S-102

Bathymetric Surface Product Specification

Edition 2.2.0 – April 2023

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Document History

Changes to this Specification are coordinated by the IHO S-100 Working Group. New editions will be made available via the IHO web site. Maintenance of the Specification shall conform to IHO Resolution 2/2007 (as amended).

Table — Document History

Version Number	Date	Approved By	Purpose
1.0.0	April 2012	TSMAD	Approved edition of S-102
2.0.0	March 2017	S-102PT	Updated clause 4.0 and 12.0. Populated clause 9.0 and Annex B.
2.0.0	May 2017	S-102PT	Modified clause 9.0 based on feedback at S-100WG2 meeting.
2.0.0	February 2018	S-102PT	Modified Clause 9.0. Deleted contents of Annex B in preparation for updated S-100 Part 10C guidance. Added Annex F: S-102 Dataset Size and Production, Annex G: Gridding Example, Annex H: Statement added for Multi-Resolution Gridding, Annex I: Statement for future S-102 Tiling.
2.0.0	June 2018	S-102PT	Modifications to align with S-100 v4.0.0, S-100 Part 10c development, and actions from 4th April S-102 Project Team Meeting. Modified content throughout the following sections: — Clause 1, 3, 4, 5, 6, 9, 10, 11, and 12. — Annexes A, B, D, F, G, and I.
2.0.0	October/November 2018	S-102PT	Entered Redline comments from HSSC Letter 02/2018 Modified content includes: — Clause 1, 3, 4, 5, 6, 9, 10, 11, and 12. — Annexes A, B, D, F, G, and I.

Version Number	Date	Approved By	Purpose
2.0.0	January/February 2019	S-102PT	Adjudicated HSSC and S102PT Comments at 5th S-102 Project Team Meeting. Modified content includes: — Clause 1, 3, 4, 5, 6, 9, 10, 11, and 12. — Annexes A, B, D, F, G, and I.
2.0.0	September/October 2019	S-102PT	Adjudicated HSSC and S102PT comments since last release Modified content includes: — Annex A, B. — Clause 4, 10, 12.
2.1.0	November 2020	S-102PT	Redline first draft of 2.1 including: S-102PT6-07.1_CHS-Paper to limit the mandate of the S-102 standard for navigation only — remove track changes and tiling options. S-102PT6_2020_05.c_Data Product Format_Prepared by CARIS-v3.pdf — adjusted with comments from 7Cs and BSH. Removed Annex B sample HDF encoding dump as it was inconsistent.
2.1.0	March 2021	S-102PT	Redline final draft of 2.1 including: S-102PT7 agreed in principle to limit the scope of S-102 v 2.1 to Navigation Only. Several sections adjusted in view of this decision. S-102PT7 revised storage locations for minimum/maximum depth and associated uncertainty. S-102PT7 agreed for metadata to be stored in a separate ISO-formatted file. Revised several internal references.
2.1.0	May 2022	S-102PT	Edited filename for exchange catalogue to be CATALOG.XML in 11.3 and in Table 12-7.

Bathymetric Surface Product Specification

1. Overview

With the advent of electronic navigation and the technological progress of surveying systems and production capabilities, the ability to enhance maritime navigation with the portrayal of high-resolution bathymetry has become a requirement. The provision and utilization of such data in a standardized format is essential to support the safe and precise navigation of marine vessels, and furthermore an important basis for many other maritime applications.

1.1. Introduction

This document describes an S-100 compliant product specification for a bathymetric surface product. Incorporating aspects of the navigation surface concept [Smith et al, 2002], an S-102 bathymetric surface product is a digital elevation model which represents the seafloor in a regular grid structure. It can be used alone or as an important element/source for future S-100 conformant ECDIS navigation. The product specification is based on the IHO S-100 framework specification and the ISO 19100 series of standards. It comprises the content model (spatial structure and metadata), encoding structure, portrayal and exchange file format for a bathymetric surface product.

1.2. References

[1] S-100 edition 5.0.0: IHO Universal Hydrographic Data Model, International Hydrographic Organization (https://iho.int/uploads/user/pubs/standards/s-100/S-100_5.0.0_Final_Clean_Web.pdf).

[2] S-44 edition 6.1.0: IHO Standards for Hydrographic Surveys, International Hydrographic Organization (https://iho.int/uploads/user/pubs/standards/s-44/S-44_Edition_6.1.0.pdf).

[3] S-49 edition 2.1.0: STANDARDIZATION of MARINERS' ROUTEING GUIDES, International Hydrographic Organization (https://iho.int/uploads/user/pubs/standards/s-49/S-49_Ed.2.1.0_Standardization%20of%20Mariners%20Routeing%20Guides_EN.pdf).

[4] S-32 edition 1.0.0: Hydrographic Dictionary — Glossary of ECDIS Related Terms, International Hydrographic Organization (http://iho-ohi.net/S32/engView.php).

[5] ISO 8601:2004: Data elements and interchange formats — Information interchange — Representation of dates and times, International Organization for Standardization (https://www.iso.org/standard/40874.html).

[6] ISO 639-2:1998: Codes for the representation of names of languages — Part 2: Alpha-3 code, International Organization for Standardization (https://www.iso.org/standard/4767.html).

[7] ISO 19103:2015: Geographic information — Conceptual schema language, International Organization for Standardization (https://www.iso.org/standard/56734.html).

[8] ISO 19111:2007: Geographic information — Spatial referencing by coordinates, International Organization for Standardization (https://www.iso.org/standard/41126.html).

[9] ISO 19115-1:2014/Amd 1:2018: Geographic information — Metadata — Part 1: Fundamentals — Amendment 1, International Organization for Standardization (https://www.iso.org/standard/73118.html).

[10] ISO 19115-2:2009: Geographic information — Metadata — Part 2: Extensions for imagery and gridded data, International Organization for Standardization (https://www.iso.org/standard/39229.html).

[11] ISO/TS 19115-3:2016: Geographic information — Metadata — Part 3: XML schema implementation for fundamental concepts, International Organization for Standardization (https://www.iso.org/standard/32579.html).

[12] ISO 19123:2005: Geographic information — Schema for coverage geometry and functions, International Organization for Standardization (https://www.iso.org/standard/40121.html).

[13] ISO/TS 19129:2009: Geographic information — Imagery, gridded and coverage data framework, International Organization for Standardization (https://www.iso.org/standard/43041.html).

[14] ISO 19131:2007/Amd 1:2011: Geographic information — Data product specifications — Amendment 1: Requirements relating to the inclusion of an application schema and feature catalogue and the treatment of coverages in an application schema., International Organization for Standardization (https://www.iso.org/standard/51790.html).

[15] ISO/IEC 19501:2005: Information technology — Open Distributed Processing — Unified Modeling Language (UML) Version 1.4.2, International Organization for Standardization and International Electrotechnical Commission (https://www.iso.org/standard/32620.html).

[16] ISO 3166-2:2013: Codes for the representation of names of countries and their subdivisions — Part 2: Country subdivision code, International Organization for Standardization (https://www.iso.org/standard/63546.html).

[17] ISO/TS 19130:2010: Geographic information — Imagery sensor models for geopositioning, International Organization for Standardization (https://www.iso.org/standard/51789.html).

[18] ISO/TS 19130-2:2014: Geographic information — Imagery sensor models for geopositioning — Part 2: SAR, InSAR, lidar and sonar, International Organization for Standardization (https://www.iso.org/standard/56113.html).

[19] ISO/TS 19139-1:2019: Geographic information — XML schema implementation — Part 1: Encoding rules, International Organization for Standardization (https://www.iso.org/standard/67253.html).

[20] ISO/IEC 10646-1:2000: Information technology — Universal Multiple-Octet Coded Character Set (UCS) — Part 1: Architecture and Basic Multilingual Plane, International Organization for Standardization and International Electrotechnical Commission (https://www.iso.org/standard/29819.html).

[21] The Navigation Surface: The Navigation Surface: A New Database Approach to Creating Multiple Products from High-Density Surveys, Smith S., Alexander L. and Armstrong A., International Hydrographic Review (http://scholars.unh.edu/ccom/976).

[22] The Open Navigation Surface Project: The Open Navigation Surface Project, Calder B., Byrne S., Brennan R., Case J., Fabre D., Gallagher B., Ladner W., Moggert F. and Patron M., International Hydrographic Review (https://scholars.unh.edu/ccom/1011).

1.3. Terms, definitions and abbreviations

1.3.1. 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.

1.3.2. Terms and definitions

1.3.2.1. Accuracy

Closeness of agreement between a test result and the accepted reference values.

NOTE A test result can be from an observation or measurement.

1.3.2.2. Coordinate

One of a sequence of *n* numbers designating the position of a point in N-dimensional space.

NOTE The numbers must be qualified by units and CRS.

1.3.2.3. Coordinate Reference System

Coordinate system which is related to the real world by a datum.

1.3.2.4. Coverage

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

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.

EXAMPLE

Examples include a digital image, polygon overlay, or digital elevation matrix

1.3.2.5. Coverage Geometry

Configuration of the **domain** of a **coverage** described in terms of **coordinates**.

1.3.2.6. Direct Position

Position described by a single set of **coordinates** within a **coordinate reference system**.

1.3.2.7. Domain

Well-defined set.

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

1.3.2.8. Depth

The vertical distance from a given water level to the bottom. In this standard, depth refers to the S-32 definition of “Depth Charted”.

NOTE The numbers must be qualified by units and datum.

1.3.2.9. Feature

Abstraction of real-world phenomena.

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

1.3.2.10. Feature Attribute

Characteristic of a **feature**.

NOTE 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 value domain of the feature attribute type.

1.3.2.11. Function

Rule that associates each element from a **domain** (source, or domain of the function) to a unique element in another domain (target, co-domain, or **range**).

NOTE The range is defined by another domain.

1.3.2.12. Geometric Object

Spatial object representing a set of **direct positions**.

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 characteristics of an object such as a feature or a significant part of a feature.

1.3.2.13. Grid

Network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in a systematic way.

NOTE The curves partition a space into grid cells.

1.3.2.14. Grid Point

Point located at the intersection of two or more curves in a **grid**.

1.3.2.15. Lidar

An optical remote sensing technique that uses a laser pulse to determine distance.

NOTE Lidar may be used to determine depth in shallow water areas.

1.3.2.16. Navigation Surface

A **coverage** representing the bathymetry and associated uncertainty with the methods by which those objects can be manipulated, combined, and used for a number of tasks, certified for safety of navigation.

1.3.2.17. Range <coverage>

Set of values associated by a **function** with the elements of the **spatiotemporal domain** of a **coverage**.

1.3.2.18. Record

Finite, named collection of related items (objects or values).

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

1.3.2.19. Rectified Grid

Grid for which there is a linear relationship between the **grid coordinates** and the **coordinates** of an external **coordinate reference system**.

NOTE If the coordinate reference system is related to the earth by a datum, the grid is a georectified grid.

1.3.2.20. Referenceable Grid

Grid associated with a transformation that can be used to convert **grid coordinate** values to values of coordinates referenced to an **external coordinate reference system**.

1.3.2.21. Sonar

A technique that uses sound propagation through water to determine distance, primarily **depth** measurement.

1.3.2.22. Spatiotemporal Domain <coverage>

Domain composed of **geometric objects** described in terms of spatial and/or temporal **coordinates**.

NOTE The spatiotemporal domain of a continuous coverage consists of a set of direct positions defined in relation to a collection of geometric objects.

1.3.2.23. Surface

Connected 2-dimensional geometric primitive, representing the continuous image of a region of a plane.

NOTE The boundary of a surface is the set of oriented, closed curves that delineate the limits of the surface.

1.3.2.24. Uncertainty

The interval (about a given value) that will contain the true value of the measurement at a specific confidence level.

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. The numbers must be qualified by units.

In this document and S-102 uncertainty is always considered to be 1-dimensional and at the 2-sigma or 95% confidence level.

1.3.2.25. Vector

Quantity having direction as well as magnitude.

NOTE A directed line segment represents a vector if the length and direction of the line segment are equal to the magnitude and direction of the vector. The term vector data refers to data that represents the spatial configuration of features as a set of directed line segments.

1.3.3. Abbreviated terms

This Product Specification adopts the following convention for presentation purposes:

API	Application Programming Interface
DS	Digital Signature
DSS	Digital Signature Scheme
ECDIS	Electronic Chart Display Information System
ECS	Electronic Chart System
ENC	Electronic Navigational Chart
GML	Geography Markup Language
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organization
ISO	International Organization for Standardization
NS	Navigation Surface
ONS	Open Navigation Surface
PK	Public Key
SA	Signature Authority
SK	Secret Key
UML	Universal Modelling Language

1.4. General S-102 data product description

Title Bathymetric Surface Product Specification

Abstract This document is a Product Specification for a bathymetric surface which may be used alone or as an important element/source for future S-100 conformant ECDIS navigation. The product is defined as a data set with different coverages. This Product Specification includes a content model and separate encodings.

Acronym S-102

Content The Product Specification defines all requirements to which S-102 bathymetric data products must conform. Specifically, it defines the data product content in terms of features and attributes within the feature catalogue. The display of features is defined by the symbols and rule sets contained in the portrayal catalogue. The Data Classification and Encoding Guide (DCEG) provides guidance on how data product content must be captured. Annex A, in addition to Section 4.3.1, will provide implementation guidance for developers.

Spatial Extent **Description**: Areas specific to marine navigation.
East Bounding Longitude: 180°
West Bounding Longitude: -180°
North Bounding Latitude: 90°
South Bounding Latitude: -90°

Purpose The primary purpose of the Bathymetric Surface Product is to provide high-resolution bathymetry in gridded form in support of safety of navigation. A Bathymetric Surface Product may exist anywhere in the maritime domain. There are no limitations to its extent. Portrayal of S-102 bathymetry with other S-100 compliant products are intended to support safe passage, precise berthing and mooring, as well as route planning of marine vessels. A secondary purpose of a bathymetric surface product is to provide high-resolution bathymetric data for other maritime applications.

1.5. 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 Chapter 12.

Title Bathymetric Surface Product Specification

S-100 Version 5.0.0

S-102 Version 2.2.0

Date April 2023

Language English

Classification Unclassified

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Maintenance Changes to the Product Specification S-102 are coordinated by the IHO S-100 Working Group (S-100WG), and must be made available via the IHO web site. Maintenance of the Product Specification must conform to IHO Resolution 2/2007, as amended.

1.6. IHO Product Specification Maintenance

1.6.1. Introduction

Changes to S-102 will be released by the IHO as a New Edition, revision, or clarification.

1.6.2. New Edition

New Editions of S-102 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 a significant impact on either existing users or future users of S-102.

1.6.3. Revisions

Revisions are defined as substantive semantic changes to S-102. Typically, *revisions* will change S-102 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-102. 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-102.

1.6.4. Clarification

Clarifications are non-substantive changes to S-102. 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-102.

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.

1.6.5. Version Numbers

The associated version control numbering to identify changes (n) to S-102 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 Scope

This product specification defines only one general scope which applies to all its sections.

Scope Identification GeneralScope

3. Data Product Identification

Title Bathymetric Surface

Abstract The Bathymetric Surface Product consists of a set of values organized to form a regular set of grid coverages, with associated metadata, for an area of the sea, river, lake, or other body of water. The final grid coverages include a depth value and optional associated uncertainty estimate for each location in the matrix.

