mandatory for S-104. DateTime format
8	Valid time of latest value	endDateTime	1	String	Mandatory for S-104. DateTime format
Additional metadata for S-104 for dataCodingFormat = 8 (fixed stations, stationwise)					
9	Location Maritime Resource Name	locationMRN	0..1	String	The Maritime Resource Name assigned to the station, if any. Must be formatted as an MRN (see IALA G1143)

[7] Approved for S-100 5.0.0 by the S-100WG at S-100WG5. See S-100WG5 Draft Actions and Minutes - Agenda item 4.18 and S-100WG5-4.18A. Note that *locationMRN* is an additional S-104-specific attribute.

12.3.1 Additional enumerations used in carrier metadata

Table 12-7 – Type of the horizontal CRS

Item	Name	Description	Code	Remarks
Enumeration	typeOfHorizontalCRS	Codes for describing the type of the two-dimensional horizontal CRS	-	
Literal	geodeticCRS2D	Two-dimensional geodetic CRS	1	
Literal	projectedCRS	Projected CRS	2	

Table 12-8 – Vertical coordinate base

Item	Name	Description	Code	Remarks
Enumeration	verticalCoordinateBase	Codes for describing the base level of the vertical coordinate system	-	
Literal	seaSurface	The base of the vertical coordinate system is the sea surface	1	
Literal	verticalDatum	The base of the vertical coordinate system is a defined vertical datum	2	
Literal	seaBottom	The base of the vertical coordinate system is the sea floor	3	

Table 12-9 – Vertical datum reference

Item	Name	Description	Code	Remarks
Enumeration	verticalDatumReference		-	
Literal	s100VerticalDatum	The vertical datum is one of those listed in S100_VerticalAndSoundingDatum	1	
Literal	EPSG	The vertical datum is one of those listed in the EPSG Registry	2	

Table 12-10 – Projection methods and their parameters

Name	EPSG Code	Parameter 1	Parameter 2	Parameter 3	Parameter 4	Parameter 5
Mercator	9805	Latitude of 1st standard parallel	Longitude of natural origin	-	-	-
Transverse Mercator	9807	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-
Oblique Mercator	9815	Latitude of projection centre	Longitude of projection centre	Azimuth of initial line	Angle from Rectified to Skew Grid	Scale factor on initial line
Hotline Oblique Mercator	9812	Latitude of projection centre	Longitude of projection centre	Azimuth of initial line	Angle from Rectified to Skew Grid	Scale factor on initial line
Lambert Conic Conformal (1SP)	9801	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-
Lambert Conic Conformal (2SP)	9802	Latitude of false origin	Longitude of false origin	Latitude of 1st standard parallel	Latitude of 2nd standard parallel	-
Oblique Stereographic	9809	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-
Polar Stereographic	9810	Latitude of natural origin	Longitude of natural origin	Scale factor at natural origin	-	-

Krovak Oblique Conic Conformal	9819	Latitude of projection centre	Longitude of projection centre	Azimuth of initial line	Latitude of pseudo standard parallel	Scale factor on pseudo standard parallel
American Polyconic	9818	Latitude of natural origin	Longitude of natural origin	-	-	-
Albers Equal Area	9822	Latitude of false origin	Longitude of false origin	Latitude of 1st standard parallel	Latitude of 2nd standard parallel	-
Lambert Azimuthal Equal Area	9820	Latitude of natural origin	Longitude of natural origin	-	-	-

12.4 Language

The language used for the Discovery Metadata and the Carrier Metadata is English.

Annex A – Data Classification and Encoding Guide

A-1 Features

A-1.1 Water Level (*WaterLevel*)

IHO Definition: **WATER LEVEL:** The vertical position of a water surface.			
S-104 Geo Feature: Water Level			
Primitives: pointSet, coverage			
S-104 Attribute	**Allowable Encoding Value**	**Type**	**Multiplicity**
Water Level Height	Must be in decimal metres, maximum resolution of 0.01 metres	RE	1,1
Water Level Trend	1: Decreasing 2: Increasing 3: Steady	EN	1,1
Water Level Time	YYYYMMDDTHHMMSSZ	DT	0..1

A-2 Feature Attributes

The number of attributes for *Water Level* is three: water level height, water level trend, and water level time. Encoding remarks are included with each attribute specification, below.

A-2.1 Water Level Height (*waterLevelHeight*)

IHO Definition: The height of a water surface relative to a vertical datum
Unit: metre (m)
Maximum Resolution: 0.01 m
Format: xxx.xx
Example: 10.54
Remarks:

- Land mask or missing value is denoted by a unique number as specified in the metadata.
- The height is relative to some vertical datum, which is defined in the metadata.
- 0.01 m equals 0.3937 inch (1 cm)

A-2.2 Water Level Trend (*waterLevelTrend*)

IHO Definition: The tendency of water level to change in a particular direction.

1 : Decreasing (*decreasing*)

2 : Increasing (*increasing*)

3 : Steady (*steady*)

Unit: none (enumeration)

Minimum Resolution: N/A (enumeration)

Format: x

Example: 3: Steady

Remarks:

- To determine category, use metadata variable *waterLevelTrendThreshold* (See Table 12-3):
  - Decreasing: trend <= -*waterLevelTrendThreshold*
  - Increasing: trend >= +*waterLevelTrendThreshold*
  - Steady: -*waterLevelTrendThreshold* < trend < +*waterLevelTrendThreshold*
- Where a value is not known, the fill value must be populated, which is 0: Unknown. The fill value may be used in non-tidal or similar regions.
- The fill value of 0: Unknown is recommended for all difference series (*typeOfWaterLevelData* = 6, 7, 8, 9, or 10).
- Native integer type H5T_STD_U8LE should be used for the base type of the numeric code (1, 2, or 3 here) when creating the enumeration.

A-2.3 Water Level Time (*waterLevelTime*)

IHO Definition: The time of the water level height, expressed in Date-time format as specified by ISO 8601.

Unit: Years, months, days, hours, minutes, seconds

Resolution: 1 second

Format: YYYYMMDDTHHMMSSZ, where Y is year, M is month, D is day, H is hour, M is minute, and S is second

Example: 19850412T101530Z denotes 10 hours, 15 minutes, and 30 seconds on 12 April 1985.

Remarks:

- Required only for fixed station (stationwise) time series data (*dataCodingFormat* = 8) with non-uniform time intervals.
- All times are in UTC (Universal Time Coordinated).

Annex B – Additional Terms and Definitions

Terms that are defined in this Annex or in Clause 1.4.2 are highlighted in **bold**.

accuracy
closeness of agreement between an observed value and the true value or a reference value accepted as true
NOTE 1: A test result can be observations or measurements
NOTE 2: For positioning services, the test result is a measured value or set of values
NOTE 3: For observations and measurements, true values are not obtainable. In their place reference values which are accepted as true values are used
[ISO 19157, ISO 19116]

application
manipulation and processing of **data** in support of user requirements
[ISO 19101]

application schema
conceptual **schema** for **data** required by one or more **applications**
[ISO 19101]

attribute
a named element within a classifier that describes a **range** of values that **instances** of the classifier may hold
NOTE: An **attribute** is semantically equivalent to a composition association; however, the intent and usage are normally different
[ISO/TS 19103]
named property of an entity
NOTE: Describes a geometrical, topological, thematic, or other **characteristic** of an entity
[ISO/TS 19130]

attribute <**UML**>
feature within a classifier that describes a **range** of values that **instances** of the classifier may hold
[ISO/TS 19103]

characteristic
abstraction of a property of an **object** or of a set of **objects**
NOTE: **Characteristics** are used for describing concepts
[ISO 1087-1, ISO 19146]
distinguishing **feature**
NOTE 1: A **characteristic** can be inherent or assigned
NOTE 2: A **characteristic** can be qualitative or Quantitative
NOTE 3: There are various classes of **characteristics**, such as the following: physical (e.g., mechanical, electrical, chemical, or biological), sensory (e.g., related to smell, touch, taste, sight, or hearing), behavioral (e.g., courtesy, honesty, or veracity), temporal (e.g., punctuality, reliability, or availability), ergonomic (e.g., physiological, or related to human safety), and functional (e.g., maximum speed of an aircraft)
[ISO 19113]

class <**UML**>
description of a set of **objects** that share the same **attributes**, operations, methods, relationships, and semantics
NOTE: A **class** may use a set of interfaces to specify collections of operations it provides to its environment. See: interface
[ISO/TS 19103-2]

classification
abstract representation of real-world phenomena using **classifiers**
[ISO 19144-1]

classifier
a **model** element that describes behavioral and structural features
[ISO/TS 19103]
definition used to assign **objects** to legend **classes**
NOTE: **Classifiers** can be defined algorithmically or according to a set of classification system-specific rules
[ISO 19144-1]

classifier <**UML**>
mechanism that describes behavioral and structural features
NOTE: Classifiers include interfaces, classes, data types, and components
[ISO/TS 19103-2]

conceptual model
model that defines concepts of a universe of discourse
[ISO 19101]

confidence
accuracy of a **data** quality result
[ISO 19157]

conformance
fulfilment of specified requirements
[ISO 19105]

constraint
condition or restriction expressed in natural-language text or in a machine-readable language for the purpose of declaring some of the semantics of an element
[ISO/TS 19103]
restriction on how a link or turn may be traversed by a vehicle, such as a vehicle **classification**, or physical or temporal **constraint**
[ISO 19133]

constraint <**UML**>
condition or restriction expressed in natural-language text or in a machine-readable language for the purpose of declaring some of the semantics of an element
[ISO/TS 19103]
NOTE: Certain **constraints** are predefined in the UML; others may be user defined. **Constraints** are one of three extensibility mechanisms in UML. See: tagged value, stereotype
[retired version of ISO/TS 19103]

content model
information view of an **application schema**
NOTE: The term “information view” comes from the ISO Reference **model** for Open distributed processing (RM-ODP) as specified in ISO 19101-2
[ISO/TS 19129]

continuous coverage
coverage that returns different values for the same **feature attribute** at different **direct positions** within a single spatial **object**, temporal **object**, or spatiotemporal **object** in its **domain**
NOTE: Although the **domain** of a **continuous coverage** is ordinarily bounded in terms of its spatial and/or temporal extent, it can be subdivided into an infinite number of **direct positions**
[ISO 19123]

coverage domain
Consists of a collection of **direct positions** in a coordinate space that may be defined in terms of up to three spatial dimensions as well as a temporal dimension.
[Springer 2012]

curve
one-dimensional **geometric primitive**, representing the continuous **image** of a line
NOTE: The boundary of a **curve** is the set of **points** at either end of the **curve**. If the **curve** is a cycle, the two ends are identical, and the **curve** (if topologically closed) is considered to not have a boundary. The first **point** is called the start **point**, and the last is the end **point**. Connectivity of the **curve** is guaranteed by the *continuous **image** of a line* clause. A topological theorem states that a continuous **image** of a connected set is connected
[ISO 19107]

data
reinterpretable representation of **information** in a formalised manner suitable for communication, interpretation, or processing
[ISO 19115]

data product specification
detailed description of a **dataset** or **dataset series** together with additional **information** that will enable it to be created, and supplied to and used by another party
NOTE: A **data product specification** provides a description of the universe of discourse and a specification for mapping the universe of discourse to a **dataset**. It may be used for production, sales, end-use, or other purpose
[ISO 19131]

data type
a descriptor of a set of values that lack identity (independent existence and the possibility of side-effects)
EXAMPLE: Integer, Real, Boolean, String, and Date
NOTE: **Data types** include primitive predefined **types** and user-definable **types**
[ISO/TS 19103]
specification of a value **domain** with operations allowed on values in this **domain**
EXAMPLE: Integer, Real, Boolean, String, and Date
NOTE 1: **Data types** include primitive predefined ***types*** and user-definable **types**
NOTE 2: A **data type** is identified by a term, e.g., Integer. Values of the **data types** are of the specified value **domain**, e.g., all integer numbers between −65 537 and 65 536. The set of operations can be +, -, *, and /, and is semantically well defined. A **data type** can be simple or complex. A simple **data type** defines a value **domain** where values are considered atomic in a certain context, e.g., Integer. A complex **data type** is a collection of **data types** which are grouped together. A complex **data type** may represent an **object** and can thus have identity
[ISO 19118]

data value
an **instance** of a **data type**; a value without identity
NOTE: A value may describe a possible state of an **object** within a **class** or **type** (**domain**)
[ISO/TS 19103]

dataset
identifiable collection of **data**
NOTE: A **dataset** may be a smaller grouping of **data** which, though limited by some **constraint** such as spatial extent or **feature type**, is located physically within a larger **dataset**. Theoretically, a **dataset** may be as small as a single **feature** or **feature attribute** contained within a larger **dataset**. A hard-copy map or chart may be considered a **dataset**
NOTE: The principles which apply to **datasets** may also be applied to **dataset series** and reporting groups
[ISO 19101, ISO 19115, ISO 19117]

dataset series
collection of **datasets** sharing the same **product specification**
[ISO 19115]

datum
parameter or set of parameters that define the **position** of the origin, the scale, and the orientation of a **coordinate** system
NOTE 1: A **datum** defines the **position** of the origin, the scale, and the orientation of the axes of a **coordinate** system
NOTE 2: A **datum** may be a geodetic **datum**, a **vertical datum**, an engineering **datum**, an **image datum**, or a temporal **datum**
[ISO 19111, ISO 19116]

depth
distance of a **point** from a chosen reference surface measured downward along a line perpendicular to that surface
NOTE: A **depth** above the reference surface will have a negative value
[ISO 19111]

element <XML>
basic **information** item of an XML document containing child **elements**, **attributes**, and character **data**
NOTE: From the XML **information** set: “Each XML document contains one or more **elements**, the boundaries of which are either delimited by start-tags and end-tags, or, for empty **elements**, by an empty-element tag. Each **element** has a **type**, identified by name, sometimes called its *generic identifier* (GI), and may have a set of **attribute** specifications. Each **attribute** specification has a name and a value.”
[ISO 19136]

elevation
the altitude of the ground level of an object, measured from a specified vertical datum.
[IHO:S100 GFM]

encoding
conversion of **data** into a series of codes
[ISO 19118]

error
discrepancy with the universe of discourse
[ISO 19138]

feature catalogue
catalogue containing definitions and descriptions of the **feature types**, **feature attributes**, and feature relationships occurring in one or more sets of geographic **data**, together with any **feature** operations that may be applied
[ISO 19101, ISO 19110]

feature type
classifier for **features**, defined by the set of **characteristic** properties that all **features** of this type carry
[ISO 19109]

class of **features** having common **characteristics**
[ISO 19156]

format
a language construct that specifies the representation, in character form, of **data objects** in a record, file, message, storage device, or transmission channel
[ISO 19145]

framework
relationship between the elements of the **content model** and the separate **encoding** and **portrayal** mechanisms
[ISO/TS 19129]

geographic location
longitude, latitude, and **elevation** of a ground or elevated **point**
[ISO/TS 19130-2]
NOTE: For the purpose of this document elevated **point** will be a **depth** based on a specified **datum**. [CARL 2015]

geometric complex
set of disjoint **geometric primitive**s where the boundary of each **geometric primitive** can be represented as the union of other **geometric primitives** of smaller dimension within the same set
NOTE: The **geometric primitives** in the set are disjoint in the sense that no **direct position** is interior to more than one **geometric primitive**. The set is closed under boundary operations, meaning that, for each element in the **geometric complex**, there is a collection (also a **geometric complex**) of **geometric primitives** that represents the boundary of that element. Recall that the boundary of a **point** (the only 0-D primitive **object** type in geometry) is empty. Thus, if the largest dimension **geometric primitive** is a solid (3-D), the composition of the boundary operator in this definition terminates after at most three steps. It is also the case that the boundary of any **object** is a cycle
[ISO 19107]

geometric object
spatial **object** representing a geometric set
NOTE: A **geometric object** consists of a **geometric primitive**, a collection of **geometric primitives**, or a **geometric complex** treated as a single entity. A **geometric object** may be the spatial representation of an **object** such as a ***feature*** or a significant part of a ***feature***
[ISO 19107]

geometric primitive
geometric object representing a single, connected, homogeneous element of space
NOTE: **Geometric primitives** are non-decomposed **objects** that present **information** about geometric configuration. They include **points**, **curves**, surfaces, and solids
[ISO 19107]

georectified
corrected for positional displacement with respect to the surface of the Earth
[ISO 19115-2]

gridded data
data whose **attribute** values are associated with **positions** on a **grid coordinate** system
[ISO 19115-2]

image
gridded **coverage** whose **attribute** values are a numerical representation of a physical parameter
NOTE: The physical parameters are the result of measurement by a sensor or a prediction from a **model**
[ISO 19115-2]

implementation
realization of a specification
NOTE: In the context of the ISO geographic **information** standards, this includes specifications of geographic **information** services and **datasets**
[ISO 19105]

information
knowledge concerning objects, such as facts, events, things, processes, or ideas, including concepts, that within a certain context has a particular meaning
[ISO 19118]

instance
individual entity having its own identity and value
NOTE: A classifier specifies the form and behavior of a set of **instances** with similar properties
[ISO/TS 19103]
object that realises a **class**
[ISO 19107]

layer
basic unit of geographic **information** that may be requested as a map from a server
[ISO 19128]

lineage
chain of legal ownership of content; history of ownership
[ISO 19153]

metadata
data about **data**
[ISO 19115]

metamodel <**UML**>
model that defines the language for expressing other models
NOTE: A **metamodel** is an instance of a meta-metamodel
[ISO/TS 19103]

model
abstraction of some aspects of reality
[ISO 19109]

navigation
combination of routing, route transversal, and tracking NOTE: This is essentially the common term **navigation**, but the definition decomposes the process in terms used in the packages defined in this international standard
[ISO 19133]

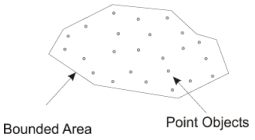
object
entity with a well-defined boundary and identity that encapsulates state and behaviour
NOTE 1: An **object** is an **instance** of a **class**
NOTE 2: This term was first used in this way in the general theory of object-oriented programming, and later adopted for use in this same sense in UML. **Attributes** and relationships represent state. Operations, methods, and state machines represent behaviour
NOTE 3: A GML **object** is an XML **element** of a **type** derived from AbstractGMLType
[ISO 19107]

object <**UML**>
a discrete entity with a well-defined boundary and identity that encapsulates state and behaviour; an **instance** of a **class**
[ISO/TS 19103]

point
zero-dimensional **geometric primitive**, representing a **position**
NOTE: The boundary of a **point** is the empty set
[ISO 19107]

point coverage
coverage that has a **domain** composed of **points**
[ISO 19123]

point set
set of 2, 3 or n dimensional points in space
[S-100]



point set coverage
coverage function associated with point value pairs in 2 dimensions
[S-100]
NOTE: a coverage function is driven by a set of points (with X, Y position) together with a record of one or more values at that position.

portrayal
presentation of **information** to humans
[ISO 19109, ISO 19117]

portrayal catalogue
collection of defined **portrayals** for a feature catalogue
NOTE: Content of a portrayal catalogue includes **portrayal functions**, **symbols**, and **portrayal context.**
[ISO 19117]

portrayal context
circumstances, imposed by factors extrinsic to a geographic dataset, that affect the **portrayal** of that dataset.
EXAMPLE: Factors contributing to portrayal context may include the proposed display or map scale, the viewing conditions (day/night/dusk), and the display orientation requirements (north not necessarily at the top of the screen or page), among others
NOTE: Portrayal context may influence the selection of portrayal functions and construction of symbols [ISO 19117]

portrayal function
function that maps geographic features to symbols NOTE: Portrayal functions can also include parameters and other computations that are not dependent on geographic feature properties
[ISO 19117]

portrayal function set
function that maps a feature catalog to a symbol set
[ISO 19117]

portrayal rule
specific kind of portrayal function expressed in a declarative language
NOTE: A declarative language is rule based and includes decision and branching statements
[ISO 19117]

portrayal service
generic interface used to portray features
[ISO 19117]

portrayal specification
collection of operations applied to the feature instance to portray it
[ISO 19117]

position
data type that describes a **point** or geometry potentially occupied by an **object** or person
NOTE: A **direct position** is a semantic subtype of **position**. **Direct positions** as described can only define a **point**, and therefore not all **positions** can be represented by a **direct position**. That is consistent with the *is type of* relation. An ISO 19107 geometry is also a **position**, but not a **direct position**
[ISO 19132]

positional accuracy
closeness of **coordinate** value to the true or accepted value in a specified reference system
NOTE: The term *absolute accuracy* is sometimes used for this concept to distinguish it from relative **positional accuracy**. Where the true **coordinate** value may not be perfectly known, **accuracy** is normally tested by comparison with available values that can best be accepted as true
[ISO 19116]

product
result of a process
[ISO 19158]

product specification
description of the universe of discourse and a **specification** for mapping the universe of discourse to a **dataset**
[ISO 19158]

profile
set of one or more base standards or subsets of base standards, and, where applicable, the identification of chosen clauses, classes, options, and parameters of those base standards, that are necessary for accomplishing a particular **function**
NOTE: A **profile** is derived from base standards so that, by definition, **conformance** to a **profile** is **conformance** to the base standards from which it is derived
[ISO 19101, ISO 19106]

profile <**UML**>
definition of a limited extension to a reference **metamodel** with the purpose of adapting the **metamodel** to a specific platform or **domain**
[ISO/TS 19103]

quadrilateral grid coverage
may be a **rectified grid** or a **referenceable grid**.
[Springer 2012]

quality
totality of **characteristics** of a **product** that bear on its ability to satisfy stated and implied needs
[ISO 19101, ISO 19109]
Degree to which a set of inherent **characteristics** fulfills requirements
NOTE 1: The term ***quality*** can be used with adjectives such as poor, good or excellent
NOTE 2: *Inherent*, as opposed to *assigned*, means existing in something, especially as a permanent **characteristic**
[ISO 19157]
NOTE 3: For the purposes of this technical specification the quality **characteristics** of **product** include:
– **Data** quality (the elements of which are described by ISO 19113)
– Volume of delivery
– Schedule of delivery
– Cost of production and/or update
[ISO 19158]

range
set of all values a **function** *f* can take as its arguments vary over its **domain**
[ISO 19136]

referenceable grid
requires a formula of higher order that transforms into a coordinate reference system.
EXAMPLE: the perspective transformation with eight parameters.
[Springer 2012]

render
conversion of digital graphics data into visual form
EXAMPLE: Generation of an image on a video display
[ISO 19117]

schema
formal description of a **model**
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)
[ISO 19101]

sequence
finite, ordered collection of related items (**objects** or values) that may be repeated
NOTE: Logically, a **sequence** is a set of pairs <item, offset>. LISP syntax, which delimits **sequences** with parentheses and separates elements in the **sequence** with commas, is used in this international standard
[ISO 19107]

set
unordered collection of related items (**objects** or values) with no repetition
[ISO 19107]

specification
declarative description of what something is or does
NOTE: Contrast: **implementation**
[retired version of ISO/TS 19103]

timestamp
value of time at which an **object**'s state is measured and recorded
[ISO 19132]

symbol
portrayal primitive that can be graphic, audible, or tactile in nature, or a combination of these
[ISO 19117]

tuple
ordered list of values
NOTE 1: The number of values in a tuple is immutable
NOTE 2: the ordered list will generally be a finite **sequence** of **features,** each of a specific **feature type**
[ISO 19136, ISO 19142]

type
a specification of the general structure and behaviour of a **domain** of **objects** without providing a physical **implementation**
NOTE: A **type** may have **attributes** and associations
[ISO/TS 19103]

UML
The Unified Modelling Language (**UML**) is a general-purpose modelling language in the field of software engineering, which is designed to provide a standard way to visualise the design of a system.

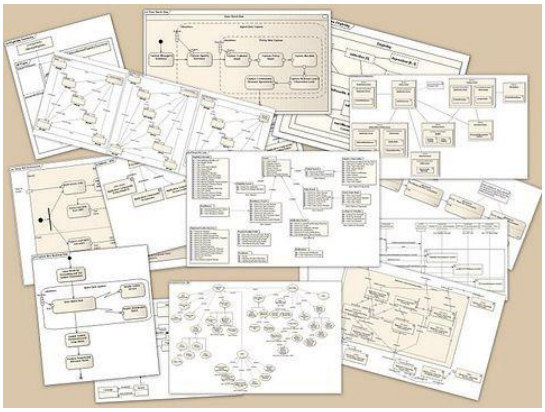


image courtesy of Kishorekumar 62 [Wikipedia 2015]

UML application schema
application schema written in UML in accordance with ISO 19109
[ISO 19136]

valid time
time when a fact is true in the abstracted reality
[ISO 19108]

vertical coordinate system
one-dimensional **coordinate** system used for gravity-related height or **depth** measurements
[ISO 19111]

vertical datum
datum describing the relation of gravity-related heights or **depths** to the Earth
NOTE: In most cases the **vertical datum** will be related to mean sea level. Ellipsoidal heights are treated as related to a three-dimensional ellipsoidal **coordinate** system referenced to a geodetic **datum**. **Vertical datums** include sounding **datums** (used for hydrographic purposes), in which case the heights may be negative heights or **depths**
[ISO 19111]

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Annex C – S-104 Comprehensive Model Including Application Schema and Carrier Metadata (UML Diagrams)

Figure C-1 below depicts the various components of the S-104 model. The Meta-features component is empty because S-104 does not define any meta-features. Figure C-2 depicts the derivation of the S-104 packages from various S-100 components.

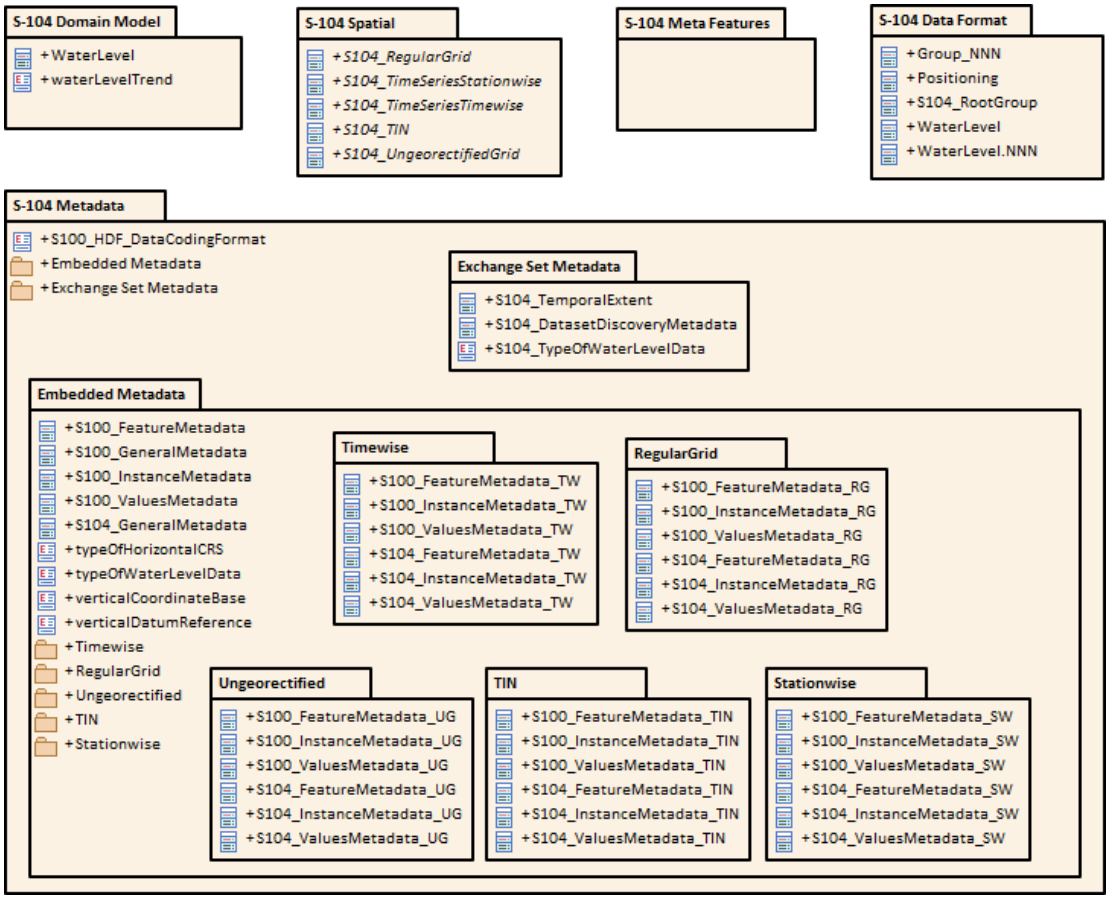

Figure C-1 – S-104 Model components

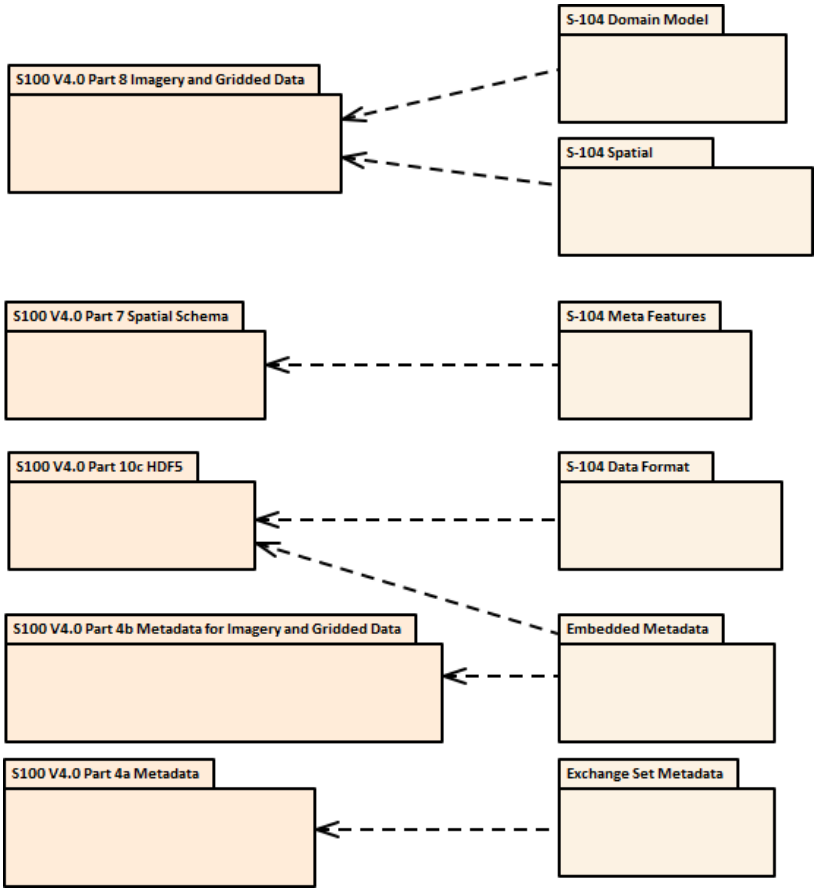

Figure C-2 – Derivations from S-100

Figure C-3 below depicts the coverage types used in S-104 and their realizations from the conceptual coverages in S-100 Part 8 and ISO 19123. This is a more detailed version of Figure 4-3. Note that the realizations are not directly from the Part 8 and ISO 19123 classes, but via corresponding notional classes for the HDF5 implementations of the various data coding formats (not included in this diagram). For example, **S104_RegularGrid** is a notional extension of a notional S-100 class Part10c::S100_HDF_RegularGrid which encapsulates the encoding of *dataCodingFormat* 2 in HDF5. The notional classes are omitted to reduce diagram clutter.