Topic Category	Main topics for the product, as according to ISO 19115-1:2014/Amd 1:2018 MD_TopicCategoryCode: 006 — elevation 014 — oceans 012 — inlandWaters
Geographic Description	Areas specific to marine navigation.
Spatial Resolution	The spatial resolution, or the spatial dimension on the earth covered by the size of a grid matrix cell (nominal ground sample distance), varies according to the model adopted by the producing hydrographic office.
Purpose	The primary purpose of the bathymetric surface product is to provide high-resolution bathymetry in gridded form in support of safety of navigation. The secondary purpose is to provide high-resolution bathymetry for other maritime applications.
Language	English (Mandatory), other (Optional)
Classification	Data can be classified as one of the following: a) Unclassified; b) Restricted; c) Confidential; d) Secret; e) Top Secret; f) Sensitive but unclassified; g) For official use only; h) Protected; or i) Limited distribution.
Spatial Representation Type	Type of spatial representation for the product, as defined by the ISO 19115-1:2014/Amd 1:2018 MD_SpatialRepresentationTypeCode: 002 — grid.
Point of Contact	Producing Agency

4. Data Content and Structure

4.1. Introduction

The Bathymetric Surface Product incorporates aspects of the Navigation Surface concept where in addition to estimation of depth, an optional estimate of the uncertainty associated with the depth can be computed and preserved. Figure 1 below shows a high-level overview of the structure of S-102. It shows that the Bathymetric Surface Product consists of a set of data comprising the HDF5 datasets plus a Digital Certification Block. The Digital Certification Block is mandatory so that the user can trace whether the data has been certified. The HDF5 file consists of metadata (spatial, feature and discovery) and collocated coverages consisting of depth and uncertainty values. S-102 uses the S-100 Data Protection Scheme to ensure certification and authentication.

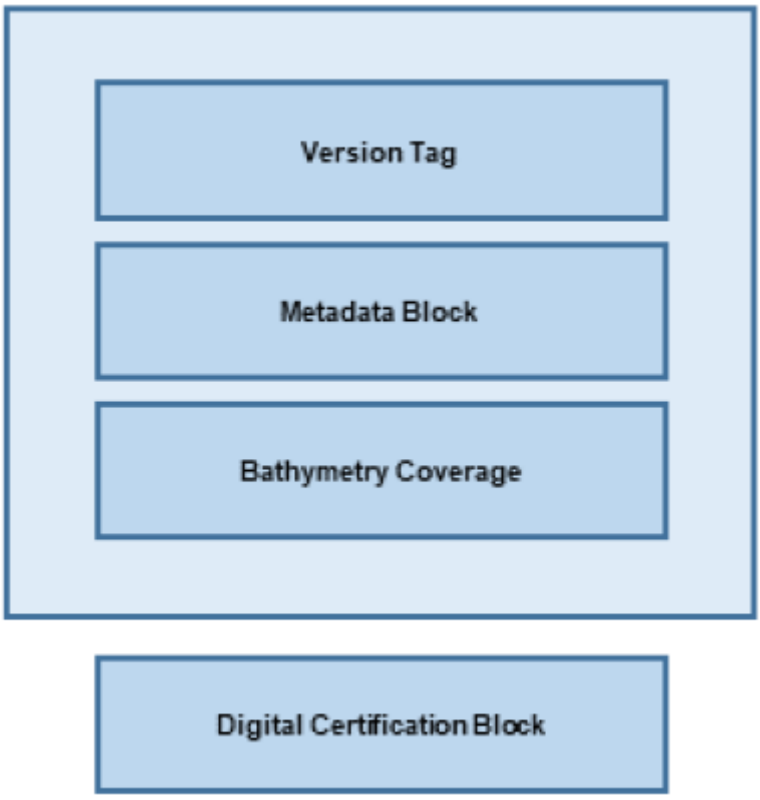

Figure 1 — Overview Structure of S-102

Thus, the Bathymetric Surface Product is a hybrid of coverages, as defined in S-100, Part 8, and metadata packages as defined in S-100, Part 4. This is described in Section 4.2.

4.2. Application Schema

The Application Schema Data Set Structure is shown in Figure 2 and Figure 3. They show a number of classes specialized for use in S-102 and two sets of implementation classes. An actual data set of S-102 bathymetry data only contains the implementation classes. All of the required attributes from the other classes in

the application schema are satisfied by statements within the Product Specification. This approach to producing the Application Schema results in a very simple structure for implementation.

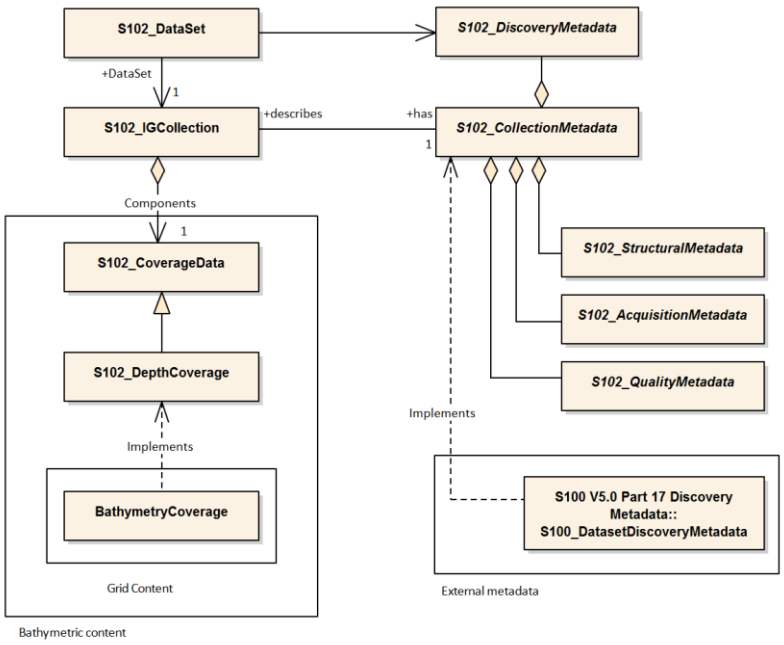

Figure 2 — Data Set Structure of S-102

The model in Figure 2 states that:

— An S-102 data set (**S102_DataSet**), which is inherited from **S100_DataSet**, references an S-102 Image and Gridded Data Collection (**S102_IGCollection**). In S-100 it is possible to have multiple collections but in S-102 only one is needed to hold the bathymetry coverage. The S-102 discovery metadata class (**S102_DiscoveryMetadata**) describes the metadata entities required for the identification of the entire data set. The required discovery metadata is implemented through the **S100_DatasetDiscovery** class defined in S-100, Part 17.

— An instance of an S-102 Image and Gridded Data Collection (**S102_IGCollection**) which is a subtype of **S100_IGCollection**, is described by a set of S-102 Collection Metadata (**S102_CollectionMetadata**). This relationship is 1 to 1 meaning that there is one set of collection metadata for each instance of **S102_IGCollection**. There is a large choice of metadata that may be used in an S-100 compliant data product. Only a small amount of this metadata is mandated by ISO 19115-1:2014/Amd 1:2018 for discovery. This edition of S-102 neither uses ISO metadata files nor extends S-100 generic metadata and therefore **S102_CollectionMetadata**, **S102_StructuralMetadata**, **S100_QualityMetadata**, and **S102_AcquisitionMetadata** are abstract classes as in S-100 Part 8 Figure 8-27. This edition of S-102 uses the dataset metadata elements defined in S-100, Part 17 and S-100, Part 10c with restrictions defined in this product specification. The metadata elements defined in S-100, Part 17 are encoded in a discovery block within the exchange catalogue (S-100, Part 12, Clause 12.6 to S-100, Part 12, Clause 12.10), and the metadata elements

defined in S-100, Part 10c are encoded as attributes and datasets within the HDF5 file (S-100, Part 12, Clause 10.2). The conceptual structure of coverage features in an S-102 dataset is discussed further in Section 4.2.1.

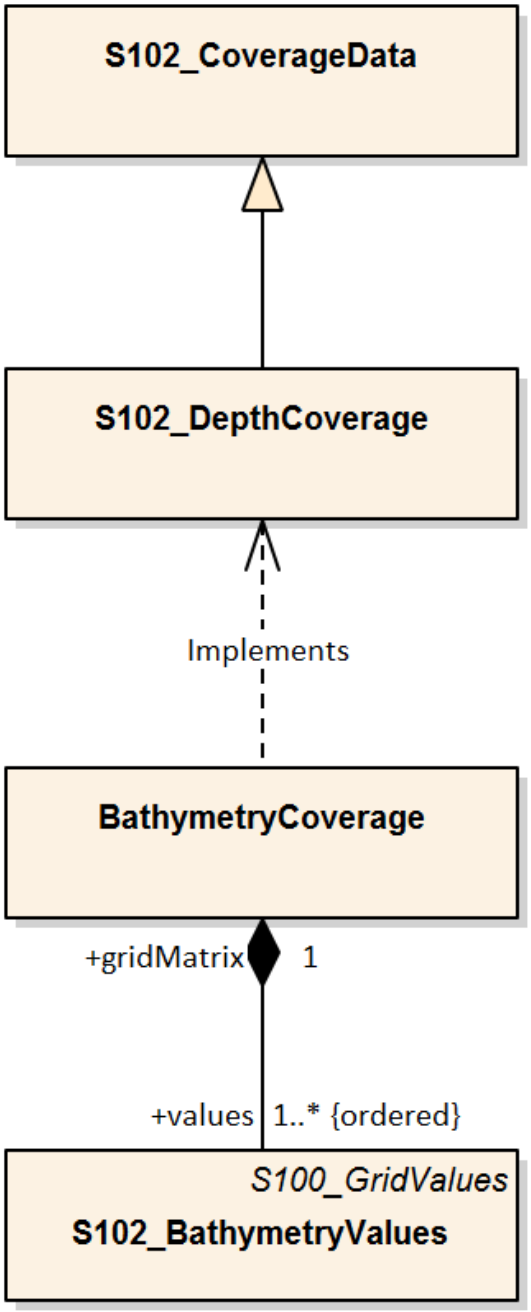

Figure 3 — Coverage Structure of S-102

The model in Figure 3 depicts the coverage type in this application schema:

— The coverage type is a discrete Regular Grid Coverage called **S102_DepthCoverage** which inherits from (**S100_GridCoverage**). Many of the parameters of the coverage are described in the product specification.

4.2.1. Application Schema implementation classes

The implementation classes for the template application schema are shown in Figure 4. The attributes are shown for the coverage related classes together with the attribute classes.

In order to simplify the implementation, a number of defaults are assumed for S-102. These defaults simplify implementation and help simplify interaction with the Navigation Surface implementation from the Open Navigation Surface Working Group and other bathymetric gridded types. In the following sub clauses, the default values are emphasized so that they do not need to be encoded when generating an encoding of the implementation classes. However, if specified they must assume the stated values unless other options are stated.

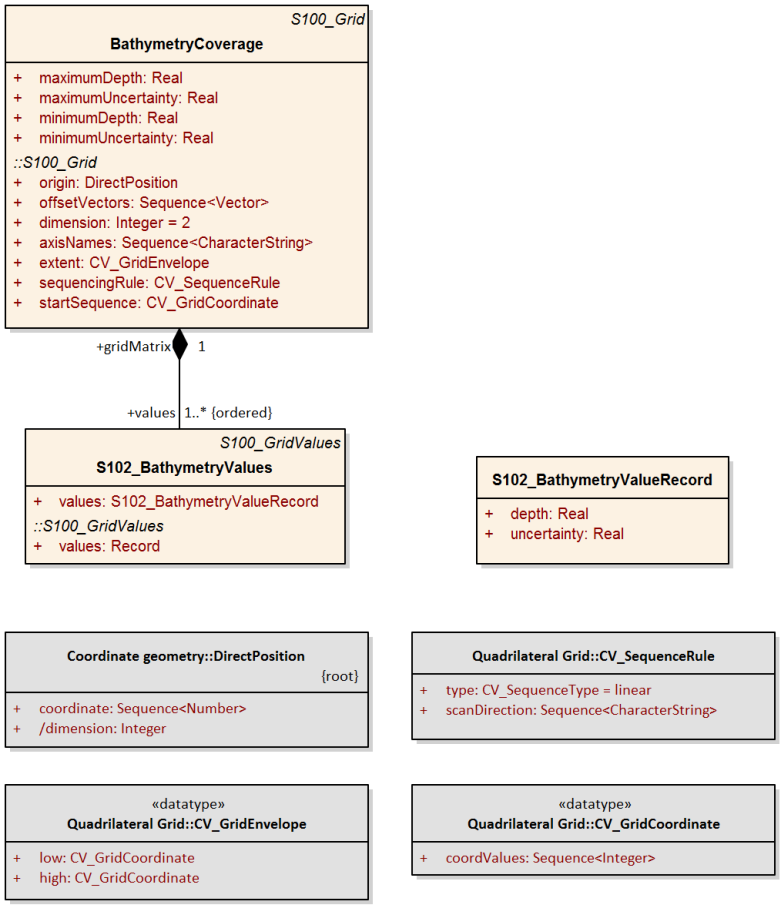

Figure 4 — Implementation of Classes of S-102

4.2.1.1. Implementation classes description

4.2.1.1.1. BathymetryCoverage

####### 4.2.1.1.1.1. BathymetryCoverage semantics

The class **BathymetryCoverage** has the attributes *minimumDepth*, *maximumDepth*, *minimumUncertainty*, and *maximumUncertainty* which bound the depth attribute and the uncertainty attribute from the **S102_BathymetryValues** record.

BathymetryCoverage additionally contains the inherited attributes *origin*, *offsetVectors*, *dimension*, *axisName*, *extent*, *sequenceRule*, and *startSequence* from **S100_Grid** and **CV_Grid**.

The origin is a position in a specified coordinate reference system, and a set of offset vectors specify the direction and distance between the grid lines. It also contains the additional geometric characteristics of a rectified grid.

4.2.1.1.1.2. minimumDepth

The attribute *minimumDepth* has the value type *Real* and describes the lower bound of the depth estimate for all the *depth* values in **S102_BathymetryValues** record. This attribute is required. There is no default.

4.2.1.1.1.3. maximumDepth

The attribute *maximumDepth* has the value type *Real* and describes the upper bound of the depth estimate for all the *depth* values in **S102_BathymetryValues** record. This attribute is required. There is no default.

4.2.1.1.1.4. minimumUncertainty

The attribute *minimumUncertainty* has the value type *Real* and describes the lower bound of the uncertainty of the depth estimate for all the *depth* values in **S102_BathymetryValues** record. If all uncertainty values are populated with the fill value (i.e., if no actual uncertainties exist in the data), this attribute shall be populated with the fill value. This attribute is required. There is no default.

4.2.1.1.1.5. maximumUncertainty

The attribute *maximumUncertainty* has the value type *Real* and describes the upper bound of the uncertainty of the depth estimate for all the *depth* values in **S102_BathymetryValues** record. If all uncertainty values are populated with the fill value (i.e., if no actual uncertainties exist in the data), this attribute shall be populated with the fill value. This attribute is required. There is no default.

4.2.1.1.1.6. origin

The attribute *origin* has the value class *DirectPosition* which is a position that shall locate the origin of the rectified grid in the coordinate reference system. This attribute is required. There is no default. In the encoding this is split into properties gridOriginLatitude and gridOriginLongitude.

4.2.1.1.1.7. offsetVectors

The attribute *offsetVectors* has the value class *Sequence<Vector>* that shall be a sequence of offset vector elements that determine the grid spacing in each direction. The data type Vector is specified in ISO 19103:2015. This attribute is required. There is no default. The HDF5 encoding implements and simplifies *offsetVectors* in the form of two HDF5 attributes: gridSpacingLatitudinal and gridSpacingLongitudinal.