The implementation of most attributes in the S-100 Part 8 model by S-100 Part 10c closely follows the names and types of the attributes. Certain attributes in the S-100 Part 8 and ISO 19123 models are simplified in S-100 Part 10c HDF5 implementation, as follows:

- HDF5 Regular Grid and Ungeorectified Grid (data coding formats 2 and 3) implement S100_Grid and CV_ReferenceableGrid respectively:
  - The attribute *origin* is implemented in the form of two HDF5 attributes, *gridOriginLatitude* and *gridOriginLongitude*.
  - The attribute *offsetVectors* is implemented in the form of two HDF5 attributes, *gridSpacingLongitudinal* and *gridSpacingLatitudinal*.
- HDF5 TIN (data coding format 7) implements S100_TINCoverage:
  - The TIN *element* relationship to multiple S100_Triangle objects is implemented as the *triangles* array in S-100 Part 10c, Table 10c-16 and the triangle vertex positions represented by S100_VertexPoint *geometry* attributes are implemented as the *geometryValues* array in S-100 Table 10c-16 (this also represents the *controlPoints* attribute of ISO 19123 GM_Tin class).

  - Triangle corners represented by the *geometry* attribute of S100_Triangle and GM_Triangle *corners* attribute are implemented by the 3-columnar structure of the *triangles* array in S-100 Table 10c-16 (each row of that array indicates the 3 corners of a triangle).
  - The ISO 19123 GM_Tin attributes stopLines, breakLines, and maxLength are not implemented in the S-100 HDF5 encoding.
- The *rangeType* attribute common to all coverage types is implemented implicitly in the S-100 Feature Catalogue's binding of attributes to a feature and in the name/datatype information in feature information datasets in the feature information group (S-100 Part 10c, Table 10c-8).

Page intentionally left blank

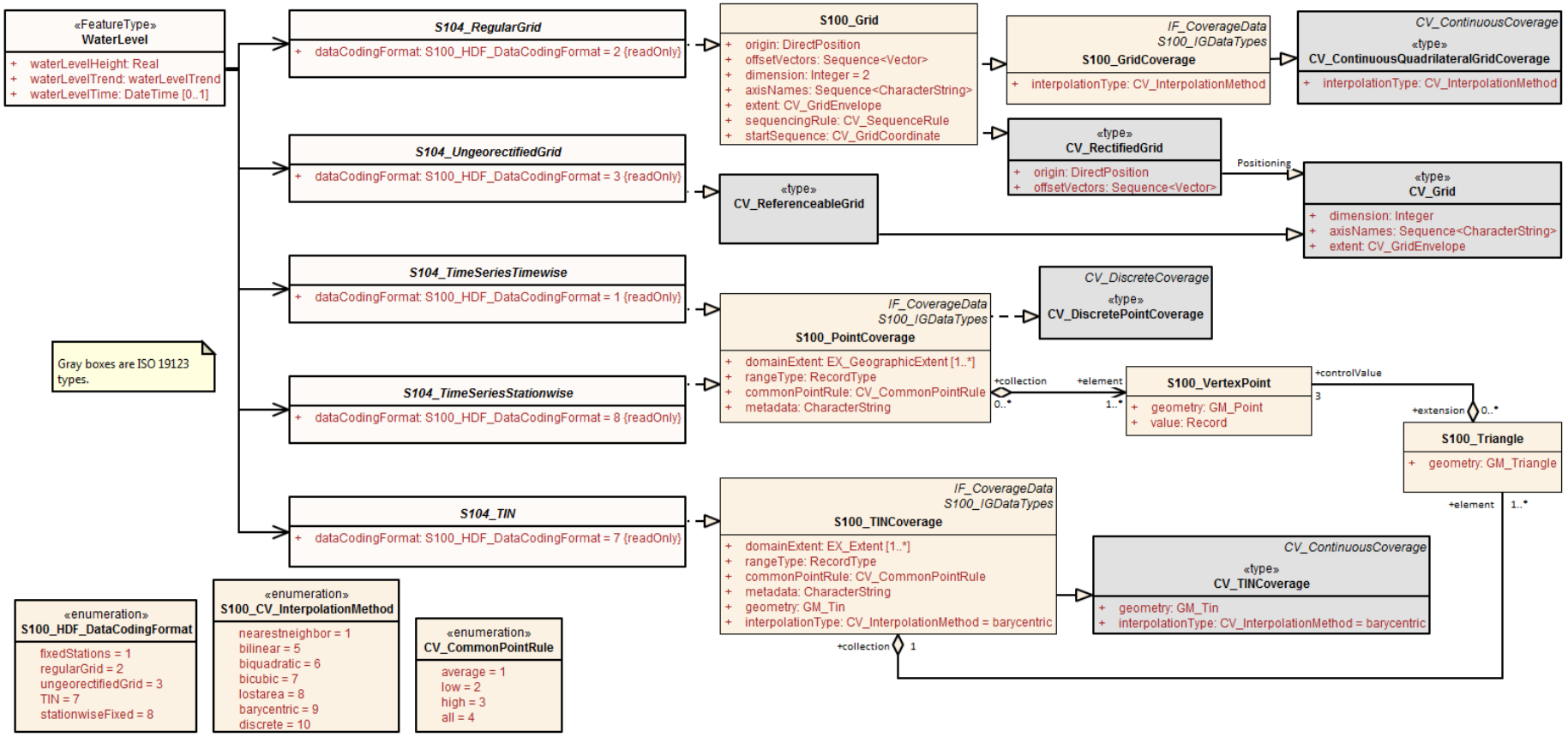

Figure C-3 – Spatial types – Coverages with realizations from S-100 Part 8 and ISO 19123

Figure C-4 below depicts the domain features. The **WaterLevel** feature and its attributes realise the values record in the S-100 Part 8 and ISO 19123 coverages models.

Figure C-4 – Domain objects

Figure C-5 depicts the external Catalogue metadata classes (the same information as Figure 12-4).

Figures C-6 through C-10 depict the same information as Figures 12-6 through 12-9, organised by coverage type instead of structural level.

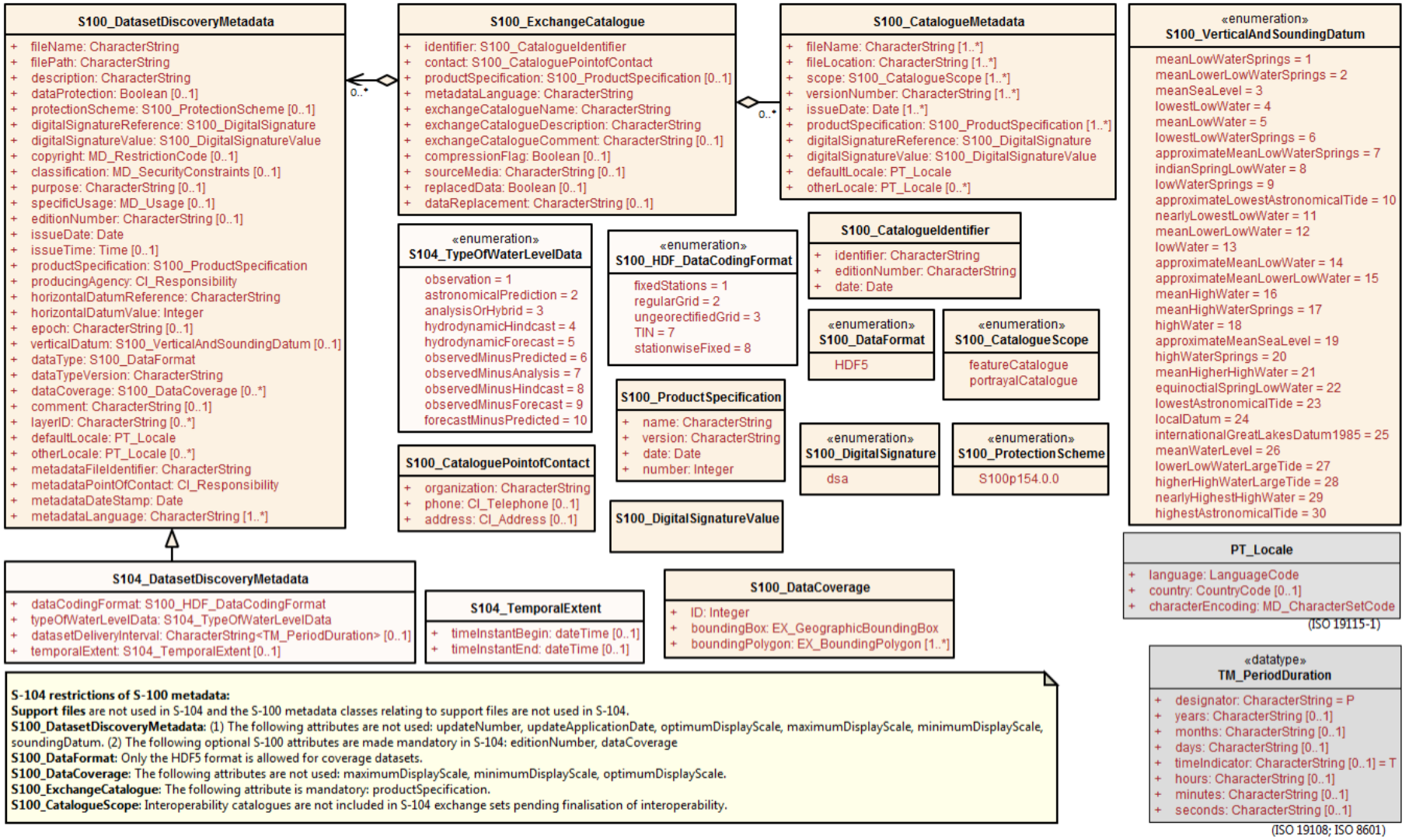

Figure C-5 – Exchange Set class details

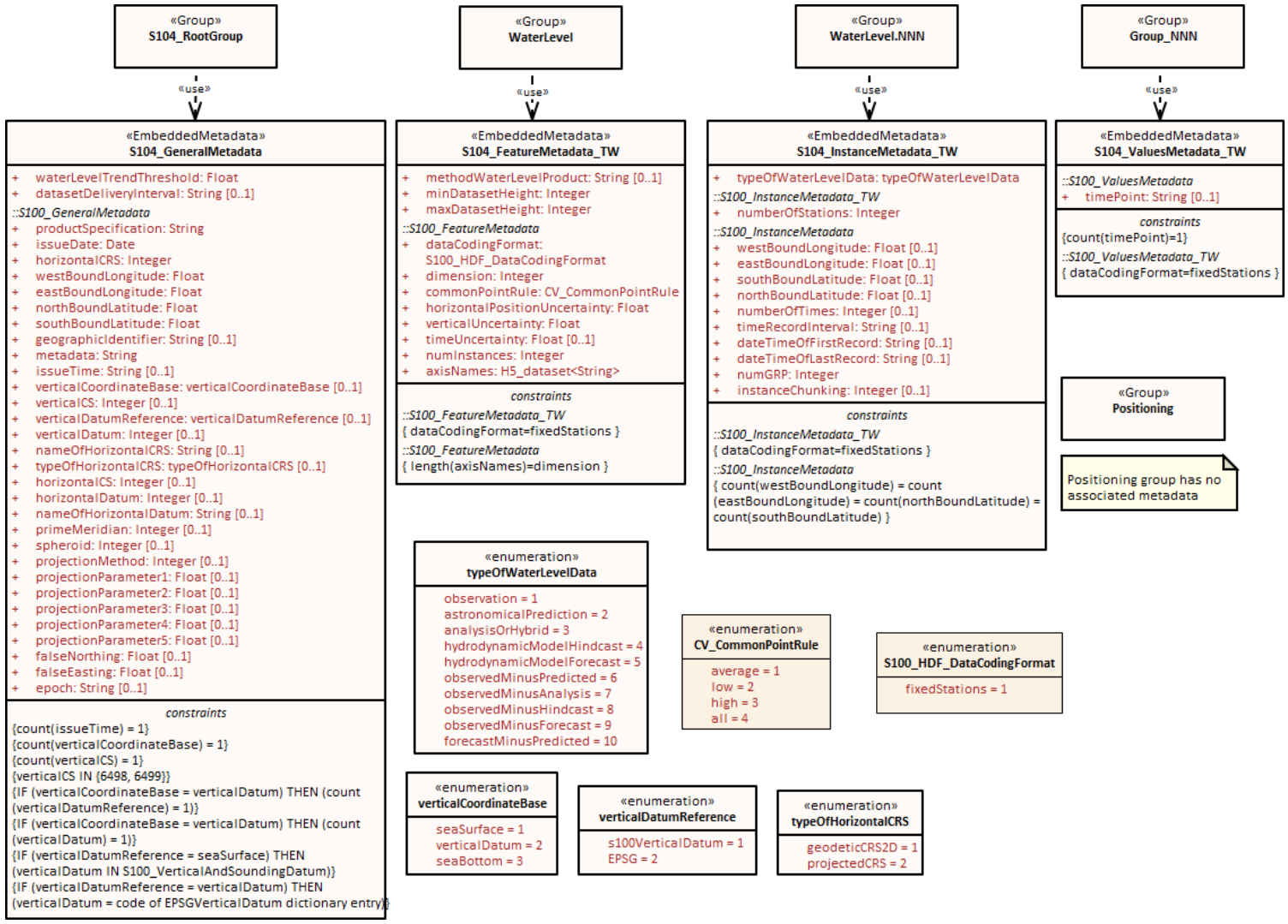

Figure C-6 – All carrier metadata for coverage type Fixed Stations (data coding format 1)

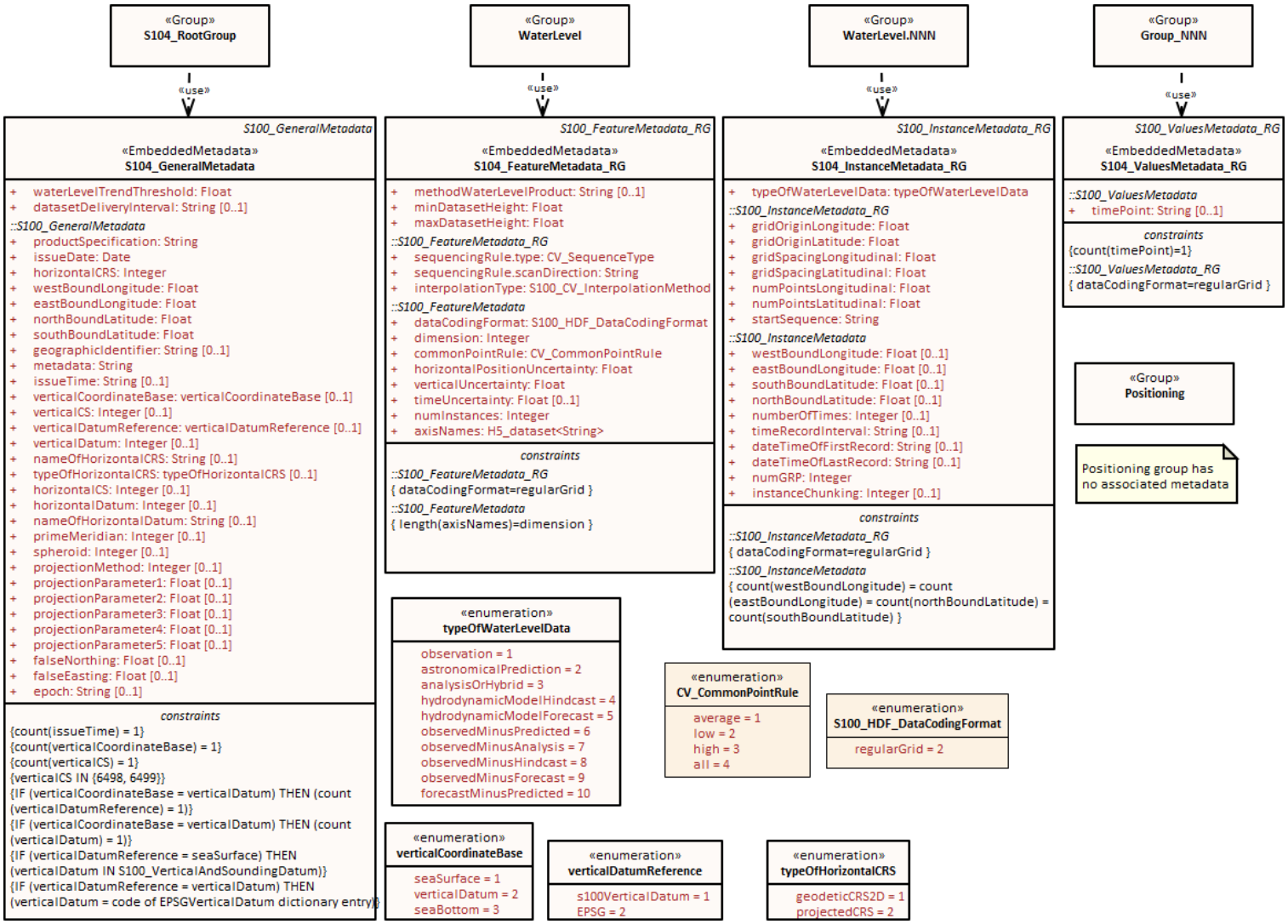

Figure C-7 – All carrier metadata for coverage type Regular Grid (data coding format 2)

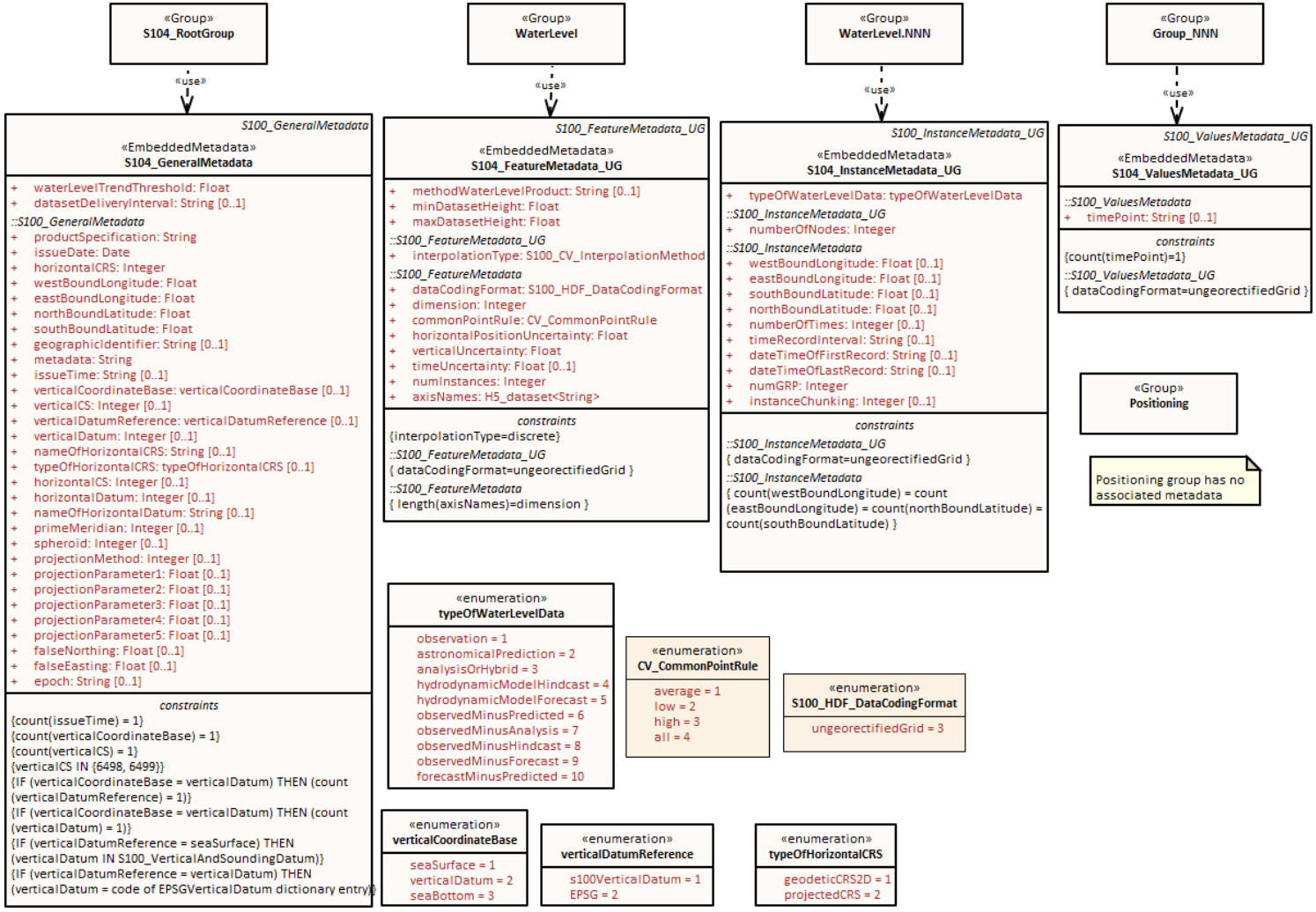

Figure C-8 – All carrier metadata for coverage type Ungeorectified Grid (data coding format 3)

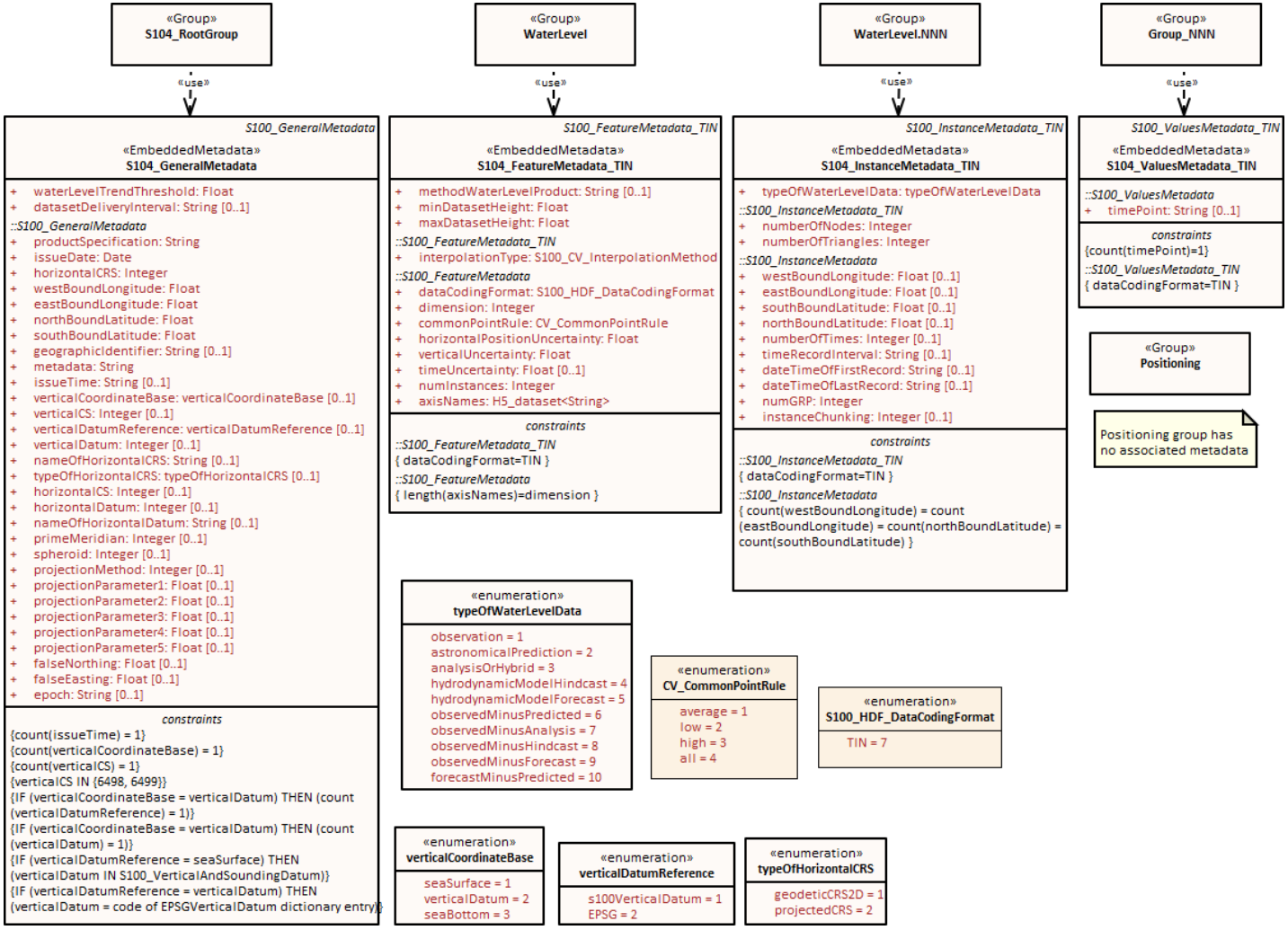

Figure C-9 – All carrier metadata for coverage type TIN (data coding format 7)

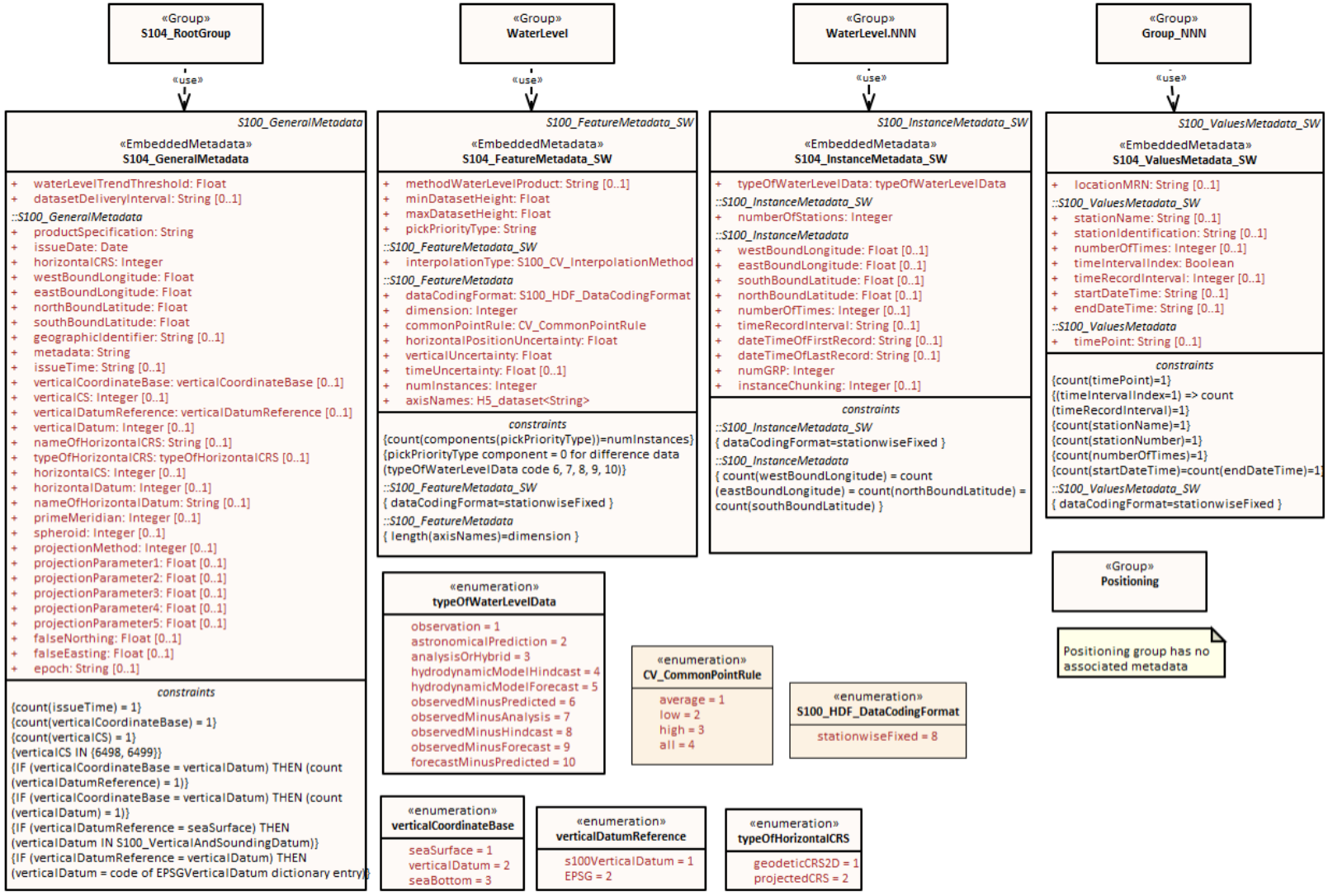

Figure C-10 – All carrier metadata for coverage type Fixed Stations (Stationwise) (data coding format 8)

Annex D – Feature Catalogue

D-1 Meta Feature Types

D-2 Geo Feature Types

D-2.1 Water Level

Definition: The vertical position of a water surface.