4.2.1.1.1.8. dimension

The attribute *dimension* has the value class Integer that shall identify the dimensionality of the grid. The value of the grid dimension in this product specification is 2. This value is fixed in this Product Specification and does not need to be encoded.

4.2.1.1.1.9. axisNames

The attribute *axisNames* has the value class *Sequence<CharacterString>* that shall be used to assign names to the grid axis. The grid axis names shall conform to those of the CRS. For the allowable CRS according to this specification, the axis names shall be “Latitude” and “Longitude” for unprojected data sets or “Northing” and “Easting” in a projected space.

4.2.1.1.1.10. extent

The attribute *extent* has the value class **CV_GridEnvelope** that shall contain the extent of the spatial domain of the coverage. It uses the value class **CV_GridEnvelope** which provides the grid coordinate values for the diametrically opposed corners of the grid. The default is that this value is derived from the bounding box for the data set or tile in a multi tile data set. In the encoding the property BoundingBox is used to hold the extent.

4.2.1.1.1.11. sequencingRule

The attribute *sequencingRule* has the value class **CV_SequenceRule** that shall describe how the grid points are ordered for association to the elements of the sequence values. The default value is “Linear”. No other options are allowed.

4.2.1.1.1.12. startSequence

The attribute *startSequence* has the value class **CV_GridCoordinate** that shall identify the grid point to be associated with the first record in the values sequence. The default value is the lower left corner of the grid. No other options are allowed.

4.2.1.1.2. S102_BathymetryValues

4.2.1.1.2.1. S102_BathymetryValues semantics

The class **S102_BathymetryValues** is related to **BathymetryCoverage** by a composition relationship in which an ordered sequence of *depth* values provide data values for each grid cell. The class **S102_BathymetryValues** inherits from S100_Grid.

4.2.1.1.2.2. values

The attribute *values* has the value type ***S102_BathymetryValueRecord*** which is a sequence of value items that shall assign values to the grid points. There are two attributes in the bathymetry value record, *depth* and *uncertainty* in the **S102_BathymetryValues** class.

4.2.1.1.3. DirectPosition

4.2.1.1.3.1. DirectPosition semantics

The class DirectPosition hold the coordinates for a position within some coordinate reference system.

4.2.1.1.3.2. coordinate

The attribute *coordinate* is a sequence of Numbers that hold the coordinate of this position in the specified reference system.

4.2.1.1.3.3. dimension

The attribute *dimension* is a derived attribute that describes the number of coordinate axes.

4.2.1.1.4. CV_GridEnvelope

4.2.1.1.4.1. CV_GridEnvelope semantics

The class **CV_GridEnvelope** provides the grid coordinate values for the diametrically opposed corners of an envelope that bounds a grid. It has two attributes.

4.2.1.1.4.2. low

The attribute *low* shall be the minimal coordinate values for all grid points within the envelope. For this specification this represents the Southwestern coordinate.

4.2.1.1.4.3. high

The attribute *high* shall be the maximal coordinate values for all grid points within the envelope. For this specification this represents the Northeastern coordinate.

4.2.1.1.5. CV_GridCoordinate

4.2.1.1.5.1. CV_GridCoordinate semantics

The class **CV_GridCoordinate** is a data type for holding the grid coordinates of a **CV_GridPoint**.

4.2.1.1.5.2. coordValues

The attribute *coordValues* has the value class *Sequence<Integer>* that shall hold one integer value for each dimension of the grid. The ordering of these coordinate values shall be the same as that of the elements of *axisNames*. The value of a single coordinate shall be the number of offsets from the origin of the grid in the direction of a specific axis.

4.2.1.1.6. CV_SequenceRule

4.2.1.1.6.1. CV_SequenceRule semantics

The class **CV_SequenceRule** contains information for mapping grid coordinates to a position within the sequence of records of feature attribute values. It has two attributes.

4.2.1.1.6.2. type

The attribute *type* shall identify the type of sequencing method that shall be used. A code list of scan types is provided in S-100, Part 10c. Only the value — linear shall be used in S-102, which describes scanning row by row by column.

4.2.1.1.6.3. scanDirection

The attribute *scanDirection* has the value class *Sequence<CharacterString>* a list of axis names that indicates the order in which grid points shall be mapped to position within the sequence of records of feature attribute values.

4.3. Feature Catalogue

4.3.1. Introduction

The S-102 Feature Catalogue describes the feature types, attributes and attribute values which may be used in the product.

The S-102 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 Geospatial Information Registry.

4.3.2. Feature types

S-102 is a coverage feature product. **BathymetryCoverage** implements **S102_DepthCoverage** and includes **S102_BathymetryValues**.

4.3.2.1. Geographic

Geographic (geo) feature types form the principle content of the dataset and are fully defined by their associated attributes. In S-102, **BathymetryCoverage** has been registered as a geographic feature type.

4.3.2.2. Meta

There are no meta features in the S-102 feature catalogue.

4.3.3. Feature relationship

S-102 does not use any feature relationships.

4.3.4. Attributes

4.3.4.1. Simple attributes

In S-102, *depth* and *uncertainty* have been registered as simple attributes, type `<real>`. Simple attributes are defined in S-100, Part 5, Clause 5–4.2.3.3.

4.3.4.2. Complex attributes

In S-102 there are currently no complex attributes defined.

4.4. Dataset types

4.4.1. Introduction

Bathymetric Surface datasets are represented as a discrete array of points contained in a regular grid. The general structure for a regular grid is defined in S-100, Part 8.

4.4.2. Regular grid

4.4.2.1. S-102 coverages

The **BathymetryCoverage** contains depth and, optionally, uncertainty. The general structure of each is defined in S-100, Part 8 as a georectified grid.

The grid properties of origin and spacing are defined by attributes in the **BathymetryCoverage.01** Feature Container Group. The grid is a two-dimensional matrix organized in row major order and starting from the southwestern-most data point. Thus, the first sample of the grid is the node at the southwest corner of the grid with location specified by the georeferencing parameters, the second is one grid resolution unit to the east of that position and at the same northing or latitude, and the third is two grid resolution units to the east and at the same northing or latitude. For C columns in the grid, the $(C+1)^{th}$ sample in the grid is located one grid resolution unit to the north but on the same easting or longitude as the first sample in the grid.

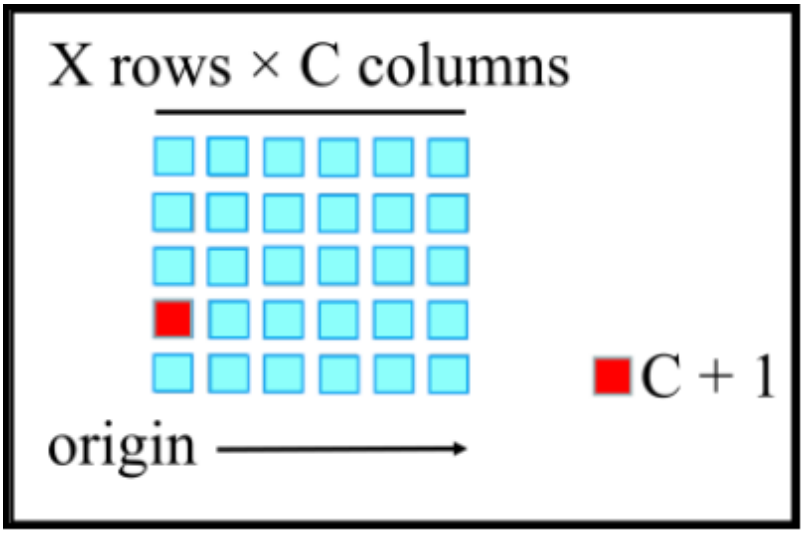

Figure 5 — S-102 Grid Node location

The two values, depth and uncertainty, are stored in the same grid as members of a data compound. The units of the depth values are in metres. The vertical distance is from a given water level to the bottom. Drying heights (drying soundings) are indicated by a negative depth value.

The reference vertical datum for the surface is one of the mandatory Metadata items. The unknown state for depth is defined to be 1,000,000.0 (1.0e6).

The uncertainty values are expressed as positive quantities at a node. As detailed in Table 14 and Table 15 the uncertainty grid supports multiple definitions of vertical uncertainty. This allows grids to span the expected range of data products from raw, full resolution grid to final compiled product. For example, a grid at the stage of final survey data processing should contain uncertainty information germane to the survey data itself and intended to be used for information compilation. A recipient of an S-102 file can refer to the uncertainty definition in the Metadata to gain an understanding of how the uncertainty was computed.

The undetermined state for uncertainty is defined to be 1,000,000.0 (1.0e6).

4.4.2.2. Extensions

In S-102 there are currently no extensions defined.

4.5. Multiple datasets

In order to facilitate the efficient processing of S-102 data, the geographic coverage of a given **maximum display Scale** may be split into multiple datasets.

4.6. Dataset rules

Each S-102 dataset must only have a single extent as it is a coverage feature.

There should be no overlapping data of the same maximum display scale, except at the agreed adjoining limits. Where it is difficult to achieve a perfect join, a buffer to be agreed upon by the producing agencies may be used.

4.7. Geometry

S-102 regular gridded coverages are an implementation of S-100 Grid Coverage (Part 8 — Imagery and Gridded Data).

5. Coordinate Reference Systems (CRS)

5.1. Introduction

The geo-referencing for an S-102 Bathymetric Surface product shall be node-based, referenced from the southwestern-most node in a grid. Each sample in a grid represents the value in the grid at a point location at the coordinate specified, rather than an estimate over any area with respect to the coordinate. The reference position included in the metadata shall be given in the coordinates used for the grid and shall contain sufficient digits of precision to locate the grid with accuracy no worse than a decimetre on the surface of the ellipsoid of rotation of the chosen horizontal datum.

The Coordinate Reference System information contained in Table 1 is defined in the manner specified in S-100, Part 6. Note the vertical datum is defined through a second association role to a vertical reference system.

5.2. Horizontal Coordinate Reference System

Table 1 — S-102 Coordinate Reference Systems (EPSG Codes)

EPSG Code	Coordinate Reference System
4326	WGS84
32601 — 32660	WGS 84 / UTM Zone 1N to Zone 60N
32701 — 32760	WGS 84 / UTM Zone 1S to Zone 60S
5041	WGS 84 / UPS North (E,N)
5042	WGS 84 / UPS South (E,N)
The full reference to EPSG can be found at www.epsg-registry.org.	

Horizontal Coordinate Reference System	EPSG (see Table 1)
Projection	NONE/UTM/UPS
Temporal reference system	Gregorian Calendar
Coordinate Reference System registry	EPSG Geodetic Parameter Registry
Date type (according to ISO 19115-1:2014/Amd 1:2018)	002 — publication
Responsible party	International Organisation of Oil and Gas Producers (OGP)

URL http://www.ogp.org.uk/

5.3. Vertical Coordinate Reference System

Although in this product there are no direct vertical coordinates the values of the depth attributes are indirectly such coordinates. Therefore, it is important to specify the vertical CRS to which these values conform. The vertical CRS is an earth gravity-based, one-axis coordinate system. The axis is oriented positive down.

The vertical datum must be taken from the code-list specified by the IHO Geospatial Information (GI) Registry for the attribute named *Vertical Datum*. It will be defined in the root element as an HDF5 attribute.

5.4. Temporal reference system

The temporal reference system is the Gregorian calendar for date and UTC for time. Time is measured by reference to Calendar dates and Clock time in accordance with ISO 8601:2004, Clause 5.4.4. A date-time variable will have the following 16-character format: *yyyymmddThhmmssZ*.

6. Data Quality

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.

6.1. Completeness

6.1.1. Commission

The S-102 bathymetric grid has a high-level of completeness regarding commission, due to the fact that the issuing hydrographic office has deemed the grid to contain all the necessary data and/or considered all contributing factors required to make a navigationally valid product. These factors are recorded in the metadata for the file.

6.1.2. Omission

The S-102 bathymetric grid has a high level of completeness in regards to omission, due to the fact that the issuing hydrographic office will have noted any major discrepancies or negative quality factors in the applicable fields of the metadata for the file.

6.2. Logical consistency

6.2.1. Conceptual consistency

The conceptual consistency of S-102 grids is maintained through this and related specifications which are conceptually consistent with the accepted standards.

6.2.2. Domain consistency

The domain consistency of S-102 grids is maintained through the definition of their primary purpose, which is safety of navigation. The data contained can also be used derivatively for other scientific/fields domains (secondary purposes). All processes used in primary purpose generation is geared solely towards the satisfaction of safety of navigation concerns.

6.2.3. Format consistency

The formatting consistency of S-102 grids is maintained due to the overriding encoding (HDF5) defined in the S-100 specification and the other IHO standards on which the data is based.

6.3. Positional accuracy

6.3.1. Gridded data positional accuracy

Gridded positional accuracy is defined by the precision of the positional reference used to specify its location within its spatial projection. These positional references are contained within the spatial metadata of the S-102 grid. It is assumed that any horizontal errors are assimilated into the vertical uncertainty. The vertical values are calculated for each node using the processes and procedures used by each hydrographic office during the creation of the S-102 grid. Appropriate selection of both the origin reference points and positional resolution are important and are another factor in gridded positional accuracy.

6.3.2. Relative internal positional accuracy

The internal positional accuracy is defined as the precision of the location of each node within the S-102 grid. The position of each node within the grid is referenced by a row and column combination. The metadata for S-102 defines a gridded resolution along both the X and Y axis of the grid. This absolute position of a node within the spatial projection of the grid is calculated using the row/column and the X/Y resolution. In this case, the accuracy is controlled by the precision used in defining these resolutions.

6.4. Temporal accuracy

Temporal accuracy, consistency, and validity of bathymetric grids are confined to elements of the vertical control processes. These aspects are addressed during the formulation and application of vertical control processes applied by the various hydrographic offices. Details of these processes will be included in the Lineage portion of the metadata defined in Chapter 12 of this Product Specification.

6.5. Thematic accuracy

6.5.1. Thematic classification correctness

For S-102 bathymetric grids there are two classifications of data values, which are land and water. There are two considerations for accessing classification correctness when using the grid. The first is that values given in the depth layer of the S-102 grid

are based on the associated hydrographic office's chosen vertical datum. Should another value in relation to a different vertical datum be required, a series of correctors would need to be applied. Secondly, when considering the data values, the value stored in the uncertainty for a given node must be considered. This uncertainty value is a +/- value and when assessing the classification correctness must be applied. The new value(s) generated when applied may cause a change in the classification.

6.5.2. Non-quantitative attribute accuracy

Thematic accuracy of S-102 bathymetric data is wholly quantitative.

6.5.3. Quantitative attribute accuracy

As defined in S-100, Part 4c the data quality for the depth coverage is also defined as a co-located coverage, uncertainty. Uncertainty is defined as the vertical uncertainty at each node location. The uncertainty coverage supports multiple definitions of vertical uncertainty.

See [tab-code-defining-how-uncertainty-was-determined].

7. Data Capture and Classification

The Data Classification and Encoding Guide (DCEG) describes how data describing the real world should be captured using the types defined in the S-102 Feature Catalogue. This Guide is located at Annex A.

A number of sounding techniques are used to capture bathymetric data. It is permitted, but not required, to include data acquisition information in the metadata of an S-102 Bathymetric Surface product. The metadata class S102_AcquisitionMetadata has been defined, but the information elements to populate this metadata class should be identified in a national profile of S-102.