CamelCase: WaterLevel

Alias:

Super type:

Feature use type: geographic

Primitive: pointSet, coverage

Remarks: No remarks.

Attribute Bindings:

S-104 Attribute	Allowable Encoding Value	Type	Multiplicity
Water Level Height		RE	1, 1
Water Level Trend	1 : Decreasing 2 : Increasing 3 : Steady	EN	1, 1
Water Level Time		DT	0, 1

D-3 Cartographic Feature Types

D-4 Information Types

D-5 Simple Attributes

D-5.1 Water Level Height

Definition: The height of a water surface relative to a vertical datum.

CamelCase: waterLevelHeight

Alias:

Value type: real

Remarks: No remarks.

Unit of measure name: metre **definition**: SI metre **symbol**: m

Quantity specification: length

Constraints:

String Length	Text Pattern	Range		Precision
(not specified)	(none)	lowerBound	-99.99	2
		upperBound	99.99	
		closure	closedInterval	

D-5.2 Water Level Time

Definition: The time of the water level height, expressed in Date-time format as specified by ISO 8601.

CamelCase: waterLevelTime

Alias:

Value type: dateTime

Remarks: Unit: Years, months, days, hours, minutes, seconds; Resolution: 1 second; Format: YYYYMMDDTHHMMSSZ, where Y is year, M is month, D is day, H is hour, M is minute, and S is second; Example: 19850412T101530Z denotes 10 hours, 15 minutes, and 30 seconds on 12 April 1985.

Constraints:

String Length	Text Pattern	Range	Precision
(not specified)	(((((19)|(20))\d{2})|(21([0-4]\d)))(1[0-2]|0[1-9])(3[01]|0[1-9]|[12][0-9])T(2[0-3]|[01][0-9]):?([0-5][0-9]):?([0-5][0-9])Z)|(21500101T000000Z)	(not specified)	(not specified)

D-5.3 Water Level Trend

Definition: The tendency of water level to change in a particular direction.

CamelCase: waterLevelTrend

Alias:

Value type: enumeration

Remarks: No remarks.

Listed Values:

Code	Label	Definition
1	Decreasing	Becoming smaller in magnitude.
2	Increasing	Becoming larger in magnitude.
3	Steady	Constant.

D-6 Complex Attributes

D-7 Roles

D-8 Information Associations

D-9 Feature Associations

D-10 Feature Catalogue XML

```
<?xml version="1.0" encoding="utf-8"?>
<S100FC:S100_FC_FeatureCatalogue xmlns:S100FC="http://www.iho.int/S100FC"
xmlns:S100Base="http://www.iho.int/S100Base"
xmlns:S100CI="http://www.iho.int/S100CI" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:S100FD="http://www.iho.int/S100FD"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.iho.int/S100FC
file:S100_SCHEMA_ROOT/S100/4.0.0/S100FC/20180611/S100FC.xsd">
  <S100FC:name>S-104</S100FC:name>
  <S100FC:scope>Water level data are intended to be used as stand-alone data or as a
layer in an ENC.</S100FC:scope>
  <S100FC:fieldOfApplication>Marine navigation</S100FC:fieldOfApplication>
  <S100FC:versionNumber>1.0.0</S100FC:versionNumber>
  <S100FC:versionDate>2021-07-16</S100FC:versionDate>
  <S100FC:producer>
    <S100CI:role>owner</S100CI:role>
    <S100CI:party>
      <S100CI:CI_Organisation>
        <S100CI:name>International Hydrographic Organization</S100CI:name>
        <S100CI:contactInfo>
              <S100CI:phone>
          <S100CI:number>+377 93 10 81 00</S100CI:number>
          <S100CI:numberType>voice</S100CI:numberType>
        </S100CI:phone>
        <S100CI:address>
          <S100CI:administrativeArea>4b quai Antoine 1er</S100CI:administrativeArea>
          <S100CI:postalCode>B.P.445</S100CI:postalCode>
          <S100CI:country>MONACO</S100CI:country>
          <S100CI:electronicMailAddress>info@iho.int</S100CI:electronicMailAddress>
        </S100CI:address>
        <S100CI:hoursOfService>24h</S100CI:hoursOfService>
      </S100CI:contactInfo>
    </S100CI:CI_Organisation>
  </S100CI:party>
  </S100FC:producer>
  <S100FC:classification>unclassified</S100FC:classification>
  <S100FC:S100_FC_DefinitionSources>
    <S100FC:FC_DefinitionSource id="IHOREG">
      <S100FC:source>
        <S100CI:title>IHO GI Registry</S100CI:title>
        <S100CI:onlineResource>
          <S100CI:linkage>http://registry.iho.int/beta/fdd/list.do</S100CI:linkage>
        </S100CI:onlineResource>
      </S100FC:source>
    </S100FC:FC_DefinitionSource>
  </S100FC:S100_FC_DefinitionSources>
  <S100FC:S100_FC_SimpleAttributes>
    <S100FC:S100_FC_SimpleAttribute>
      <S100FC:name>Water Level Height</S100FC:name>
      <S100FC:definition>The height of a water surface relative to a vertical
datum.</S100FC:definition>
      <S100FC:code>waterLevelHeight</S100FC:code>
      <S100FC:definitionReference>
        <S100FC:sourceIdentifier>910</S100FC:sourceIdentifier>
        <S100FC:definitionSource ref="IHOREG"/>
```

```
      </S100FC:definitionReference>
      <S100FC:valueType>real</S100FC:valueType>
      <S100FC:uom>
        <S100Base:name>metre</S100Base:name>
      <S100Base:definition>SI metre</S100Base:definition>
      <S100Base:symbol>m</S100Base:symbol>
      </S100FC:uom>
      <S100FC:quantitySpecification>length</S100FC:quantitySpecification>
      <S100FC:constraints>
        <S100FD:range>
          <S100Base:lowerBound>-99.99</S100Base:lowerBound>
          <S100Base:upperBound>99.99</S100Base:upperBound>
          <S100Base:closure>closedInterval</S100Base:closure>
        </S100FD:range>
        <S100FD:precision>2</S100FD:precision>
      </S100FC:constraints>
    </S100FC:S100_FC_SimpleAttribute>
    <S100FC:S100_FC_SimpleAttribute>
      <S100FC:name>Water Level Time</S100FC:name>
      <S100FC:definition>The time of the water level height, expressed in Date-time
format as specified by ISO 8601.</S100FC:definition>
      <S100FC:code>waterLevelTime</S100FC:code>
      <S100FC:remarks>Unit: Years, months, days, hours, minutes, seconds; Resolution:
1 second; Format: YYYYMMDDTHHMMSSZ, where Y is year, M is month, D is day, H is
hour, M is minute, and S is second; Example: 19850412T101530Z denotes 10 hours, 15
minutes, and 30 seconds on 12 April 1985.</S100FC:remarks>
      <S100FC:definitionReference>
        <S100FC:sourceIdentifier>313</S100FC:sourceIdentifier>
      <S100FC:definitionSource ref="IHOREG"/>
      </S100FC:definitionReference>
      <S100FC:valueType>dateTime</S100FC:valueType>
      <!-- Date range constraints cannot be expressed in the Edition 4.0.0 FC model -->
      <S100FC:constraints>
        <S100FD:textPattern>(((((19)|(20))\d{2})|(21([0-4]\d)))(1[0-2]|0[1-
9])(3[01]|0[1-9]|[12][0-9])T(2[0-3]|[01][0-9]):?([0-5][0-9]):?([0-5][0-
      9])Z)|(21500101T000000Z)</S100FD:textPattern>
      </S100FC:constraints>
    </S100FC:S100_FC_SimpleAttribute>
    <S100FC:S100_FC_SimpleAttribute>
      <S100FC:name>Water Level Trend</S100FC:name>
      <S100FC:definition>The tendency of water level to change in a particular
direction.</S100FC:definition>
      <S100FC:code>waterLevelTrend</S100FC:code>
      <S100FC:definitionReference>
        <S100FC:sourceIdentifier>378</S100FC:sourceIdentifier>
        <S100FC:definitionSource ref="IHOREG"/>
      </S100FC:definitionReference>
      <S100FC:valueType>enumeration</S100FC:valueType>
      <S100FC:listedValues>
        <S100FC:listedValue>
          <S100FC:label>Decreasing</S100FC:label>
          <S100FC:definition>Becoming smaller in magnitude.</S100FC:definition>
          <S100FC:code>1</S100FC:code>
          <S100FC:definitionReference>
            <S100FC:sourceIdentifier>1387</S100FC:sourceIdentifier>
            <S100FC:definitionSource ref="IHOREG"/>
          </S100FC:definitionReference>
```

```
      </S100FC:listedValue>
      <S100FC:listedValue>
        <S100FC:label>Increasing</S100FC:label>
        <S100FC:definition>Becoming larger in magnitude.</S100FC:definition>
        <S100FC:code>2</S100FC:code>
        <S100FC:definitionReference>
          <S100FC:sourceIdentifier>1388</S100FC:sourceIdentifier>
          <S100FC:definitionSource ref="IHOREG"/>
        </S100FC:definitionReference>
      </S100FC:listedValue>
      <S100FC:listedValue>
        <S100FC:label>Steady</S100FC:label>
        <S100FC:definition>Constant.</S100FC:definition>
        <S100FC:code>3</S100FC:code>
        <S100FC:definitionReference>
          <S100FC:sourceIdentifier>1389</S100FC:sourceIdentifier>
          <S100FC:definitionSource ref="IHOREG"/>
        </S100FC:definitionReference>
      </S100FC:listedValue>
    </S100FC:listedValues>
  </S100FC:S100_FC_SimpleAttribute>
</S100FC:S100_FC_SimpleAttributes>
<S100FC:S100_FC_FeatureTypes>
  <S100FC:S100_FC_FeatureType isAbstract="false">
    <S100FC:name>Water Level</S100FC:name>
    <S100FC:definition>The vertical position of a water surface.</S100FC:definition>
    <S100FC:code>WaterLevel</S100FC:code>
    <S100FC:definitionReference>
      <S100FC:sourceIdentifier>369</S100FC:sourceIdentifier>
      <S100FC:definitionSource ref="IHOREG"/>
    </S100FC:definitionReference>
    <S100FC:attributeBinding sequential="false">
      <S100FC:multiplicity>
        <S100Base:lower>1</S100Base:lower>
        <S100Base:upper xsi:nil="false" infinite="false">1</S100Base:upper>
      </S100FC:multiplicity>
      <S100FC:attribute ref="waterLevelHeight"/>
    </S100FC:attributeBinding>
    <S100FC:attributeBinding sequential="false">
      <S100FC:multiplicity>
        <S100Base:lower>1</S100Base:lower>
        <S100Base:upper xsi:nil="false" infinite="false">1</S100Base:upper>
      </S100FC:multiplicity>
      <S100FC:permittedValues>
        <S100FC:value>1</S100FC:value>
        <S100FC:value>2</S100FC:value>
        <S100FC:value>3</S100FC:value>
      </S100FC:permittedValues>
      <S100FC:attribute ref="waterLevelTrend"/>
    </S100FC:attributeBinding>
    <S100FC:attributeBinding sequential="false">
      <S100FC:multiplicity>
        <S100Base:lower>0</S100Base:lower>
        <S100Base:upper xsi:nil="false" infinite="false">1</S100Base:upper>
      </S100FC:multiplicity>
      <S100FC:attribute ref="waterLevelTime"/>
    </S100FC:attributeBinding>
```

```
      <S100FC:featureUseType>geographic</S100FC:featureUseType>
      <S100FC:permittedPrimitives>pointSet</S100FC:permittedPrimitives>
      <S100FC:permittedPrimitives>coverage</S100FC:permittedPrimitives>
    </S100FC:S100_FC_FeatureType>
  </S100FC:S100_FC_FeatureTypes>
</S100FC:S100_FC_FeatureCatalogue>
```

Annex E – Sample HDF5 Encoding

The following are examples of HDF5 water level data files for each of the five data coding formats. The general structure of the data product is shown in Table 10-2, and the specific variables contained in the attributes are explained in Tables 12-3, 12-4, 12-5 and 12-6. The sample HDF5 files were produced by MATLAB® and were displayed in HDFView version 2.14.

E-1 Common Groups and Attributes

Information shown in Figures E-1 through E-4 is common to all the data coding formats.