7.1. Quality and source metadata

Quality and source metadata in S-102 are intended to enable and support future navigation software to appropriately auto-generate and attribute cartographic features such as custom depth contours and soundings from S-102 products, all while minimally impacting the overall file size of the product.

Quality and source metadata are encoded in a raster attribute table that is compliant with HDF-5 and S-100 and will provide valuable information about the bathymetry on a node-by-node basis compared to traditional vector-based metadata files, simplifying the interpretation and implementation by navigation software systems.

The fields of the feature attribute table are defined elsewhere in this Product Specification (Table 13).

Quality and source metadata in S-102 are based on S-101 quality attributes, with significant augmentations and omissions described below. The quality and source metadata support a three-fold purpose:

a) Support S-101-defined attribution of auto-generated vector depth areas, depth contours, and soundings created directly from the S-102 dataset.

    1) The attribute, featureSizeVar is meant to augment featureSize which corresponds to S-101 size of features detected. As noted in S-101, size of features detected is intended to be described as the smallest size in cubic metres the survey was capable of detecting. Depending on the type of survey this definition might force different depth ranges to have different values. For example, a survey vessel that works at a fixed height off the seafloor, such as an autonomous underwater survey vessel, could maintain a fixed feature detection size capability over a wide range of depths. A surface vessel working over those same range of depths may have a feature detection capability that varies with depth causing the detection capability to be ambiguous and potentially misrepresented. For this reason, featureSizeVar is the percentage of depth that a feature of such size could be detected. When both featureSize and featureSizeVar are present, the greater of the two should be considered valid. The expectation is that featureSizeVar will be set to zero if the feature size does not scale with depth. As with featureSize, featureSizeVar should be ignored if significantFeatures is False.

    2) Note that depth range maximum and minimum in S-101 are omitted. The assumption is that if this information is required than the corresponding nodes in the elevation layer can be queried for a minimum and maximum depth for each table row.

b) Provide necessary uncertainty information as an input into critical underkeel clearance precision navigation systems.

c) Prevent the automated selection of soundings from interpolated nodes, while still providing continuous data required or depth contour creation. This is done by the “bathyCoverage” Boolean attribute field, which flags nodes populated by interpolation across gaps of bathymetric observations greater than the S-102 raster resolution. This is especially useful in side-scan surveys which are characterized by gaps in bathymetric observations with full coverage side-scan imagery (interpolated gaps between bathymetry coverage in this situation would show fullCoverage = True and bathyCoverage = False). If full coverage = False, bathyCoverage must also equal False, such as gaps between single beam echosounder data without correlating side scan sonar coverage. Thus, this will provide navigation software systems with the required information necessary to preferably select soundings from direct bathymetric observations.

Quality and source metadata are encoded as records within a QualityOfSurvey information group, dataset featureAttributeTable (Table 13).

8. Data Maintenance

8.1. Maintenance and update frequency

Datasets are maintained by replacement on a dataset basis. That is, the entire data product and the associated metadata are replaced as a unit. This is unlike vector

data that may be updated incrementally. Also, each replacement data set must have its own digital signature.

8.2. Data source

Data producers must use applicable sources to maintain and update data and provide a brief description of the sources that were used to produce the dataset.

8.3. Production process

Data Producers should follow their established production processes for maintaining and updating datasets.

9. Portrayal

9.1. Introduction

This clause describes the display of bathymetric surface data to support the safe navigation of marine vessels. The following portrayal options are intended to enhance mariner decision making while taking into consideration the need to minimize cluttering of the navigation display. S-102 portrayal options:

— Display of gridded bathymetry

— Colouring options to support safe navigation.

9.2. Generation and display of gridded bathymetry

Most modern hydrographic surveys are conducted using high-resolution multibeam sonar systems. While these systems provide a highly detailed depiction of the seafloor, the storage and processing requirements (that is, data management) can be challenging. A typical hydrographic survey can collect upwards of 10 billion depth estimates over a 30-day collection period.

Utilization of a gridded data structure eases the data management concerns of the hydrographer, providing the ability to safely reduce the total sum of collected depth estimates into a manageable quantity of representative nodal depths for processing and production. All gridded datasets should be exposed to rigid Quality Assurance/Control procedures to ensure the final gridded dataset accurately represents the real-world environment. Once a dataset passes an established Quality Assurance/Control process, modern chart production software is used to extract candidate nodal depths from the grid for consideration as final charted soundings.

Table 9 provides a listing of S-102 accepted gridding methods.

Annex F provides an example gridding process, discussing the difference between full-resolution source bathymetry, product scale grid, and charted sounding.

9.2.1. Charted soundings/contours vs. gridded bathymetry

Depth information on a nautical chart is generally displayed as depth soundings, depth contours, and depth areas. Depth contours are used to connect soundings of equal elevation referenced to a specific sounding datum.

The introduction of an additional depth source, S-102 gridded data, enhances navigation decision making by providing the mariner with the ability to visualize and colour a pseudo three-dimensional, sun-illuminated, contiguous image of the seafloor. While this is a benefit, producers should understand that the selection of an improper grid resolution (that is too coarse, or too fine) may complicate the overall navigation solution when displayed with traditional depth information. Table 16 provides informative grid resolutions for each charting scale to aid in the selection of a final grid resolution. It should be noted that Table 16 does not contain mandatory resolutions. Final identification of the “appropriate” resolution is left to the data producer.

9.2.2. Use of sun-illumination

S-102 data can be visualized as a sun-illuminated or static (flat) dataset. The depiction of sun-illumination requires the entry of a sun azimuth and corresponding elevation. Figure 6 shows the difference between a sun-illuminated and static (flat) surface.

Informative values for sun azimuth angle and elevation have been provided in Table 2.

Table 2 — Sun Azimuth and Elevation Values

Attribute	Value in Degrees	
	Sun-Illuminated	**Flat Surface**
Sun Azimuth Angle	315 Degrees	0.0 Degrees
Sun Elevation	45 Degrees	0.0 Degrees

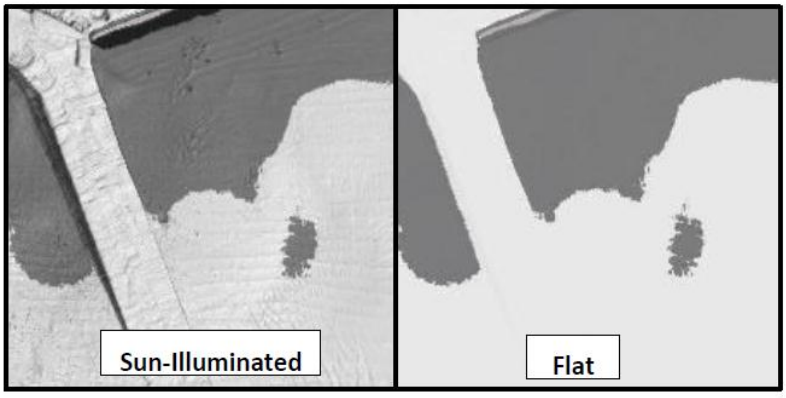

Figure 6 — Sun-illuminated and Static (Flat) Shading

9.2.3. Transparency

S-102 dataset transparency display settings are identified in Table 3. The level of opaqueness is represented by the value alpha. A value of 1 represents zero transparency. A value of 0 represents 100% transparency.

Table 3 — Transparency values for S-102 Dataset

ENC Display Setting	Alpha
ENC Day	1.0
ENC Dusk	0.4
ENC Night	0.2

9.3. Generation and display of navigation zones

The addition of an S-102 dataset enhances the mariner's ability to render and display, using colours, and higher resolution depth zoning directly from the grid.

At time of ingest a display system will delineate and display navigational depth zones by comparing the depth layer of the S-102 dataset to the mariner-defined vessel draft or default safety contour. Depth zone naming and colouring (Table 4 — Table 6, and Figure 7) may follow IHO S-52, Edition 6.1(.1).

NOTE colour parameters listed in Table 4, Table 5 and Table 6 are specified in CIE x, y, L co-ordinates.

Table 4 — Depth Zone and Colour Token Information for Day

Depth Zone Name	Description	Colour	X	Y	L
Deep Water (DEPDW):	Deeper than the deep contour	White	.28	.31	80
Medium-deep water (DEPMD):	Depths between the deep contour and the safety contour	Blue	.26	.29	65
Medium-shallow (DEPMS):	Depths between the safety contour and the shallow contour	Blue	.23	.25	55
Very Shallow Water (DEPVS):	Depths between the shallow contour and the zero metre contour	Blue	.21	.22	45
Drying Foreshore (DEPIT):	Intertidal area	YellowGreen	.26	.36	35

Table 5 — Depth Zone and Colour Token Information for Dusk

Depth Zone Name	Description	Colour	X	Y	L
Deep Water (DEPDW):	Deeper than the safety contour	White	.28	.31	00
Shallow Water (DEPVS):	Shallower than the safety contour	Blue	.21	.22	5.0
Intertidal (DEPIT):	Area exposed at low water	YellowGreen	.26	.36	6.0

Table 6 — Depth Zone and Colour Token Information for Night

Depth Zone Name	Description	Colour	X	Y	L
Deep Water (DEPDW):	Deeper than the safety contour	White	.28	.31	00
Shallow Water (DEPVS):	Shallower than the safety contour	Blue	.21	.22	0.8
Intertidal (DEPIT):	Area exposed at low water	YellowGreen	.26	.36	1.2

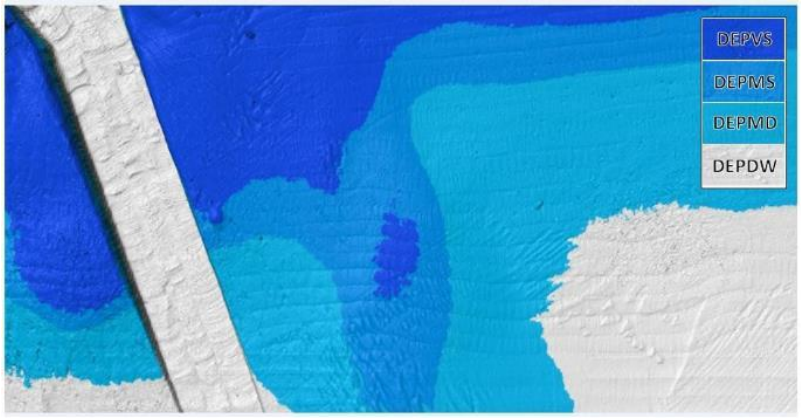

Figure 7 — S-52, Edition 6.1(.1) Depth Zone Colouring for Day

10. Data Product Format (Encoding)

10.1. Introduction

The S-102 data set must be encoded using the Hierarchical Data Format standard, Version 5 (HDF5).

Format Name HDF5

Version 1.8

Character Set UTF-8

Specification https://www.hdfgroup.org/

The key idea behind the S-102 product structure is that each coverage is a feature. Each of these features is co-located with the others. Therefore, they share the same spatial metadata and each is required to correctly interpret the others.

For the use of HDF5, the following key concepts (S-100, Part 10c, Clause 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; (Enumerations are encoded with unsigned 8-bit or unsigned 16-bit indices, depending on the number of transported values.)
Attribute	a named data value associated with a group, dataset, or named datatype;
Property List	a collection of parameters (some permanent and some transient).

In addition, datasets may be a compound (a single record consisting of an array of simple value types) and have multiple dimensions.

10.2.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 is given in Figure 8.

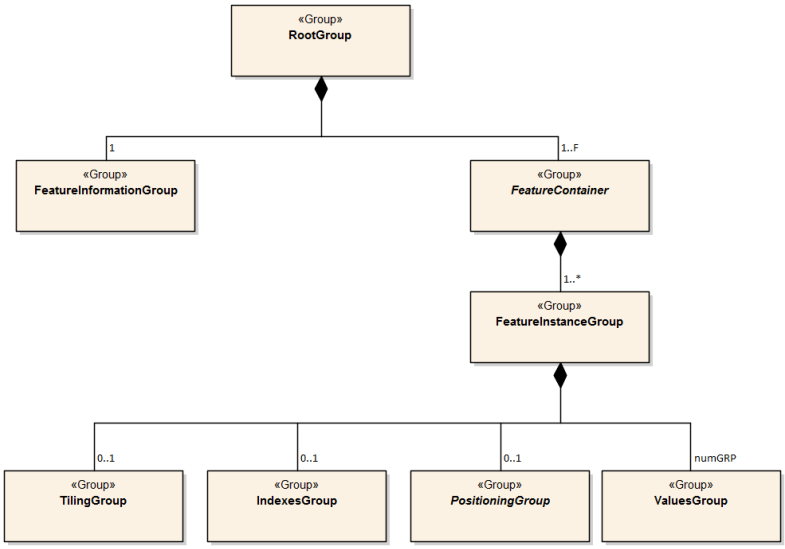

Figure 8 — Outline of the generic data file structure

Figure 8 shows the four levels defined within the HDF encoding as defined in S-100, Part 10c. Below is a further definition of these levels.

Level 1 At the top level lies the Root Group, and it contains the Root Metadata 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 the feature **BathymetryCoverage** and the feature attribute codes. The Feature Container Group contains the Feature Metadata and one or more Feature Instance Groups.

Level 3 This level contains a Feature Instance group. A feature instance is a bathymetric gridded data set for a single region.

Level 4 This level contains the actual data for each feature. In S-102 the BathymetryCoverage uses the ValuesGroup to define the content. The other groups at this level are not used.

In Table 7 below, levels refer to HDF5 structuring (see S-100, Part 10c, Figure 9). Naming in each box below the header line is as follows: Generic name; S-100 or S-102 name, or nothing if none; and (*HDF5 type*) group, attribute or attribute list, or dataset. Figure 9 depicts the same structure using a graphical representation.

Table 7 — Overview of S-102 Data Product

LEVEL 1 CONTENT	LEVEL 2 CONTENT	LEVEL 3 CONTENT	LEVEL 4 CONTENT
General Metadata (metadata) *(h5_attribute)*			
Feature Codes Group_F *(h5_group)*	Feature Name BathymetryCoverage *(h5_dataset)*		
	QualityOfSurvey *(h5_dataset)*		
	Feature Codes featureCode *(h5_dataset)*		
Feature Type BathymetryCoverage *(h5_group)*	Type Metadata (metadata) *(h5_attribute)*		
	Feature Instance BathymetryCoverage.01 *(h5_group)*	Instance Metadata (metadata) *(h5_attribute)*	
		First data group Group_001 *(h5_group)*	Group Metadata (metadata) *(h5_attribute)*
	X and Y Axis Names axisNames *(h5_dataset)*		Bathymetric Data Array values *(h5_dataset)*
Feature Type QualityOfSurvey *(h5_group)*	Metadata *(h5_attribute)* (same as BathymetryCoverage)		
	QualityOfSurvey.01 *(h5_group)*	Group_001 *(h5_group)*	Group Metadata (metadata) *(h5_attribute)*
			Quality of Survey Data Array values *(h5_dataset)*

LEVEL 1 CONTENT	LEVEL 2 CONTENT	LEVEL 3 CONTENT	LEVEL 4 CONTENT
	Feature Attribute Table *(h5_dataset)*		

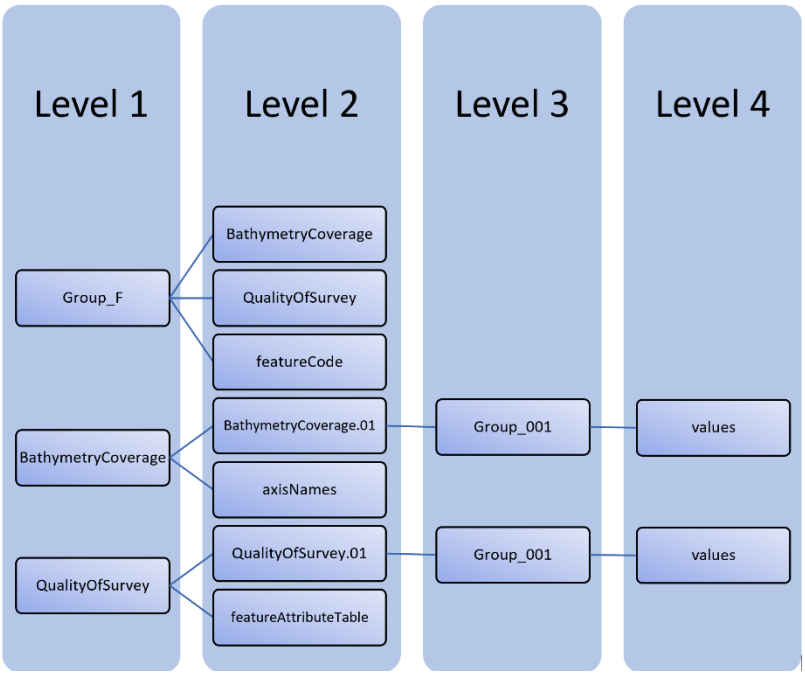

Figure 9 — Hierarchy of S-102 Data Product

The following sections explain entries in Table 7 in greater detail.

10.2.1. Root Group

The root group is required by HDF5. The S-100 HDF5 format (S-100, Part 10c) attaches metadata attributes applicable to the whole dataset to this group. S-102 uses all the S-100 attributes except *geographicIdentifier* and *metaFeatures*. The attributes used in S-102 are listed in Table 8, with specific requirements, if any, added in the Remarks column.

Table 8 — Root group attributes

No	Name	Camel Case	Mult	Data Type	Remarks
1	Product specification number and version	productSpecification	1	String	S-100, Part 10c, Table 6 Example: INT.IHO.S-102.2.2
2	Time of data product issue	issueTime	0..1	String (Date Format)	

No	Name	Camel Case	Mult	Data Type	Remarks
3	Issue date	issueDate	1	String (Time Format)	
4	Horizontal CRS	horizontalCRS	1	Integer 32-bit	The identifier (EPSG code) of the horizontal CRS as defined in Section 5.2 (see Section 10.2.1, Note 1).
5	Name of the horizontal CRS	nameOfHorizontalCRS	0..1	String	Mandatory if horizontalCRS = -1
6	Type of the horizontal CRS	typeOfHorizontalCRS	0..1	Enumeration	Mandatory if horizontalCRS = -1 See S-100, Part 10c, Clause 5.
7	Horizontal coordinate system	horizontalCS	0..1	Integer 32-bit	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)
8	Horizontal datum	horizontalDatum	0..1	Integer 32-bit	Mandatory if horizontalCRS = -1 EPSG code or -1 if user defined
9	Name of horizontal datum	nameOfHorizontalDatum	0..1	String	Mandatory if horizontalDatum = -1

No	Name	Camel Case	Mult	Data Type	Remarks
10	Prime meridian	primeMeridian	0..1	Integer 32-bit	Mandatory if horizontalDatum = -1; EPSG Code
11	Spheroid	spheroid	0..1	Integer 32-bit	Mandatory if horizontalDatum = -1; EPSG Code
12	Projection method	projectionMethod	0..1	Integer 32-bit	Mandatory if typeOfHorizontalCRS = 2; EPSG Code See S-100, Part 10c, Clause 8.
13	Projection parameter 1	projectionParameter1	0..1	Float 64-bit	Only if projectionMethod is used. See S-100, Part 10c, Clause 8.
14	Projection parameter 2	projectionParameter2	0..1	Float 64-bit	Only if projectionMethod is used. See S-100, Part 10c, Clause 8.
15	Projection parameter 3	projectionParameter3	0..1	Float 64-bit	Only if projectionMethod is used. See S-100, Part 10c, Clause 8.
16	Projection parameter 4	projectionParameter4	0..1	Float 64-bit	Only if projectionMethod is used. See S-100, Part 10c, Clause 8.
17	Projection parameter 5	projectionParameter5	0..1	Float 64-bit	Only if projectionMethod is used. See S-100, Part 10c, Clause 8.
18	False northing	falseNorthing	0..1	Float 64-bit	Only if projectionMethod is used.

No	Name	Camel Case	Mult	Data Type	Remarks
					To be applied to the coordinates at axis Northing. [m]
19	False easting	falseEasting	0..1	Float 64-bit	Only if projectionMethod is used. To be applied to the coordinates at axis Easting. [m]
20	Epoch of realization	epoch	0..1	String	
21	Bounding box	westBoundLongitude	1	Float 32-bit	The values are in decimal degrees. If a projected CRS is used for the dataset, these values refer to those of the baseCRS underlying the projected CRS (see Section 10.2.1, Note 3).
21		eastBoundLongitude	1	Float 32-bit	
21		southBoundLatitude	1	Float 32-bit	
21		northBoundLatitude	1	Float 32-bit	
22	Metadata	metadata	1	String	Name of metadata file MD_<HDF5 data file base name>.XML (or .xml) ISO metadata (per S-100, Part 10c, Clause 12).
23	Vertical coordinate system	verticalCS	1	Integer 32-bit	Mandatory in S-102. EPSG code; Allowed values: *6498 (Depth—metres—orientation down) *6499 (Height—metres—orientation up)
24	Vertical coordinate base	verticalCoordinateBase	1	Enumeration	Mandatory in S-102. The only allowed value is 2: verticalDatum

No	Name	Camel Case	Mult	Data Type	Remarks
					(see S-100, Part 10c, Clause 6).
25	Vertical datum reference	verticalDatumReference	1	Enumeration	Mandatory in S-102. The only allowed value is 1: s100VerticalDatum (see S-100, Part 10c, Clause 7).
26	Vertical datum	verticalDatum	1	Integer unsigned 16-bit	Numeric code from IHO GI Registry *Vertical Datum* attribute except *47 (seaFloor) *48 (seaSurface) *49 (hydrographicZero).
Additional attributes for S-102					
27	Gridding method	griddingMethod	0..1	Enumeration	See S102_GriddingMethod

NOTE 1 The remark in S-100 Edition 5.0.0 is outdated. The *productIdentifier* (“S-102”) and *version* fields (N.N.N) of S100_ProductSpecification must be used instead of *name* and *number*.

NOTE 2 The value horizontalCRS specifies the horizontal Coordinate Reference System. At the time of writing, S-100 does not yet provide a mechanism for this value’s definition within HDF5 encoding (such as an enumeration of horizontal CRSs). Consequently, this configuration causes a deviation from S-100. The horizontal datum is implicitly defined by this CRS because each horizontal CRS consists of a coordinate system and a datum. S-102 does not use “user defined” CRS as mentioned in S-100, Part 10c, Table 6.

NOTE 3 The baseCRS is the geodetic CRS on which the projected CRS is based. In particular, the datum of the base CRS is also used for the derived CRS (see S-100, Part 6, Table 6).

10.2.1.1. Gridding method

Table 9 — S102_GriddingMethod parameters

Role name	Name	Description	Code	Remarks
Enumeration	S102_GriddingMethod	Gridding methods	-	-
Value	basicWeightedMean	The **Basic Weighted Mean** algorithm computes an average depth for each grid node. Contributing depth estimates within a given area of influence are weighted and averaged to compute the final nodal value.	1	
Value	shoalestDepth	The **Shoalest Depth** algorithm examines depth estimates within a specific area of influence and assigns the shoalest value to the nodal position. The resulting surface represents the shallowest depths across a given area.	2	
Value	tpuWeightedMean	The **Total Propagated Uncertainty (TPU) Weighted Mean** algorithm makes use of the depth and associated total propagated uncertainty for each contributing depth estimate to compute a weighted average depth for each nodal position.	3	TPU is a measure of the expected accuracy of the depth estimate when all relevant error/uncertainty sources have been considered.

Role name	Name	Description	Code	Remarks
Value	cube	The **Combined Uncertainty and Bathymetric Estimator, or CUBE** makes use of the depth and associated total propagated uncertainty for each contributing depth estimate to compute one or many hypotheses for an area of interest. The resulting hypotheses are used to estimate statistical representative depths at each nodal position.	4	
Value	nearestNeighbour	The **Nearest Neighbour** algorithm identifies the nearest depth value within an area of interest and assigns that value to the nodal position. This method does not consider values from neighbouring points.	5	
Value	naturalNeighbour	**Natural Neighbour** interpolation identifies and weights a subset of input samples within the area of interest to interpolate the final nodal value.	6	

Role name	Name	Description	Code	Remarks
Value	polynomialTendency	The **Polynomial Tendency** gridding method attempts to fit a polynomial trend, or best fit surface to a set of input data points. This method can project trends into areas with little to no data, but does not work well when there is no discernible trend within the data set.	7	
Value	spline	The **Spline** algorithm estimates nodal depths using a mathematical function to minimize overall surface curvature. The final “smoothed” surface passes exactly through the contributing input depth estimates.	8	
Value	kriging	**Kriging** is a geostatistical interpolation method that generates an estimated surface from a scattered set of points with a known depth.	9	

10.2.2. Feature Codes (Group_F)

No attributes.

This group specifies the S-100 features to which the data applies, and consists of three components:

featureCode — a 1-dimesional dataset with the featureCode(s) of the S-100 feature(s) contained in the data product. For S-102, the dataset has only two

elements — the string “**BathymetryCoverage**” and “**QualityOfSurvey**” (without quotes). The entries in this dataset give the names of the other two components of Group_F.

BathymetryCoverage — A 1-dimensional dataset that contains the standard definition of the bathymetry coverage feature class in terms of its attributes and their types, units of measure, etc. The datatype of its elements is the compound type described in S-100, Part 10c, Table 8.

QualityOfSurvey — A 1-dimensional dataset of the same datatype as the **BathymetryCoverage** dataset described above. This **QualityOfSurvey** dataset contains the definition of the reference to metadata records. The reference is a single integer which identifies a metadata record in *featureAttributeTable* (described in S-100, Part 10c, Clause 9.6.2 and Section 10.2.8.

10.2.3. BathymetryCoverage and QualityOfSurvey Tables (in Group_F)

BathymetryCoverage and QualityOfSurvey are arrays of compound type elements, whose components are the 8 components specified in Table 10.

Table 10 — Sample contents of the BathymetryCoverage and QualityOfSurvey arrays

Name	**Explanation**	**BathymetryCoverage**		**QualityOfSurvey**
		S-100 Attribute 1	S-100 Attribute 2	Attribute 1

Name	Explanation	BathymetryCoverage		QualityOfSurvey
code	Camel Case code of attribute as in Feature Catalogue	depth	uncertainty	id
name	Long name as in Feature Catalogue	depth	uncertainty	
uom.name	Units (uom.name from S-100 Feature Catalogue)	metres	metres	(empty)
fillValue	Fill value (integer or float, string representation, for missing values)	1000000	1000000	0
datatype	HDF5 datatype, as returned by H5Tget_class() function	H5T_FLOAT	H5T_FLOAT	H5T_INTEGER
lower	Lower bound on value of attribute	-12000	0	1
upper	Upper bound on value of attribute	12000	12000	(empty)
closure	Open or Closed data interval. See S100_IntervalType in S-100, Part 1.	closedInterval	gtLeInterval	geSemiInterval

According to S-100, Part 10c, Clause 9.5, “All the numeric values in the feature description dataset are string representations of numeric values; for example, “-9999.0” not the float value -9999.0.”

While the sample contents are shown in the two attributes columns, these are actually rows in the BathymetryCoverage table. They are also each a single HDF5 compound type and represent a single HDF5 element in the table.

All cells shall be HDF5 variable length strings. The minimum and maximum values are stored in lower and upper columns. Variable length strings allow future proofing the format in the event editing is allowed or correcting these values is required.

10.2.4. Root BathymetryCoverage

Table 11 — Attributes of **BathymetryCoverage** feature container group

No	Name	Camel Case	Mult	Data Type	Remarks
1	Data organization index	dataCodingFormat	1	Enumeration	Value: 9
2	Dimension	dimension	1	Integer unsigned 8-bit	Value: 2
3	Common point rule	commonPointRule	1	Enumeration	Value: 1 (average) or other values from part-10c,table=20.
4	Horizontal position uncertainty	horizontalPositionUncertainty	1	Float 32-bit	Value: -1.0 (if unknown or not available)
5	Vertical position uncertainty	verticalUncertainty	1	Float 32-bit	Value: -1.0 (if unknown or not available)
6	Number of feature instances	numInstances	1	Integer unsigned 8-bit	Value: 1
7a	Sequencing rule	sequencingRule.type	1	Enumeration	Value: 1 (linear) see S-100, Part 10c, Table 21.
7b		sequencingRule.scanDirection	1	String	Value: <axisNames entry> (comma-separated). For example, “latitude,longitude”. Reverse scan direction along an axis is indicated by prefixing a ‘-’ sign to the axis name. See Section 4.2.1.1.6.3
8	Interpolation type	interpolationType	1	Enumeration	Code value from S-100, Part 10c, Table 22

10.2.5. Feature Instance group — BathymetryCoverage.01

Per S-100, Part 10c, Clause 9.7 and S-100, Part 10c, Table 12: Attributes of feature instance groups

Table 12 — Attributes of **BathymetryCoverage** feature instance group

No	Name	Camel Case	Mult	Data Type	Remarks
1a	Bounding box	westBoundLongitude	1	Float 32-bit	Coordinates should refer to the previously defined Coordinate Reference System.
1b		eastBoundLongitude	1	Float 32-bit	
1c		southBoundLatitude	1	Float 32-bit	
1d		northBoundLatitude	1	Float 32-bit	
2	Number of groups	numGRP	1	Integer unsigned 8-bit	The number of data values groups contained in this instance group. Value: 1
3	Longitude of grid origin	gridOriginLongitude	1	Float 64-bit	Longitude or easting of grid origin. Unit: (to correspond with previously defined Coordinate Reference System)
4	Latitude of grid origin	gridOriginLatitude	1	Float 64-bit	Latitude or northing of grid origin. Unit: (to correspond with previously defined Coordinate Reference System)
5	Grid spacing, longitude	gridSpacingLongitudinal	1	Float 64-bit	Cell size in x dimension.
6	Grid spacing, latitude	gridSpacingLatitudinal	1	Float 64-bit	Cell size in y dimension.
7	Number of points, longitude	numPointsLongitudinal	1	Integer unsigned 32-bit	Number of points in x dimension.
8	Number of points, latitude	numPointsLatitudinal	1	Integer unsigned 32-bit	Number of points in y dimension.

No	Name	Camel Case	Mult	Data Type	Remarks
9	Start sequence	startSequence	1	String	Grid coordinates of the grid point to which the first in the sequence of values is to be assigned. The choice of a valid point for the start sequence is determined by the sequencing rule. Format: n, n Example: “0,0” (without quotes)

The gridOriginLongitude, gridOriginLatitude, gridSpacingLongitudinal, and gridSpacingLatitudinal attributes should be in the same geographic units as the bounding box. Note that this practice deviates from S-100 where it indicates that this value should be in Arc Degrees. This practice has the effect that gridOriginLongitude and gridOriginLatitude are identical to westBoundLongitude and southBoundLatitude.