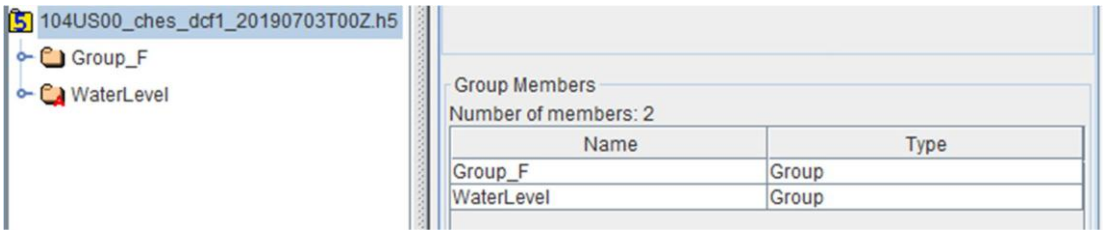

Figure E-1 – Typical HDF5 file (left) and its two groups, '*Group_F*' and '*WaterLevel*' (right)

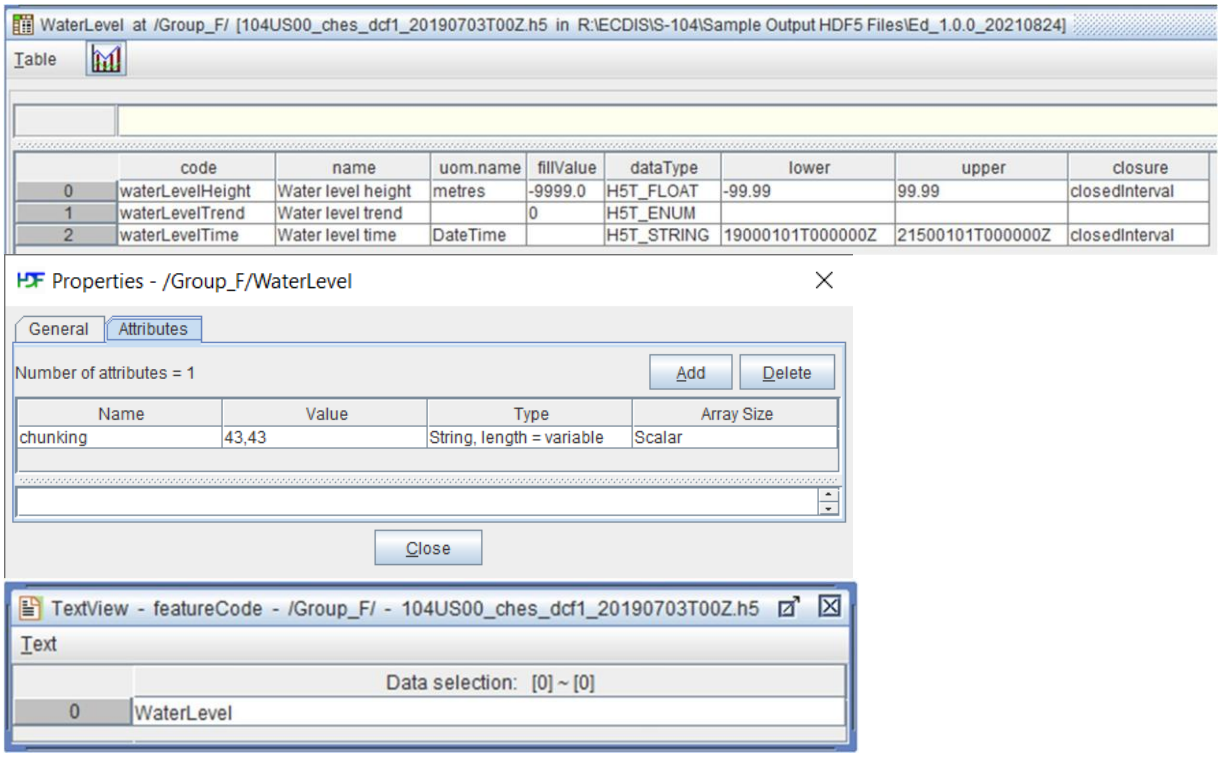

Figure E-2 – *Group_F* includes the (top panel) compound dataset '*WaterLevel*' and (bottom panel) the scalar dataset '*featureCode*'. The dataset '*WaterLevel*' (middle panel) contains the attribute '*chunking*'. All values provided here except for *chunking* are required

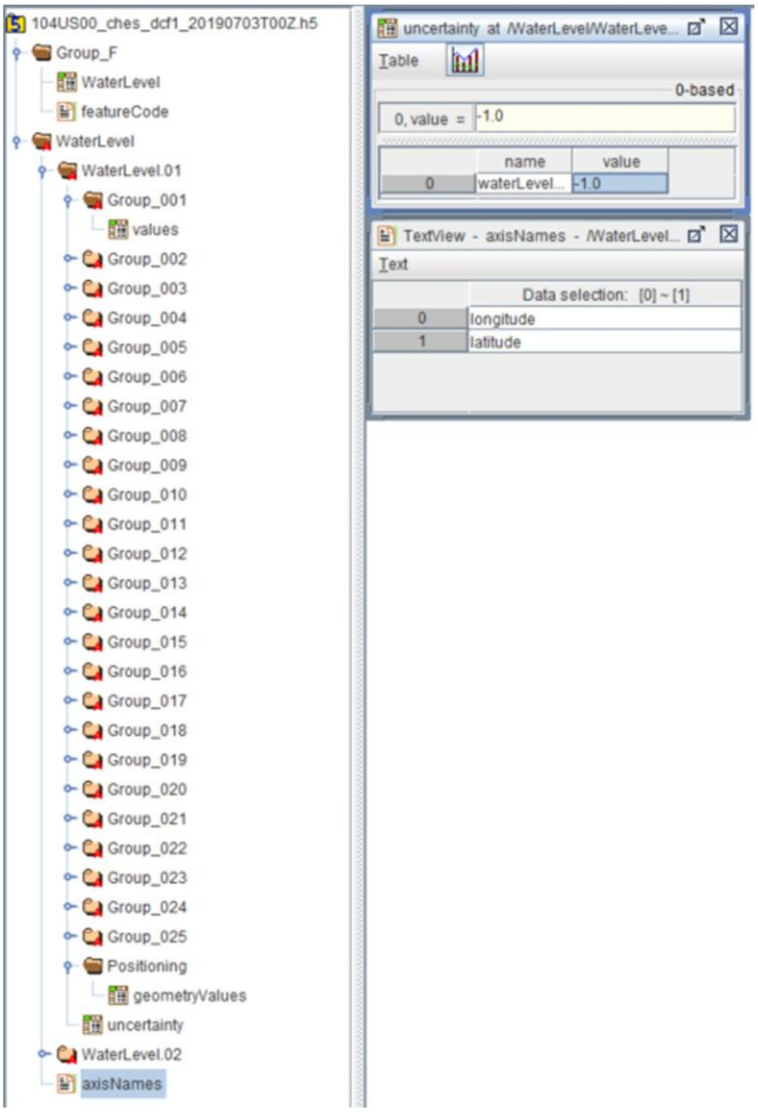

Figure E-3 – General structure of the HDF5 dataset (left panel); however, for *dataCodingFormat* = 2, the group '*Positioning'* is absent. On the right, the contents of the datasets '*uncertainty'* (top right panel) within the group *WaterLevel.01*, and '*axisNames'* (bottom right panel) within the group *WaterLevel*

Properties - /

General | Attributes | User Block

Number of attributes = 15 Add Delete

Name	Value	Type	Array Size
eastBoundLongitude	-76.19	64-bit floating-point	Scalar
geographicIdentifier	Chesapeake Bay	String, length = 14	Scalar
horizontalCRS	4326	16-bit integer	Scalar
issueDate	20210824	String, length = 8	Scalar
issueTime	122600Z	String, length = 7	Scalar
metadata	MD_104US00_ches_dcf1_20190703T00Z.XML	String, length = 37	Scalar
northBoundLatitude	39.250123	64-bit floating-point	Scalar
productSpecification	INT.IHO.S-104.1.0	String, length = 17	Scalar
southBoundLatitude	38.21	64-bit floating-point	Scalar
verticalCS	6499	16-bit integer	Scalar
verticalCoordinateBase	Vertical datum	8-bit enum (Sea surface=1 Vertical datum=2 Sea bottom=3)	Scalar
verticalDatum	12	16-bit integer	Scalar
verticalDatumReference	S-100 Vertical datum	8-bit enum (S-100 Vertical datum=1 EPSG code=2)	Scalar
waterLevelTrendThreshold	0.2	32-bit floating-point	Scalar
westBoundLongitude	-76.41	64-bit floating-point	Scalar

Figure E-4 – Sample HDF5 attributes (see Table 12-3) of the root group

E-2 Values Groups Attributes

Attributes for the values groups have two forms: A short form for *dataCodingFormat* 1 through 7 (Figure E-5); and a longer form for *dataCodingFormat* 8 (Figure E-6).

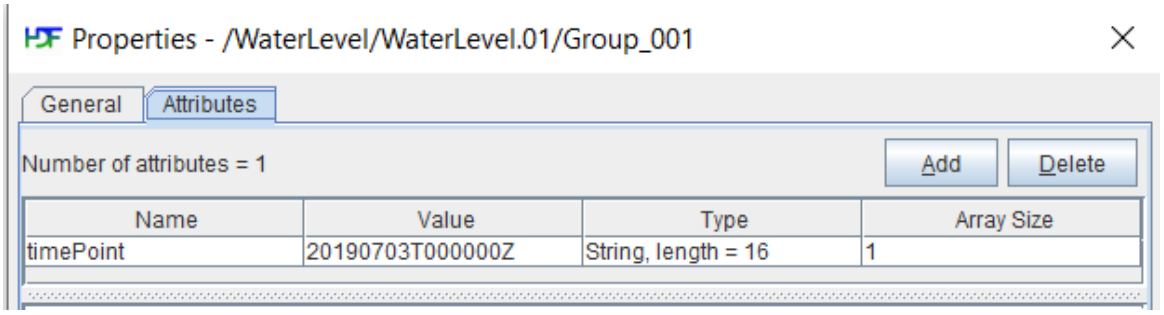

Figure E-5 – Short form of attributes of the values group '*Group_001*.' Used for *dataCodingFormat* = 1 to 7

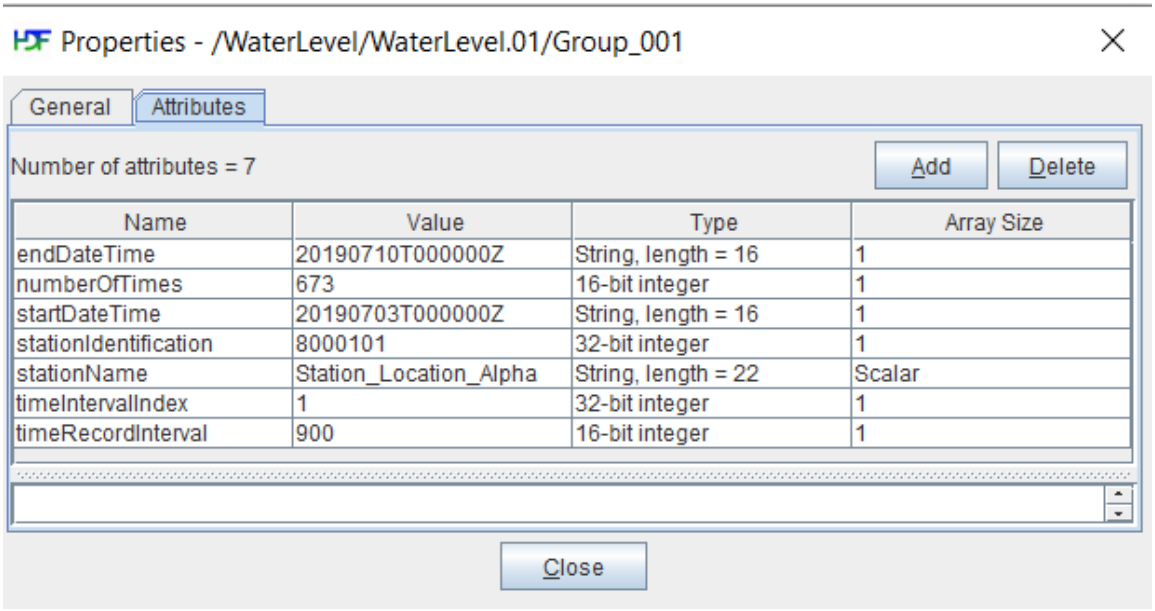

Figure E-6 – Long form of attributes of the values group '*Group_001*'. Used for *dataCodingFormat* = 8

E-3 Fixed Stations (dataCodingFormat = 1)

For this coding format, the height and trend are stored in the one-dimensional compound array 'values', corresponding to data at all stations at one point in time. In each element of the array, the first variable is 'waterLevelHeight' and the second is 'waterLevelTrend'. The spelling and order of variable names are important.

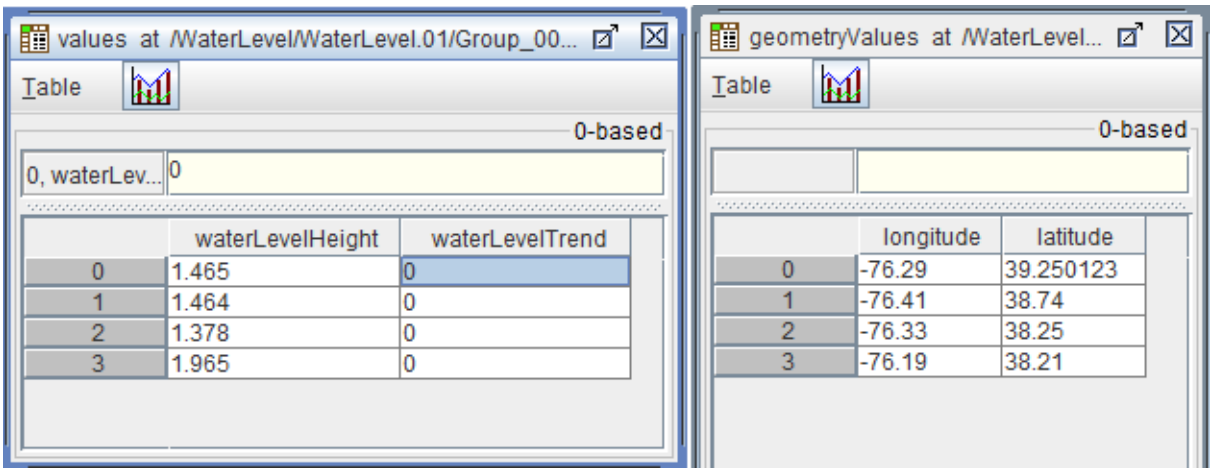

Figure E-7 – (left) For *dataCodingFormat* = 1, sample contents of the dataset 'values' in *Group_001* and (right) the geometry group '*Positioning'*, which contains location information on four fixed stations in the dataset '*geometryValues'*. The HDF5 file structure is shown in Figure E-3

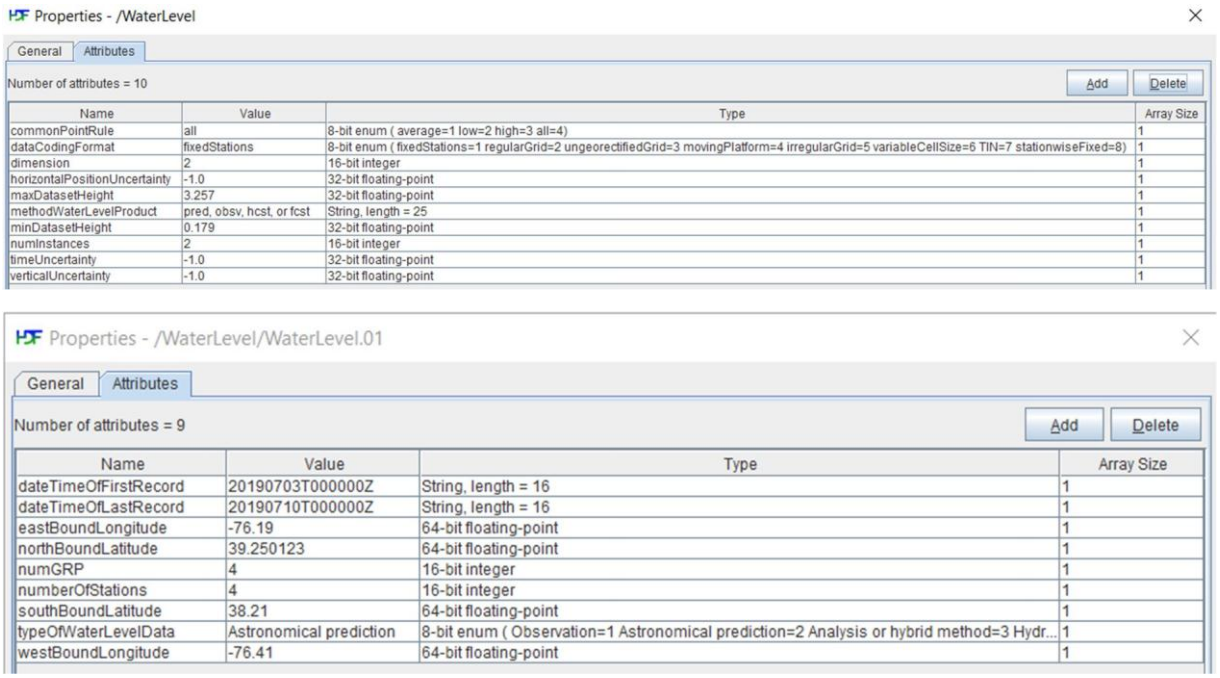

Figure E-8 – Attributes for (top panel) the feature metadata (see Table 12-4) and (bottom panel) the instance metadata (see Table 12-5)

E-4 Regular Grid (dataCodingFormat = 2)

For this coding format, the height and trend are stored in the two-dimensional compound array 'values'. The entire array in the values group represents one point in time. In each element of the array, the first variable is 'waterLevelHeight' and the second is 'waterLevelTrend'. The spelling and order of variable names are important.