The gridOriginLongitude and gridOriginLatitude are the cell center of the cell.

numPointsLongitude and numPointsLatitude must contain the number of cells in the x and y dimensions of the values table.

10.2.6. The values group — Group_001

This group contains the following attributes. These attributes are not defined by S-100, Part 10c. They are an extension of this Product Specification.

Table 13 — Attributes of values group

No	Name	Camel Case	Mult	Data Type	Remarks
1	minimum Depth	minimumDepth	1	Float 32-bit	The minimum depth value in the values dataset(s) of this group
2	maximum Depth	maximumDepth	1	Float 32-bit	The maximum depth value in the values dataset(s) of this group
3	minimum Uncertainty	minimumUncertainty	1	Float 32-bit	The minimum uncertainty value in the values dataset(s) of this group. If no uncertainty values are in the dataset(s) the value must be the fillValue
4	maximum Uncertainty	maximumUncertainty	1	Float 32-bit	The maximum uncertainty value in the values dataset(s) of this group. If no uncertainty values are in the dataset(s) the value must be the fillValue

The group contains an HDF5 dataset named values containing the bathymetric gridded data.

10.2.7. BathymetryCoverage feature instance group — values dataset

This dataset contains the compound data arrays containing bathymetric gridded data. These components are explained below.

For bathymetric gridded data, the dataset includes a two-dimensional array containing both the depth and uncertainty data. These dimensions are defined by *numPointsLongitudinal* and *numPointsLatitudinal*. By knowing the grid origin and the grid spacing, the position of every point in the grid can be simply computed. If uncertainty data is not used, it must be filled with the fillValue specified in the Group_F feature information dataset.

The depth and uncertainty values (depth and uncertainty) are stored in two-dimensional arrays with a prescribed number of columns (numCOL) and rows (numROW). This grid is defined as a regular grid (dataCodingFormat = 2); therefore, the depth and uncertainty values will be for each discrete point in the grid. The data type of the array values is a compound with two members.

10.2.8. Root QualityOfSurvey

The QualityOfSurvey container group has the same metadata attributes as BathymetryCoverage container group (see Table 11). The values of the attributes must also be the same as the BathymetryCoverage container group.

The QualityOfSurvey container group contains an additional 1-dimensional array named featureAttributeTable (S-100, Part 10c, Table 9; S-100, Part 10c, Clause 9.6.2). This dataset is mandatory within the QualityOfSurvey group. Each element of this array is a metadata record of HDF5 compound type. The fields are described in Table 14 below.

Table 14 — Elements of featureAttributeTable compound datatype

No	Attribute	Description	Mult	Data Type	Remarks
1	id	Metadata record identifier	1	Integer unsigned 32-bit	Each record must have a unique identifier.
2	dataAssessment	The categorization of the assessment level of	0..1	Integer unsigned 8-bit	*1: Assessed *2: Unassessed *3:

No	Attribute	Description	Mult	Data Type	Remarks
		bathymetric data for an area.			Oceanic
3	featuresDetected.leastDepthOfDetectedFeaturesMeasured	Expression stating if the least depth of detected features in an area was measured.	0..1	Integer unsigned 8-bit	Boolean, Values: *1 (TRUE) *0 (FALSE). See Section 10.2.8, Note 1.
4	featuresDetected.significantFeaturesDetected	A statement expressing if significant features have or have not been detected in the course of a survey.	0..1	Integer unsigned 8-bit	Boolean, Values: *1 (TRUE) *0 (FALSE). See Section 10.2.8, Note 2.
5	featuresDetected.sizeOfFeaturesDetected	The size of detected bathymetric features in an area.	0..1	Float 32-bit	See Section 10.2.8, Note 3 and Section 10.2.8, Note 4.
6	featureSizeVar	Percentage of depth that a feature of such size could be	0..1	Float 32-bit	Set to zero if the feature size does not scale

No	Attribute	Description	Mult	Data Type	Remarks
		detected.			with depth. See Section 10.2.8, Note 3 and Section 10.2.8, Note 4.
7	fullSeafloorCoverageAchieved	Expression stating if full seafloor coverage has been achieved in the area by hydrographic surveys.	0..1	Integer unsigned 8-bit	Boolean, Values: *1 (TRUE) *0 (FALSE). See Section 10.2.8, Note 5.
8	bathyCoverage	Flag for nodes populated by interpolation.	0..1	Integer unsigned 8-bit	Boolean, Values: *1 (TRUE) *0 (FALSE). See Section 10.2.8, Note 6.
9	zoneOfConfidence.horizontalPositionUncertainty.uncertaintyFixed	The best estimate of the fixed horizontal or vertical accuracy component for	0..1	Float 32-bit	

No	Attribute	Description	Mult	Data Type	Remarks
		positions, depths, heights, vertical distances, and vertical clearances.			
10	zoneOfConfidence.horizontalPositionUncertainty.uncertaintyVariableFactor	The factor to be applied to the variable component of an uncertainty equation so as to provide the best estimate of the variable horizontal or vertical accuracy component for positions, depths, heights, vertical distances, and vertical clearances.	0..1	Float 32-bit	
11	surveyDateRange.dateStart	The start date of the period of the hydrogra	0..1	String	ISO 8602:2004 date format. Comple

No	Attribute	Description	Mult	Data Type	Remarks
		phic survey.			te or truncated date, see S-100, Part 1, Table 2.
12	surveyDateRange.dateEnd	The end date of the period of the hydrographic survey.	0..1	String	ISO 8602:2004 date format. Complete or truncated date, see S-100, Part 1, Table 2.
13	sourceSurveyID	The survey filename or ID.	0..1	String	
14	surveyAuthority	The authority which was responsible for the survey.	0..1	String	
15	bathymetricUncertaintyType	An estimate of the magnitude of the difference between true and estimated	0..1	Enumeration	See Table 15. See Section 10.2.8, Note 7.

No	Attribute	Description	Mult	Data Type	Remarks
		bathymetric depth, after all appropriate corrections are made.			

NOTE 1 A feature in this context is any object, whether manmade or not, projecting above the sea floor, which may be a danger for surface navigation S-44. Least depth of detected features measured does not describe the least depth of features that were actually detected during a hydrographic survey, but the ability of the survey to detect the least depth of features with a maximum uncertainty as defined in S-44.

NOTE 2 A feature in this context is any object, whether manmade or not, projecting above the sea floor, which may be a danger for surface navigation S-44. Significant features detected does not describe if significant features were actually detected during a hydrographic survey, but whether the survey had the capacity to detect significant features.

NOTE 3 The role of the attribute, featureSizeVar is described in Section 7.1. The expectation is that featureSizeVar will be set to zero if the feature size does not scale with depth. As with featureSize, featureSizeVar should be ignored if significantFeatures is False.

NOTE 4 When both featureSize and featureSizeVar are present, the greater of the two should be considered valid.

NOTE 5 Full seafloor coverage achieved applies to both the spatial completeness of feature detection and to the spatial completeness of the measurement of the regular seafloor. The former is further specified by the complex attribute features detected; the latter by the attributes depth range maximum value and depth range minimum value.

NOTE 6 The attribute bathyCoverage is especially useful in side-scan surveys which are characterized by gaps in bathymetric observations with full coverage side-scan imagery (interpolated gapes between bathymetry coverage in this situation would show fullCoverage = True and bathyCoverage = False). If fullCoverage = False, bathyCoverage must also equal False, such as gaps between single beam echosounder data without correlating side-scan sonar coverage.

NOTE 7 Names and listed values which are not currently defined in the IHO GI Registry are subject to change upon acceptance in the Registry.

Table 15 — Codes defining how uncertainty of bathymetric depth was determined

Role Name	Name	Description	Code	Remarks
Enumeration	S102_BatymetricUncertaintyType	An estimate of the magnitude of the difference between true and estimated bathymetric depth, after all appropriate corrections are made.	-	
Value	rawStandardDeviation	Raw standard deviations of soundings that contributed to the node.	1	-
Value	cUBEStandardDeviation	Standard deviation of soundings captured by a CUBE hypothesis (that is, CUBE's standard output of uncertainty).	2	-
Value	productUncertainty	The greater of (1) standard deviation of the soundings contributing to the depth solution or, (2) the *a priori* computed uncertainty estimate (that is, modelled Total Vertical Uncertainty).	3	-
Value	historicalStandardDeviation	Estimated standard deviation based on historical/archive data.	4	-

Role Name	Name	Description	Code	Remarks
Value	(fill value representing “unknown”)	(fill value when the uncertainty is an unknown layer type)	0	This is a “fill value” and will not be in the feature catalogue.

10.2.9. Instance group QualityOfSurvey.01

The QualityOfSurvey.01 instance group has the same metadata attributes as BathymetryCoverage.01 instance group (see Table 12). The values of the attributes must also be the same as the BathymetryCoverage instance group.

10.2.10. Values group for QualityOfSurvey

The values group for QualityOfSurvey contains no metadata attributes and a single dataset named values, which is described in Section 10.2.11.

10.2.11. Values dataset for QualityOfSurvey

The values dataset for QualityOfSurvey is a single two-dimensional array of unsigned integers (the same datatype and size as the “id” field in featureAttributeTable — Table 13). The array must have the same dimensions as the values dataset in the BathymetryCoverage feature instance (Section 10.2.7).

Each cell in this values dataset must be populated with a value that is one of the record identifiers in the featureAttributeTable dataset or with the fill value 0 (zero).

10.2.12. Mandatory Naming Conventions

The following group and attribute names are mandatory in S-100: **Group_F *featureCode *(for S-102) *BathymetryCoverage**

11. Data Product Delivery

11.1. Introduction

This clause describes how S-102 data will be delivered from the charting authority to the mariner.

Units of Delivery Exchange Set

Transfer Size See Section 11.2.2.

Medium Name Digital Data Delivery

Other Delivery Information

Each dataset must be contained in a physically separate, uniquely identified file on the transfer medium.

Each exchange set has a single exchange catalogue which contains the discovery metadata for each dataset.

An exchange set is encapsulated into a form suitable for transmission by a mapping called an encoding. An encoding translates each of the elements of the exchange set into a logical form suitable for writing to media and for transmission online. An encoding may also define other elements in addition to the exchange set contents (This is media identification, data extents etc. …) and may define commercial constructs such as encryption and compression methods.

If the data is transformed in S-102 it must not be changed.

This Product Specification defines the encoding which must be used as a default for transmission of data between parties.

The encoding encapsulates exchange set elements as follows:

Mandatory Elements

— S-102 datasets — HDF encoding

— Exchange Catalogue — the XML encoded representation of exchange set catalogue features [discovery metadata].

Optional Elements

— S-102 Feature Catalogue — If it is necessary to deliver the latest Feature Catalogue to the end user it may be done using the S-102 exchange set mechanism for datasets

— S-102 Portrayal Catalogue — If it is necessary to deliver the latest Portrayal Catalogue to the end user it may be done using the S-102 exchange set mechanism for datasets.

11.2.Dataset

11.2.1. Dataset management

Three types of dataset files may be produced and contained within an exchange set:

— New dataset: Initial.

— New edition of a dataset: Includes new information. New editions must cover at least the same area as its predecessor.

— Cancellation: The dataset is cancelled and no longer available to be displayed or used.

11.2.2. Dataset size

S-102 delivery will take place in one form: network transfer to platform (that is, internet download). An example scenario has been provided below:

NOTE The use of 10 MB in this and other sections should be treated as informative information only. Additionally, any computed values associated with either file size limit should be treated as approximate answers. Final selection of an appropriate file size limit or grid resolution is left to the discretion of the data producer.

Network Transfer To minimize overall file size, the HO produces a 10 MB file for wireless transmission to marine vessels. In uncompressed form, this file would contain roughly 600 nodes by 600 nodes.

Table 16 provides general information to aid in the compilation of S-102 data for specific charting scales.

Annex D discusses in greater detail the physical size components of an S-102 file.

11.2.2.1. S-102 grid resolution and tiling

Table 16 — Informative Grid Resolution and Resulting Tile Size at Chart Scale

Scale	**Informative Grid Resolution**	**Resulting Tile Size @ 10 MB**
NULL (only allowed on minimum display scale where the maximum display scale = 10,000,000)		Approximate Linear Distance in Nautical Miles (M) for a 600 X 600 node grid
1:10,000,000	900 metres	291 X 291
1:3,500,000	900 metres	291 X 291
1:1,500,000	450 metres	145 X 145
1:700,000	210 metres	68 X 68
1:350,000	105 metres	34 X 34
1:180,000	54 metres	17.5 X 17.5
1:90,000	27 metres	8.7 X 8.7
1:45,000	13 metres	4.2 X 4.2
1:22,000	6 metres	1.9 X 1.9

Scale	Informative Grid Resolution	Resulting Tile Size @ 10 MB
1:12,000	3 metres	1.0 X 1.0
1:8,000	2 metres	0.6 X 0.6
1:4,000	1 metres	0.3 X 0.3
1:3,000	1 metres	0.3 X 0.3
1:2,000	1 metres	0.3 X 0.3
1:1,000	1 metres	0.3 X 0.3

11.2.3. Dataset file naming

Dataset naming must follow a standard pattern to give implementers greater predictability of incoming datasets. S-102 dataset naming conventions must follow these rules.

102CCCCØØØØØØØØØØØØ.H5 102

the first 3 characters identify the dataset as an S-102 dataset (mandatory).

CCCC

the fourth to seventh characters identify the producer code of the issuing agency (mandatory for S-102). Where the producer code is derived from a 2- or 3-character format (for instance when converting S-57 ENCs), the missing characters of the producer code must be populated with zeros (“00” or “0” respectively) for the sixth and seventh characters of the dataset file name, as required ØØØØØØØØØØØØ::: the eighth to the maximum nineteenth characters are optional and may be used in any way by the producer to provide the unique file name. The following characters are allowed in the dataset name: A to Z, 0 to 9 and the special character _ (underscore).

H5

denotes and HDF5 file.

11.3.Exchange Set

The structure of an S-102 Exchange Set must be according to the structure described below, which is based on S-100, Part 17, Clause 17–4.2.

a) An S-102 Exchange Set must contain an Exchange Set Catalogue, CATALOG.XML, its digital signature CATALOG.SIGN, and may contain any number of S-102 conformant dataset files, support files, and Catalogue files.

b) 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.

c) The S100_ROOT folder must contain a subfolder named S-102. This subfolder holds content specific to the S-102 Product Specification.

d) The S-102 subfolder must contain subfolders for the component dataset files (DATASET_FILES) and Catalogues (CATALOGUES) as required.

e) The required Exchange Set Catalogue XML document instance must be named CATALOG.XML and placed in the S100_ROOT folder, together with its digital signature (CATALOG.SIGN) file. All other digital signatures are included within their corresponding resource metadata records in the CATALOG.XML.

f) Support files are not allowed in S-102 exchange sets for this edition of S-102.

11.4. Exchange Catalogue

The Exchange Catalogue acts as the table of contents for the Exchange Set. The Catalogue file of the Exchange Set must be named CATATLOG.XML. No other file in the Exchange Set may be named CATALOG.XML. The contents of the Exchange Catalogue are described in Chapter 12.

11.5. Data integrity and encryption

S-100 Part 15 defines the algorithms for compressing, encrypting and digitally signing datasets based on the S-100 Data Model. The individual Product Specifications provide details about which of the elements are being used and on which files in the dataset.

11.5.1. Use of compression

The data producer decides if compression will be used on the S-102 product files (HDF5). It is expected that a hydrographic office will make a policy decision and that all the S-102 datasets from the producer will be either compressed or uncompressed.

It is recommended to compress all the dataset files, for example HDF5 files. The ZIP compression method defined in S-100 Part 15 must be applied to the product files.

11.5.2. Use of data protection

It is recommended to encrypt all the dataset files, for example HDF5. The encryption method defined in S-100, Part 15 must be applied.

11.5.3. Use of digital signatures

Digital signatures shall be used on all files included in a S-102 compliant Exchange Set to meet the requirements of IMO resolution MSC.428(98) to reduce cyber security risks among users, especially when used in navigations systems at sea. The recommended signature method is defined in S-100, Part 15.

The digital signature information is encoded in the corresponding discovery block in the exchange catalogue for each file included in the Exchange Set.

12. Metadata

12.1. Introduction

The Metadata elements used in the Bathymetric Surface product are derived from S-100 and from ISO 19115-1:2014/Amd 1:2018 and ISO 19115-2:2009. Optionally

additional metadata may be derived from ISO/TS 19130:2010 and ISO/TS 19130-2:2014 especially metadata relating to the sonar equipment which may have been used to acquire the bathymetric data.

S-102 metadata is encoded in two places:

— Metadata used for the discovery, identification, and use of S-102 datasets in S-100-based navigations systems (specifically, an S-100-capable ECDIS) is encoded in the exchange catalogue. This metadata conforms to S-100 Part 17, with product-specific restrictions added.

— Metadata required by the S-100 HDF5 encoding (S-100, Part 10c) and product-specific metadata defined by this product specification are encoded at various levels in the HDF5 group hierarchy, as specified by S-100, Part 10c or Section 10.2.

12.2.Exchange Set metadata

For information exchange, there are several categories of metadata required: metadata about the overall Exchange Catalogue, metadata about each of the datasets contained in the Catalogue.

Figure 10 depicts the relationships of exchange set elements (datasets and feature/portrayal catalogues) and exchange set metadata. This figure is derived from Figure 17-2 in S-100 Edition 5.0.0 with relationships not applicable to S-102 omitted.

Figure 11 depicts the structure of the exchange catalogue and its component discovery metadata blocks. The structure is the same as in S-100, Part 17.

More detailed information about the various classes is shown in in Figure 12 and a textual description in Tables 17 to 32.

The discovery metadata classes have numerous attributes which enable important information about the datasets 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 and Portrayal.

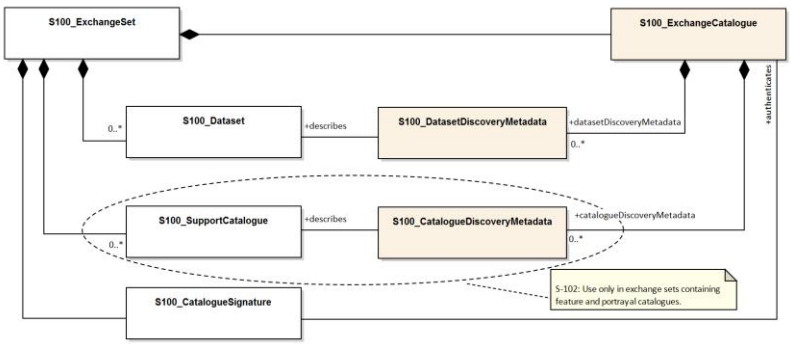

Figure 10 — Components and associated metadata for the S-102 exchange set (S-100 5.0.0 Figure 17-2 with items not used by S-102 omitted)

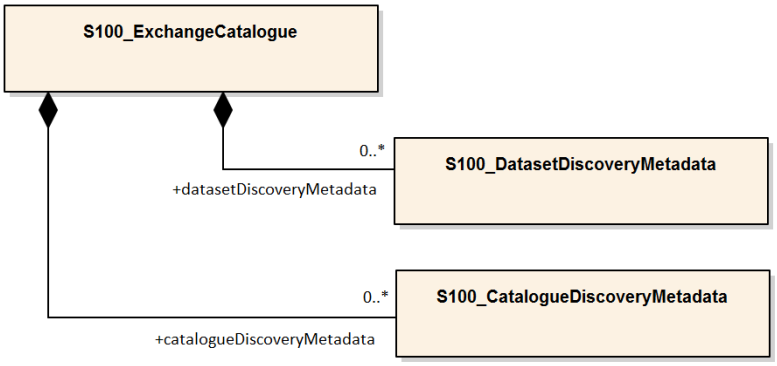

Figure 11 — Relationship between exchange catalogue, discovery metadata, and dataset (from S-100 5.0.0 Figure 17-6)

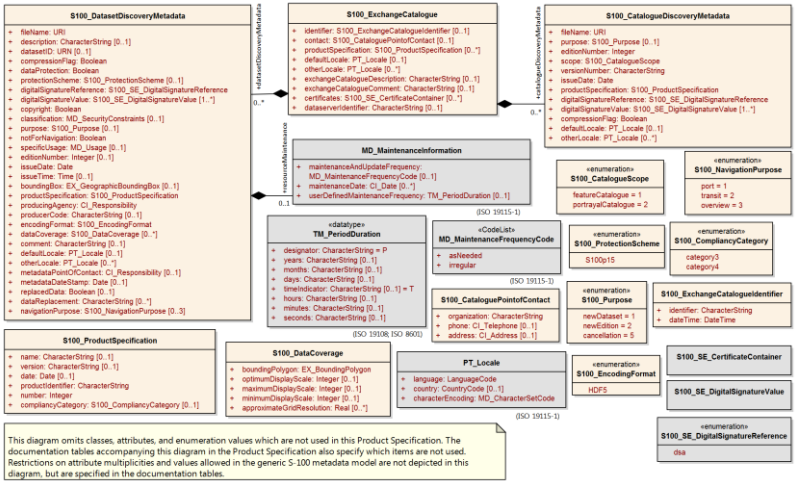

Figure 12 — S-102 Exchange Set Class Details

The following clauses define the mandatory and optional metadata needed for S-102. In some cases, the metadata may be repeated in a national language. If this is the case it is noted in the Remarks column.

The XML schemas for S-102 exchange catalogues will be available from the IHO Geospatial Information (GI) Registry and/or the S-100 GitHub site (https://github.com/IHO-S100WG).

The S-102 exchange catalogue uses the S-100 exchange catalogue schemas which are available from the S-100 schema server at https://schemas.s100dev.net (downloadable archives are also available on the site for offline use). Implementation of the S-102-specific constraints described in clauses 12.X to 12.Y below is left to developer decision as it can be done in various ways depending on implementation frameworks and the requirements of production or application software.

12.3.Language

The exchange language must be English.

Character strings must be encoded using the character set defined in ISO/IEC 10646-1:2000, in Unicode Transformation Format-8 (UTF-8). A BOM (byte order mark) must not be used.

12.4.S102_ExchangeCatalogue

Each Exchange Set has a single S100_ExchangeCatalogue which contains meta information for the data in the Exchange Set.

S-102 uses S100_ExchangeCatalogue without extension. S-102 restricts certain attributes and roles as described in Table 17. These restrictions are in bold type and noted in the Remarks column.

Table 17 — S102_ExchangeCatalogue parameters

Role name	**Name**	**Description**	**Mult**	**Type**	**Remarks**
Class	S100_ExchangeCatalogue	An exchange catalogue contains the discovery metadata about the exchange datasets and support files	-	-	Support file discovery metadata is not permitted because S-102 does not use support files
Attribute	identifier	Uniquely identifies this Exchange Catalogue	1	S100_ExchangeCatalogueIdentifier	**Mandatory in S-102**
Attribute	contact	Details about the issuer of this Exchange Catalogue	1	S100_CataloguePointOfContact	**Mandatory in S-102**
Attribute	productSpecification	Details about the Product Specifications used for the datasets contained in the Exchange Catalogue	0..*	S100_ProductSpecification	

Role name	Name	Description	Mult	Type	Remarks
Attribute	defaultLocale	Default language and character set used for all metadata records in this Exchange Catalogue	0..1	PT_Locale	Default is English and UTF-8
Attribute	otherLocale	Other languages and character sets used for the localized metadata records in this Exchange Catalogue	0..*	PT_Locale	Required if any localized entries are present in the Exchange Catalogue
Attribute	exchangeCatalogueDescription	Description of what the Exchange Catalogue contains	0..1	CharacterString	
Attribute	exchangeCatalogueComment	Any additional information	0..1	CharacterString	
Attribute	certificates	Signed public key certificates referred to by digital signatures in the Exchange Set	0..*	S100_SE_CertificateContainer	Content defined in S-100, Part 15. All certificates used, except the SA root certificate (installed separately by the implementing system) shall be included.

Role name	Name	Description	Mult	Type	Remarks
Attribute	dataServerIdentifier	Identifies the data server for the permit	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	catalogueDiscoveryMetadata	Metadata for catalogue	0..*	Aggregation S100_CatalogueDiscoveryMetadata	Metadata for the feature, portrayal, and interoperability catalogues, if any

12.4.1. S100_ExchangeCatalogueIdentifier

S-102 uses S100_ExchangeCatalogueIdentifier without modification.

Table 18 — S100_ExchangeCatalogueIdentifier parameters

Role name	Name	Description	Mult	Type	Remarks
Class	S100_ExchangeCatalogueIdentifier	An identifier for an Exchange Catalogue	-	-	The concatenation of identifier, edition number, and dateTime for the unique name.
Attribute	identifier	Uniquely identifies this Exchange Catalogue	1	CharacterString	(Rules, if any, for S-102 identifiers are TBD.)
Attribute	dateTime	Creation date and time of the Exchange Catalogue, including time zone	1	DateTime	Format: yyyy-mm-ddThh:mm:ssZ

12.4.2. S100_CataloguePointOfContact

S-102 uses S100_CataloguePointOfContact without modification.

Table 19 — S100_CataloguePointOfContact parameters

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	

12.5.S100_DatasetDiscoveryMetadata

Dataset discovery metadata in S-102 restricts certain attributes and roles as described in Table 20. Optional S-100 attributes which are mandatory in S-102 are indicated in the Remarks column.

Table 20 — S100_DatasetDiscoveryMetadata parameters

Role name	Name	Description	Mult	Type	Remarks
Class	S100_DatasetDiscoveryMetadata	Metadata about the individual datasets in the Exchange Catalogue	-	-	The optional S-100 attributes updateApplicationNubmer, updateApplicationDate, referenceID, and temporalExtent are not used in S-102.

Role name	Name	Description	Mult	Type	Remarks
					References to support file discovery metadata are not permitted because S-102 does not use support files.
Attribute	fileName	Dataset file name	1	URI	Format: file:/S-102/DATASET_FILES/<ds name> Dataset file name <dsname> must be according to format defined in Section 11.2.3.
Attribute	description	Short description giving the area or location covered by the dataset	0..1	CharacterString	For example a harbour or port name, between two named locations, etc.
Attribute	datasetID	Dataset ID expressed as a Maritime[a] Resource Name	0..1	URN	The URN must be an MRN. MRN construction rules will be defined by the IHO.
Attribute	compressionFlag	Indicates if the resource is compressed	1	Boolean	*True* indicates a compressed dataset resource. *False* indicates an uncompressed dataset resource.

Role name	Name	Description	Mult	Type	Remarks
Attribute	dataProtection	Indicates if the data is encrypted	1	Boolean	*True* indicates an encrypted dataset resource. *False* indicates an unencrypted dataset resource.
Attribute	protectionScheme	Specification of method used for data protection	0..1	S100_ProtectionScheme	**Populate if and only if dataProtection = *True*.**
Attribute	digitalSignatureReference	Specifies the algorithm used to compute digitalSignatureValue	0..1	S100_SE_DigitalSignatureReference (see S-100, Part 15)	
Attribute	digitalSignatureValue	Value derived from the digital signature	1..*	S100_SE_DigitalSignatureValue (see S-100, Part 15)	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	1	Boolean	*True* indicates the resource is copyrighted. *False* indicates the resource is not copyrighted.

Role name	Name	Description	Mult	Type	Remarks
Attribute	classification	Indicates the security classification of the dataset	0..1	Class MD_SecurityConstraints>MD_ClassificationCode (codelist)	a) unclassified b) restricted c) confidential d) secret e) top secret f) sensitive but unclassified g) for official use only h) protected i) limited distribution
Attribute	purpose	The purpose for which the dataset has been issued	1	S100_Purpose	**Mandatory in S-102**
Attribute	notForNavigation	Indicates the dataset is not intended to be used for navigation	1	Boolean	*True* indicates the dataset **is not** intended to be used for navigation. *False* indicates the dataset **is** intended to be used for navigation.

Role name	Name	Description	Mult	Type	Remarks
Attribute	specificUsage	The use for which the dataset is intended	0..1	MD_USAGE>specificUsage (character string)	
Attribute	editionNumber	The edition number of the dataset	1	Integer	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-102**
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
Attribute	boundingBox	The extent of the datast limits	1	EX_GeographicBoundingBox	**Mandatory in S-102**

Role name	Name	Description	Mult	Type	Remarks
Attribute	productSpecification	The Product Specification used to create this dataset	1	S100_ProductSpecification	
Attribute	producingAgency	Agency responsible for producing the data	1	CI_Responsibility>CI_Organisation	See S-100, Part 17, Table 17–3
Attribute	producerCode	The official IHO Producer Code from S-62	0..1	CharacterString	
Attribute	encodingFormat	The encoding format of the dataset	1	S100_EncodingFormat	**The only allowed value is HDF5**
Attribute	dataCoverage	Provides information about data coverages within the dataset	1..*	S100_DataCoverage	**This optional S-100 attribute is mandatory in S-102**
Attribute	comment	Any additional information	0..1	CharacterString	
Attribute	defaultLocale	Default language and character set	0..1	PT_Locale	In absence of defaultLocale, the language

Role name	Name	Description	Mult	Type	Remarks
		used in the dataset			is English, and the character set is UTF-8.
Attribute	otherLocale	Other languages and character sets used in the dataset	0..*	PT_Locale	
Attribute	metadataPointOfContact	Point of contact for metadata	0..1	CI_Responsibility>CI_Individual or CI_Responsibility>CI_Organisation	Only if metadataPointOfContact differs from producingAgency
Attribute	metadataDateStamp	Date stamp for metadata	0..1	Date	May or may not be the issue date
Attribute	replacedData	If a data file is cancelled, it is replaced by another data file.	0..1	Boolean	
Attribute	dataReplacement	Cell name	0..*	CharacterString	A dataset may be replaced by 1 or more datasets.
Attribute	navigationPurpose	Classification of intended navigation purpose (for Catalogue	1..3	S100_NavigationPurpose	If Product Specification is intended for creation of navigational products, this attribute should be mandatory. **Mandatory in S-102**

Role name	Name	Description	Mult	Type	Remarks
		indexing purposes)			
Role	resourceMaintenance	Information about the frequency and scope of resource updates	0..1		S-100 restricts the multiplicity to 0..1 and adds specific restrictions on the ISO 19115 structure and content. See <iho-s100,part=17>>. Format: PnYnMnDTnHnMnS (XML built-in type for ISO 8601 duration). See S-100, Part 17, Clause 17–4.9. **S-102 discovery metadata blocks should populate maintenance information if and only if the date of the next edition is definite, whether it is due on a regular or irregular schedule.**

[a] S-100 5.0.0 uses an incorrect term: “**Marine** Resource Name”.

12.5.1. S100_NavigationPurpose

Table 21 — S100_NavigationPurpose

Role Name	Name	Description	Code	Remarks
Enumeration	S100_NavigationPurpose	The purpose of the dataset	-	
Value	port	For port and near shore operations	1	-
Value	transit	For coast and planning purposes	2	-
Value	overview	For ocean crossing and planning purposes	3	-

12.5.2. S100_DataCoverage

S-102 uses S100_DataCoverage without modification.