Using the values in the metadata, the longitude and latitude of any point (*i_index* and *j_index*) in the grid is computed by:

longitude = gridOriginLongitude + (i_index)(gridSpacingLongitudinal)

latitude = gridOriginLatitude + (j_index)(gridSpacingLatitudinal).

The values of *i_index* start at 0 and increase up to *numPointsLongitudinal-1,* and similarly for *j_index.*

Properties - /WaterLevel

General | Attributes

Number of attributes = 13 [Add] [Delete]

Name	Value	Type	Array Size
commonPointRule	all	8-bit enum (average=1 low=2 high=3 all=4)	1
dataCodingFormat	regularGrid	8-bit enum (fixedStations=1 regularGrid=2 ungeorectifiedGrid=3 movingPlatform=4 irregularGrid=5 variableCellSize=6 TIN=7 stationwiseFixed=8)	1
dimension	2	16-bit integer	1
horizontalPositionUncertainty	-1.0	32-bit floating-point	1
interpolationType	bilinear	8-bit enum (nearestneighbor=1 bilinear=5 biquadratic=6 barycentric=9)	1
maxDatasetHeight	2.082	32-bit floating-point	1
methodWaterLevelProduct	regularly gridded model	String, length = 23	1
minDatasetHeight	1.229	32-bit floating-point	1
numInstances	1	16-bit integer	1
sequencingRule.scanDirection	latitude,longitude	String, length = 18	1
sequencingRule.type	linear	8-bit enum (linear=1 boustrophedonic=2 CantorDiagonal=3 spiral=4 Morton=5 Hilbert=6)	1
timeUncertainty	-1.0	32-bit floating-point	1
verticalUncertainty	-1.0	32-bit floating-point	1

Properties - /WaterLevel/WaterLevel.01

General | Attributes

Number of attributes = 17 [Add] [Delete]

Name	Value	Type	Array Size
dateTimeOfFirstRecord	20190606T120000Z	String, length = 16	1
dateTimeOfLastRecord	20190606T160000Z	String, length = 16	1
eastBoundLongitude	-74.373398	64-bit floating-point	1
gridOriginLatitude	33.567799	64-bit floating-point	1
gridOriginLongitude	-75.123398	64-bit floating-point	1
gridSpacingLatitudinal	0.25	64-bit floating-point	1
gridSpacingLongitudinal	0.25	64-bit floating-point	1
northBoundLatitude	35.317799	64-bit floating-point	1
numGRP	5	16-bit integer	1
numPointsLatitudinal	8	16-bit integer	1
numPointsLongitudinal	4	16-bit integer	1
numberOfTimes	5	16-bit integer	1
southBoundLatitude	33.567799	64-bit floating-point	1
startSequence	0,0	String, length = 3	1
timeRecordInterval	3600	16-bit integer	1
typeOfWaterLevelData	Hydrodynamic model forecast	8-bit enum (Observation=1 Astronomical prediction=2 Analysis or hybrid method=3 Hydrodynamic model hindcast...	1
westBoundLongitude	-75.123398	64-bit floating-point	1

Figure E-9 – Attributes for (top panel) the feature metadata (see Table 12-4) and (bottom panel) the instance metadata (see Table 12-5)

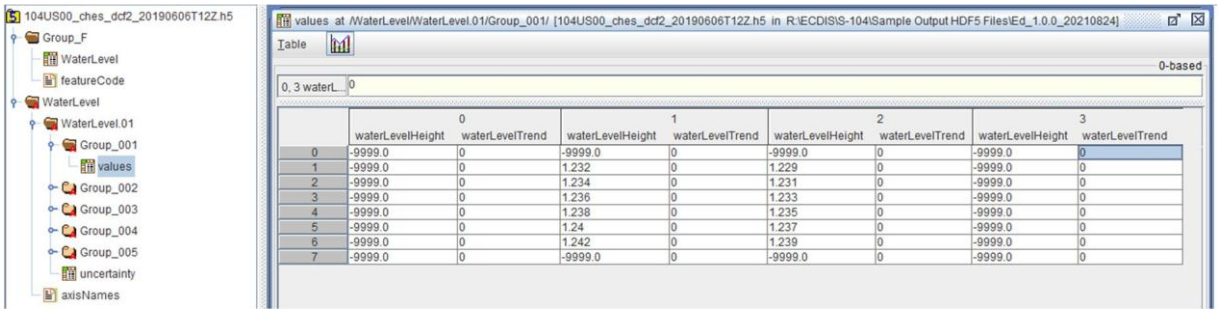

Figure E-10 – Sample HDF5 structure (left panel) and the dataset '*values'* (right panel) for a two-dimensional array of regularly gridded data

E-5 Ungeorectified Grid (dataCodingFormat = 3)

For this coding format, the height and trend are stored in the one-dimensional compound array ‘values’. Data in the values group is for all nodes in the grid at one time point. In each element of the array, the first variable is ‘waterLevelHeight’ and the second is ‘waterLevelTrend’. The spelling and order of variable names are important.

Properties - /WaterLevel

General | Attributes

Number of attributes = 11 — Add | Delete

Name	Value	Type	Array Size
commonPointRule	all	8-bit enum (average=1 low=2 high=3 all=4)	1
dataCodingFormat	ungeorectifiedGrid	8-bit enum (fixedStations=1 regularGrid=2 ungeorectifiedGrid=3 movingPlatform=4 irregularGrid=5 variableCellSize=6 TIN=7 stationwiseFixed=8)	1
dimension	2	16-bit integer	1
horizontalPositionUncertainty	-1.0	32-bit floating-point	1
interpolationType	nearestneighbor	8-bit enum (nearestneighbor=1 bilinear=5 biquadratic=6 barycentric=9)	1
maxDatasetHeight	2.502	32-bit floating-point	1
methodWaterLevelProduct	ungeorectified gridded model	String, length = 28	1
minDatasetHeight	1.229	32-bit floating-point	1
numInstances	1	16-bit integer	1
timeUncertainty	-1.0	32-bit floating-point	1
verticalUncertainty	-1.0	32-bit floating-point	1

Figure E-11 – Attributes for the feature metadata (see Table 12-4)

Properties - /WaterLevel/WaterLevel.01

General | Attributes

Number of attributes = 11 — Add | Delete

Name	Value	Type	Array Size
dateTimeOfFirstRecord	20190606T120000Z	String, length = 16	1
dateTimeOfLastRecord	20190606T180000Z	String, length = 16	1
eastBoundLongitude	-74.62339782714844	64-bit floating-point	1
northBoundLatitude	35.06779861450195	64-bit floating-point	1
numGRP	7	16-bit integer	1
numberOfNodes	12	16-bit integer	1
numberOfTimes	7	16-bit integer	1
southBoundLatitude	33.81779861450195	64-bit floating-point	1
timeRecordInterval	3600	16-bit integer	1
typeOfWaterLevelData	Hydrodynamic model forecast	8-bit enum (Observation=1 Astronomical prediction=2 Analysis or hybrid method=3 Hydrodynamic model hindcast=...	1
westBoundLongitude	-74.87339782714844	64-bit floating-point	1

Figure E-12 – Attributes for the instance metadata (see Table 12-5)

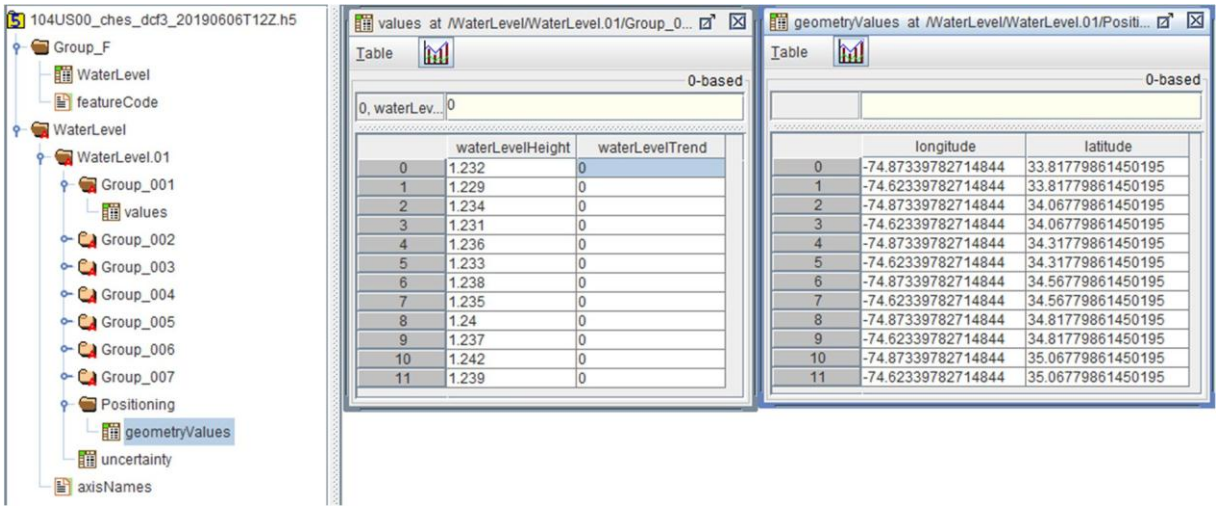

Figure E-13 – Sample HDF5 file (left panel) for ungeorectified gridded data. The middle panel shows the dataset ‘*values*’ and the right panel the dataset ‘*geometryValues*’

E-6 TINs (dataCodingFormat = 7)

For this coding format, the height and trend are stored in the one-dimensional compound array ‘values’. Data in the values group is for all nodes in the TIN grid at one time point. In each element of the array, the first variable is ‘waterLevelHeight’ and the second is ‘waterLevelTrend’. There are also the required *triangles* and optional *adjacency* arrays for TINs. The spelling and order of variable names are important.

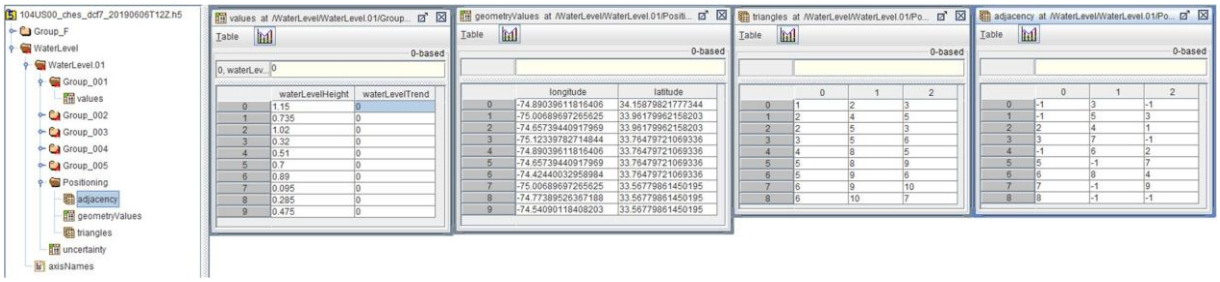

Figure E-14 – Sample HDF5 file (left panel) for a TIN. The second panel shows the dataset 'values', the third panel the dataset '*geometryValues*', the fourth panel the dataset '*triangles*', and the fifth panel the dataset '*adjacency*'

Properties - /WaterLevel

General | Attributes

Number of attributes = 11 — Add | Delete

Name	Value	Type	Array Size
commonPointRule	all	8-bit enum (average=1 low=2 high=3 all=4)	1
dataCodingFormat	TIN	8-bit enum (fixedStations=1 regularGrid=2 ungeorectifiedGrid=3 movingPlatform=4 irregularGrid=5 variableCellSize=6 TIN=7 stationwiseFixed=8)	1
dimension	2	16-bit integer	1
horizontalPositionUncertainty	-1.0	32-bit floating-point	1
interpolationType	barycentric	8-bit enum (nearestneighbor=1 bilinear=5 biquadratic=6 barycentric=9)	1
maxDatasetHeight	2.1486	32-bit floating-point	1
methodWaterLevelProduct	TIN model	String, length = 9	1
minDatasetHeight	0.095	32-bit floating-point	1
numInstances	1	16-bit integer	1
timeUncertainty	-1.0	32-bit floating-point	1
verticalUncertainty	-1.0	32-bit floating-point	1

Figure E-15 – Attributes for the feature metadata (see Table 12-4)

Properties - /WaterLevel/WaterLevel.01

General | Attributes

Number of attributes = 12 — Add | Delete

Name	Value	Type	Array Size
dateTimeOfFirstRecord	20190606T120000Z	String, length = 16	1
dateTimeOfLastRecord	20190606T160000Z	String, length = 16	1
eastBoundLongitude	-74.42440032958984	64-bit floating-point	1
northBoundLatitude	34.15879821777344	64-bit floating-point	1
numGRP	5	16-bit integer	1
numberOfNodes	10	16-bit integer	1
numberOfTimes	5	16-bit integer	1
numberOfTriangles	9	16-bit integer	1
southBoundLatitude	33.56779861450195	64-bit floating-point	1
timeRecordInterval	3600	16-bit integer	1
typeOfWaterLevelData	Hydrodynamic model forecast	8-bit enum (Observation=1 Astronomical prediction=2 Analysis or hybrid method=3 Hydrodynamic model hindcast=4 Hydrodynami...	1
westBoundLongitude	-75.12339782714844	64-bit floating-point	1

Figure E-16 – Attributes for the instance metadata (see Table 12-5)

E-7 Stationwise Fixed Stations (dataCodingFormat = 8)

For this coding format, the height and trend are stored in the one-dimensional compound array 'values', corresponding to data at one station for all time points (see d*ataCodingFormat* = 1, where the data is for all stations for one time point).

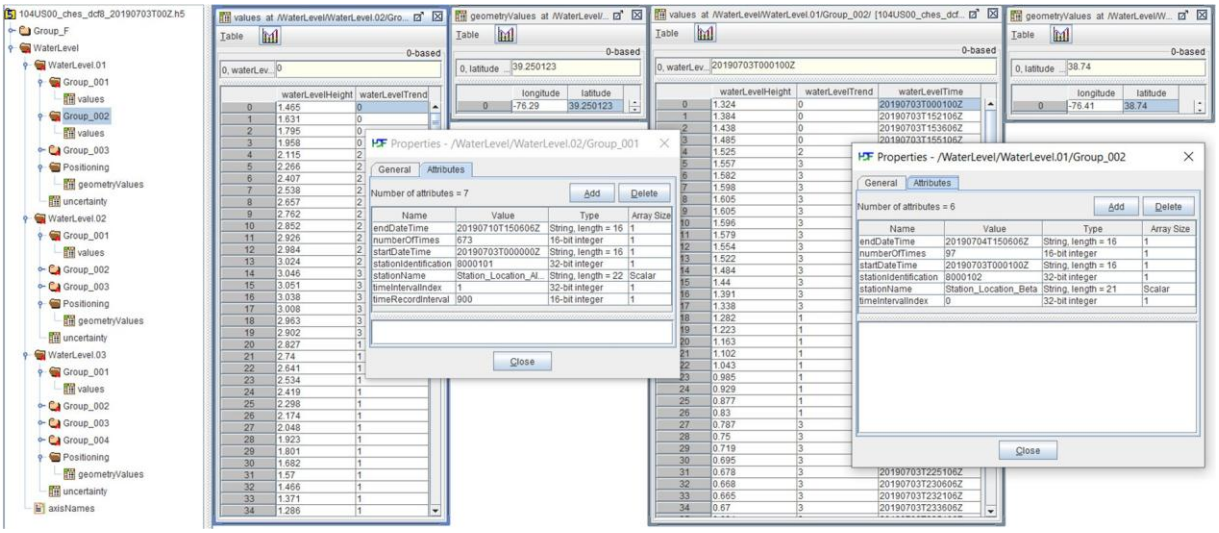

Figure E-17 – Sample HDF5 file (left panel) for stationwise fixed stations data. The second panel shows the dataset '*values*' (for one station), and the third panel the dataset '*geometryValues*'. The fourth panel shows the dataset '*values*' (for a station but different type of time series) but with non-uniform time interval data so *waterLevelTime* at each element is provided. The fifth panel shows the dataset '*geometryValues*' for that second station. Also shown in foreground are the Values Group Attributes for each station time series

Properties - /WaterLevel

General | Attributes

Number of attributes = 11 — Add | Delete

Name	Value	Type	Array Size
commonPointRule	all	8-bit enum (average=1 low=2 high=3 all=4)	1
dataCodingFormat	stationwiseFixed	8-bit enum (fixedStations=1 regularGrid=2 ungeorectifiedGrid=3 movingPlatform=4 irregularGrid=5 variableCellSize=6 TIN=7 stationwiseFixed=8)	1
dimension	2	16-bit integer	1
horizontalPositionUncertainty	-1.0	32-bit floating-point	1
maxDatasetHeight	3.403	32-bit floating-point	1
methodWaterLevelProduct	pred, obsv, fcst	String, length = 16	1
minDatasetHeight	0.439	32-bit floating-point	1
numInstances	3	16-bit integer	1
pickPriorityType	2,1,5	String, length = 5	1
timeUncertainty	-1.0	32-bit floating-point	1
verticalUncertainty	-1.0	32-bit floating-point	1

Figure E-18 – Attributes for the feature metadata (see Table 12-4)

Properties - /WaterLevel/WaterLevel.02

General | Attributes

Number of attributes = 9 — Add | Delete

Name	Value	Type	Array Size
dateTimeOfFirstRecord	20190703T000000Z	String, length = 16	1
dateTimeOfLastRecord	20190710T000000Z	String, length = 16	1
eastBoundLongitude	0.0	64-bit floating-point	1
northBoundLatitude	39.250123	64-bit floating-point	1
numGRP	1	16-bit integer	1
numberOfStations	1	16-bit integer	1
southBoundLatitude	0.0	64-bit floating-point	1
typeOfWaterLevelData	Astronomical prediction	8-bit enum (Observation=1 Astronomical prediction=2 Analysis or hybrid method=3 Hydrodynamic model hindcast=4 Hydro...	1
westBoundLongitude	-76.41	64-bit floating-point	1

Figure E-19 – Attributes for the instance metadata (see Table 12-5)

Annex F – Validation Checks

[Reserved for future development.]

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Annex G – Use Cases

G-1 German Water Level Data and Forecast

G-1.1 Summary

Name:	German S-104 Water Level Data and Forecast (Courtesy: BSH - Bundesamt für Seeschifffahrt und Hydrographie)
Description:	The usage of S-104 format for data delivery and the operational regular data transfer in near real time allows several applications. The optimised water level forecast builds the basis for safe navigation, especially in areas with strong tides, as the inner German Bight. The S-104 data may be used for route planning, allowing to adapt to changing water depth. Optimised water level forecasting leads to better route monitoring as well as route planning and a more efficient loading of ships. Furthermore, the potential data transfer on ships helps for direct navigation of a vessel. It will allow a more efficient usage of narrow shipping channels or areas with high traffic density. The main users are shipping companies and administration, pilots, and organisations for harbour and waterway management. Further applications are possible in fields of civil protection, protection of marine environment, support of offshore and coastal activities, as well as coastal engineering.
Potential Actors:	Navigators, Marine Pilots, Shipping Companies, Vessel Control Centres, Ship and Harbour Managements, Port Authorities, BSH (Bundesamt für Seeschifffahrt und Hydrographie), WSV (Wasserstraßen- und Schifffahrtsverwaltung des Bundes).
Potential Applications:	1. Route monitoring. 2. Route planning and forecast of safety corridor. 3. Other applications as civil protection, protection of marine environment, support of offshore and coastal activities, as well as coastal engineering.
Data Requirements:	• High quality water level forecast (with adequate spatial and temporal resolution). • Astronomical prediction. • Near real time observational data.
Technical Aspects and Post Processing:	• Different kinds of water level data are stored in one file. Portrayal of real time observation, optimised water level forecast and astronomic prediction with the help of a WMS. • Transformation of all kinds of data. • Route planning with respect to forecasted water level.

G-1.2 Additional details

G-1.2.1 Types of data used to create S-104 test datasets

1. Operational Numerical Forecast Model Output
   a. Hydrodynamic model forecast for Elbe Estuary / German Bight
   b. 90m x 90m grid spacing / 900m x 900m grid spacing
   c. Forecast interval: 48h, 15 Minutes time step
   d. 1155 x 728 grid points / 1030 x 1761 grid points
   e. Update: 2 times daily
2. Observation
   a. Discrete observations from gauge stations

   b. Time spacing: 1 minute
   c. Update: near real time
3. Astronomical prediction
   a. Forecast for discrete locations
   b. Long range prediction
   c. Update: yearly
4. Model output statistics [MOS]
   a. Statistical method for optimizing numerical model forecast
   b. Available for some locations
   c. Forecast up to 7 days
   d. Time spacing: 15 Minutes
   e. Update: every 15 Minutes

G-1.2.2 Data processing

Numerical model output and model output statistics (MOS) at several stations have been combined for an optimised areal water level forecast. The method uses the surface shape of a hydrodynamic model forecast and corrects it with high accurate MOS forecasts at specific locations. This leads to an overall optimised and frequently updated water level surface forecast.

G-1.2.3 S-104 data transformation

The data described above, especially the post processed data, builds the basis for the creation of S-104 test data sets. The transformation of different formats are achieved by a tuple of tools:

1. S-104 regular grid converter
   a. Input: Hydrodynamic model forecast (MOS-corrected)
   b. Output: S-104 conformant HDF5 file
2. S-104 station data converter
   a. Input: Observation, Astronomic Prediction, MOS-Data, Numerical Model data (MOS-corrected) for discrete locations
   b. Output: single S-104 HDF5 file

G-1.2.4 Results

Figure G-1 below shows one application of S-104 data sets, a WMS to display the S-104 data for the use case Pick Report. The request pops up a figure displaying the data described above. The green line represents the observation, blue the astronomical prediction and black represents the hydrodynamic model forecast optimised with MOS. The purple line shows the difference between prediction and hydrodynamic model forecast.

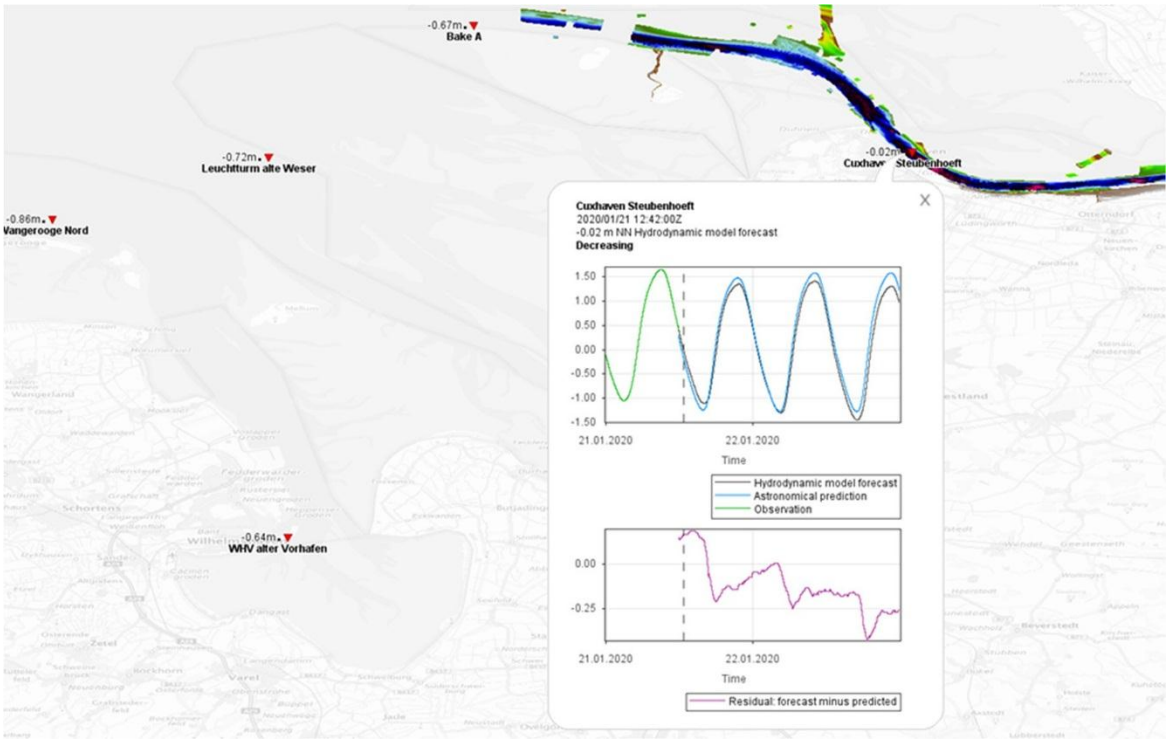

Figure G-1 – Pick Report for S-104 test data

As a practical example, S-104 data sets were produced as a suitable format to deliver different kinds of water level data in one file. A regular data transfer via FTP has been established and the S-104 data has been integrated in a WMS for a highly frequented region. The “Pick Report” portrayal has been implemented. It has been confirmed by consensus of a user workshop that the display of water level data as a pick report like specified in S-104 is good practice.

G-2 Depth adjustment in ECDIS

G-2.1 Summary

Name:	Depth adjustment in ECDIS
Description:	S-104 data may be used for route planning, in combination with S-101 ENC and S-102 Bathymetric Surface data to provide navigation officers with dynamic water depth information for the purpose of route planning. This will allow efficient use of waterways with tidal or other dynamic variations of water levels, saving vessels transit time and fuel costs. The main users are commercial vessels and pilots.
Potential Actors:	Navigators, Marine Pilots, Hydrographic Offices.
Potential Applications:	• Route planning and assessments of safe depths. • Safety contours according to dynamic depths instead of the static contours currently provided by ENC data alone.

Data Requirements:	• High quality water level forecast (with adequate spatial and temporal resolution). • Astronomical prediction. • Near real time observational data. • S-102 bathymetry data (with adequate spatial resolution). • Availability of underlying ENC data. • Vertical datums in S-102 and S-104 data should match.
Technical Aspects and Post Processing:	• S-104 data must be provided as a continuous coverage (data coding format 2 (regular grid), 3 (ungeorectified grid) or 7 (TIN)). • ECDIS must implement S-98 interoperability in order to integrate S- 101, S-102, and S-104 data. • ECDIS must have functionality to implement route planning with respect to forecasted water levels.

G-2.2 Additional details

G-2.2.1 Types of data

S-104 data, available as forecasted data in grid format covering the projected time of the transit and the planned route.

S-102 data, available in grid format covering the planned route. Relevant vessel parameters (draught, squat) are available to the ECDIS.

G-2.2.2 Processing

The ECDIS is used in route planning mode and the navigator plots the planned route or imports it from an S-421 dataset.

The navigator sets the projected start time of the transit and the route parameters such as speed over ground, cross-track deviation, etc.

The navigator selects a time interval based on the speed of the vessel and the time record interval between S-104 records that is encoded in the S-104 forecast data (see Table 12-5).

Adjustment zones are created by the ECDIS based on the route schedule, speed, and a buffer (calculated either as a multiple of cross-track deviation or a user-specified value). The extent of each adjustment zone depends on the speed and cross-track buffer.

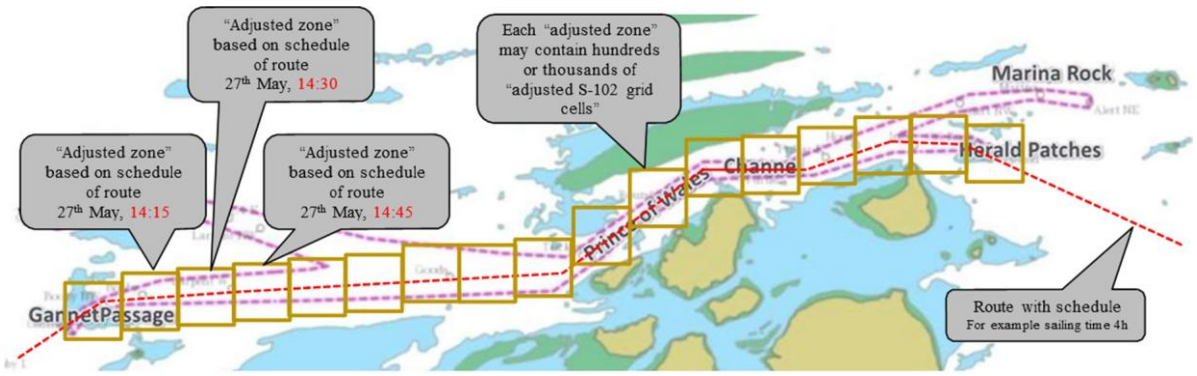

Figure G-2 – Adjustment zones based on planned route. (Courtesy: Furuno Electric Company, Ltd)

The ECDIS computes an "integrated and dynamic safety contour" in the region covered by the combined adjustment zones, computed from bathymetry data adjusted by the dynamic water levels extracted from the S-104 record(s) corresponding to the time the vessel is transiting each adjustment zone.