Table 22 — S100_DataCoverage parameters

Role name	Name	Description	Mult	Type	Remarks
Class	S100_DataCoverage	A spatial extent where data is provided along with the display scale information for the provided data	-	-	This field is used by user systems as part of the data loading and unloading algorithms, and it is stringly encouraged that Product Specifications mandate the use of one or more of the displayScale provided as part of S100_DataCoverage. **The S-100 optional attribute temporalExtent is not used in S-102.**
Attribute	boundingPolygon	A polygon which defines the actual data limit	1	EX_BoundingPolygon	-
Attribute	optimumDisplayScale	The scale at which the data is optimally displayed	0..1	Integer	Example: A scale of 1:25000 is encoded as 25000
Attribute	maximumDisplayScale	The maximum scale at which the data is displayed	0..1	Integer	
Attribute	minimumDisplayScale	The minimum scale at which the data is displayed	0..1	Integer	

Role name	Name	Description	Mult	Type	Remarks
Attribute	approximateGridResolution	The resolution of gridded or georeferenced data (in metres)	1..2	Real	**Mandatory in S-102** A single value may be provided when all axes have a common resolution. For multiple value provision, use axis order as specified in dataset. May be approximate for ungeorectified data (**not applicable to this edition of S-102**). For example, for 5-metre resolution, the value 5 must be encoded. See Section 12.5.2, Note.
NOTE If the grid cell size varies over the extent of the grid, an approximated value based on model parameters or production metadata should be used.					

12.5.3. S100_Purpose

Table 23 — S100_Purpose

Role name	Name	Description	Code	Remarks
Enumeration	S100_Purpose	The purpose of the dataset	-	The S-100 values *update*, *reissue*, and *delta* are not used in S-102.
Value	newDataset	Brand new dataset	1	No data has previously been produced for this area.
Value	newEdition	New edition of the dataset or Catalogue	2	Includes new information which has not been previously distributed by updates
Value	cancellation	Dataset or Catalogue that has been cancelled	5	Indicates the dataset or Catalogue should no longer be used and can be deleted

12.5.4. S100_EncodingFormat

S-102 uses S100_EncodingFormat with a restriction on the allowed values to permit only the S-100 HDF5 format for S-102 datasets.

Table 24 — S100_EncodingFormat parameters

Role name	Name	Description	Code	Remarks
Enumeration	S100_EncodingFormat	The encoding format	-	The only value allowed in S-102 is “HDF5”.
Value	HDF5	The HDF5 data format as defined in S-100, Part 10c	3	

12.5.5. S100_ProductSpecification

S-102 uses S100_ProductSpecification without modification. The Product Specification attributes encoded must be for this edition of S-102.

Table 25 — S100_ProductSpecification parameters

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 GI Registry should be used for this field. For S-102, this name is “Bathymetric Surface” (as of 24 January 2023).
Attribute	version	The version number of the Product Specification	1	CharacterString	
Attribute	date	The version date of the Product Specification	1	Date	
Attribute	productIdentifier	Machine readable unique identifier of a product type	1	CharacterString (Restricted to Product ID values from the IHO Product Specification Register in the IHO Geospatial Information (GI) Registry)	For S-102, this identifier is “S-102” (without quotes).

Role name	Name	Description	Mult	Type	Remarks
Attribute	number	The number used to lookup the product in the Product Specification Register of the IHO GI registry	1	Integer	For IHO Product Specifications, these numbers should be taken from the IHO Product Specification Register in the IHO GI Registry.
Attribute	compliancyCategory	The level of compliance of the Product Specification to S-100	0..1	S100_CompliancyCategory	See S-100, Part 4a, Clause 4a–5.5 and Section 12.5.6 below.

12.5.6. S100_CompliancyCategory

S-102 exchange sets conforming to this edition of S-102 and using a CRS from the EPSG registry may be encoded as category 3 or 4 when the *compliancyCategory* metadata attribute is populated. Because S-98 interoperability assumes *category4* datasets, *category4* may be used for test purposes, though the absence of test datasets and of a published IHO interoperability catalogue mean this edition of S-102 does not yet qualify for *category4*. **Given the uncertainty about interoperability testing requirements and availability of test datasets, the S-100 WG chair and S-102 PT chair should be consulted for up-to-date guidance.**

Table 26 — S100_CompliancyCategory

Role Name	Name	Description	Code + (see Section 12.5.6, Note)	Remarks
Enumeration	S100_CompliancyCategory	(not provided in S-100 Ed. 5.0.0)	-	S-102 should use *category3* or *category4*, subject to the guidance provided in Section 12.5.6.
Value	category1	IHO S-100 object model compliant	1	**S-102 conforms to the S-100 object model. Not used for S-102; use *category3* or *category4* instead.**
Value	category2	IHO S-100 compliant with non-standard encoding	2	**Qualifies as *category1*; plus: Product Specification complies with S-100, Part 11; metadata complies with S-100, Part 4 or an extension thereof; S-100, Part 10 encoding or custom encoding mapped to the S-100 GFM. [S-100 5.0.0 4a-5.5.2] Not used for S-102; use *category3* or *category4* instead.**
Value	category3	IHO S-100 compliant with standard encoding	3	**Qualifies as *category2*; plus "The Product Specification uses only an encoding method defined in S-100, Part 10" [S-100 5.0.0 4a-5.5.3] Allowing for S-100 Edition 5.0.0 separation of metadata into Part 17, this edition of S-102 qualifies.**

Role Name	Name	Description	Code + (see Section 12.5.6, Note)	Remarks
Value	category4	IHO S-100 and IMO harmonized display compliant	4	**Qualifies as *category3*; plus additional requirements, including a portrayal catalogue, cybersecurity (digital signatures and encryption), test material, use of a CRS from the EPSG Registry, and compliance with the IHO S-98 interoperability catalogue. [S-100 5.0.0 4a-5.5.4]**
NOTE Numeric codes are not provided in S-100 Edition 5.0.0 but have since been determined by the S-100WG; they are needed only if the enumeration is also encoded as an HDF5 enumeration.				

12.5.7. S100_ProtectionScheme

Table 27 — S100_ProtectionScheme parameters

Role name	Name	Description	Code	Remarks
Enumeration	S100_ProtectionScheme	Data protection schemes	-	-
Value	S100p15	IHO S-100 Part 15	-	See S-100, Part 15.

12.6.MD_MaintenanceInformation

Table 28 — MD_MaintenanceInformation parameters

Role Name	Name	Description	Mult	Type	Remarks
Class	MD_MaintenanceInformation	Information about the scope and frequency of updating	-	-	S-100 restricts the ISO 19115-class to: * prohibit maintenanceScope, maintenanceNote, and contact attributes * define restrictions on maintenanceAndUpdateFrequency, maintenanceDate, and userDefinedMaintenanceFrequency attributes
Attribute	maintenanceAndUpdateFrequency	Frequency with which changes and additions are made to the resource after the initial resource is completed	0..1	MD_MaintenanceFrequencyCode (codelist)	Must be populated if userDefinedMaintenanceFrequency is not present, otherwise optional. See Table 29 for values allowed in S-100 metadata.

Role Name	Name	Description	Mult	Type	Remarks
Attribute	maintenanceDate	Date information associated with maintenance of the resource	0..1	CI_Date	Exactly one of maintenanceDate and userDefinedMaintenanceFrequency must be populated. Allowed value for dateType: nextUpdate
Attribute	userDefinedMaintenanceFrequency	Maintenance period other than those defined	0..1	TM_PeriodDuration	Exactly one of maintenanceDate and userDefinedMaintenanceFrequency must be populated. Only positive durations allowed

12.7.MD_MaintenanceFrequencyCode

S-100 (and therefore S-102) use a subset of the values allowed in ISO 19115-1.

Table 29 — MD_MaintenanceFrequencyCode parameters

Role Name	Name	Description	Code	Remarks
Enumeration	MD_MaintenanceFrequencyCode	Frequency with which modifications and deletions are made to the data after it is first produced	-	S-100 is restricted to only the values listed in this table (from the ISO 19115-1 codelist). The conditions for the use of a particular value are described in its Remarks.
Value	asNeeded	Resource is updated as deemed necessary.	1	Use only for datasets which normally use a regular interval for update or supersession but will have the next update issued at an interval different from the usual. Allowed if and only if userDefinedMaintenanceFrequency is not populated
Value	irregular	Resource is updated in intervals that are uneven in duration.	2	Use only for datasets which do not use a regular schedule for update or supersession. Allowed if and only if userDefinedMaintenanceFrequency is not populated

12.8.S100_CatalogueDiscoveryMetadata

S-102 uses S100_CatalogueMetadata without modification.

Table 30 — S102_CatalogueMetadata parameters

Role name	Name	Description	Mult	Type	Remarks
Class	S100_CatalogueMetadata	Class for S-100 Catalogue metadata	-	-	-
Attribute	filename	The name for the catalogue	1	URI	See S-100, Part 1, Clause 1–4.6.
Attribute	purpose	The purpose for which the Catalogue has been issued	0..1	S100_Purpose	The values must be one of the following: * 2 new edition * 5 cancellation Default is new edition See Table 23.
Attribute	editionNumber	The Edition number of the Catalogue	1	Integer	Initially set to 1 for a given productSpecification.number Increased by 1 for each subsequent newEdition Uniquely identifies the version of the Catalogue
Attribute	scope	Subject domain of the Catalogue	1	S100_CatalogueScope	
Attribute	versionNumber	The version identifier of the Catalogue	1	CharacterString	Human readable version identifier

Role name	Name	Description	Mult	Type	Remarks
Attribute	issueDate	The issue date of the Catalogue	1	Date	
Attribute	productSpecification	The Product Specification used to create this file	1	S100_ProductSpecification	
Attribute	digitalSignatureReference	Specifies the algorithm used to compute digitalSignatureValue	1	S100_SE_DigitalSignatureReference (see S-100, Part 15)	
Attribute	digitalSignatureValue	Value derived from the digital signature	1..*	S100_SE_DigitalSignatureValue	The value resulting from application of digitalSignatureReference Implemented as the digital signature format specified in S-100, Part 15
Attribute	compressionFlag	Indicates if the resource is compressed.	1	Boolean	*True* indicates a compressed resource. *False* indicates an uncompressed resource.
Attribute	defaultLocale	Default language and character set used in the Exchange Catalogue	0..1	PT_Locale	In absence of defaultLocale, the language is English, and the character set is UTF-8.

Role name	Name	Description	Mult	Type	Remarks
Attribute	otherLocale	Other languages and character sets used in the Exchange Catalogue	0..*	PT_Locale	

12.8.1. S100_CatalogueScope

S-102 uses S100_CatalogueScope without modification.

Table 31 — S100_CatalogueScope parameters

Role name	Name	Description	Code	Remarks
Enumeration	S100_CatalogueScope	The scope of the Catalogue	-	-
Value	featureCatalogue	S-100 feature catalogue	1	
Value	portrayalCatalogue	S-100 portrayal catalogue	2	
Value	interoperabilityCatalogue	S-100 interoperability information	3	

12.8.2. PT_Locale

Table 32 — PT_Locale parameters

Role name	Name	Description	Mult	Type	Remarks
Class	PT_Locale	Description of a locale	-	-	From ISO 19115-1:2014/Amd 1:2018
Attribute	language	Designation of the locale language	1	LanguageCode	ISO 639-2:1998 3-letter language codes. **(S-100 Part 17 mandates the "T" codes.)**
Attribute	country	Designation of the specific country of the locale language	0..1	CountryCode	ISO 3166-2:2013 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	UTF-8 is used in S-100

The class PT_Locale is defined in ISO 19115-1:2014/Amd 1:2018. LanguageCode, CountryCode, and MD_CharacterSetCode are ISO codelists which are defined in a codelists file which is part of the S-100 Edition 5.0.0 schema distribution.

12.9.Certificates and Digital Signatures

The classes S100_SE_CertificateContainer, S100_SE_DigitalSignatureReference, and S100_DigitalSignatureValue are defined in S-100, Part 15 and implemented in the S-100 generic schemas.

In accordance with S-100, Part 15, only the DSA algorithm is allowed from the S100_SE_DigitalSignatureReference enumeration.

S-102 uses S100_DigitalSignatureValue without modification. As stated in S-100, Part 15, Clause 15–8.11.4:

“The class S100_SE_DigitalSignatureValue is realized as one of either S100_SE_SignatureOnData (a digital signature of a particular identified resource) or an additional digital signature defined using the class S100_SE_AdditionalSignature, each of which is either a S100_SE_SignatureOnData or S100_SE_SignatureOnSignature element as described in clause 15-8.8. S-100 Part 17 metadata thus allows for multiple digital signatures, a single mandatory S100_SE_SignatureOnData and any number of additional signatures, either of the data or other signatures.”

Annex A
Data Classification and Encoding Guide

A.1. Features

A.1.1. BathymetryCoverage

Table A.1 — BathymetryCoverage feature parameters

IHO Definition: Bathymetry Coverage. A set of value items required to define a dataset representing a depth calculation and its associated uncertainty.			
Primitive: S-100_Grid_Coverage			
Attribute	**Allowable Encoding Value**	**Type**	**Multiplicity**
depth	Must be in decimal metres with resolution not to exceed 0.01 metres	real (32-bit Float)	1
uncertainty	Must be in decimal metres with resolution not to exceed 0.01 metres	real (32-bit Float)	1

A.2. Feature Attributes

A.2.1. BathymetryCoverage

Table A.2 — BathymetryCoverage feature attribute parameters

IHO Definition: **depth**. The vertical distance from a given water level to the bottom [S-32].
Unit: metres
Resolution: 0.01
Remarks: — Drying heights (drying depths) are indicated by a negative value.
IHO Definition: **uncertainty**. The interval (about a given value) that will contain the true value of the measurement at a specific confidence level [S-44].
Unit: metres
Resolution: 0.01
Remarks: — Represents a +/- value defining the possible range of associated depth. — Expressed as a positive number.

Annex B
Normative Implementation Guidance

NOTE Normative Implementation Guidance to be addressed in a future version of S-102.

Annex C
Portrayal Catalogue

NOTE Portrayal Catalogue currently under development.

Annex D
S-102 Dataset Size and Production

D.1. Header Record

An S-102 file will contain two header sections. The first section contains, at minimum, the mandatory metadata elements as defined in S-100 Part 4. The second section contains, at minimum, the mandatory metadata elements as defined in Chapter 12 of the S-102 Product Specification. The producers may add optionally defined metadata to these sections, as their processes/standards require.

Given that the contents of these metadata attributes will vary between producers, it is impossible to define a definitive size for the file header. The estimated maximum size for the full header of an S-102 file is 3 MB. This is an estimate based on the expected encoding of mandatory metadata in both S-100/S-102, usage of the optional metadata elements and expected verbosity of those elements.

D.2. Data Records/Nodes

The data contained within an S-102 file consists of a single data type. This data is the **BathymetryCoverage** and is defined as a two-dimensional array of nodes containing bathymetric data. Each of the nodes within this array contains two data values (depth and uncertainty). Both values are stored as a 4-byte floating point. The total size of each node will therefore be 8 bytes.

D.3. File Estimates

Table D.1 estimates the possible number of records for a given S-102 file. This estimation is based on file size constraints and the estimates described above. Rounded to the nearest hundred, this estimate allows us to state that a file not exceeding 600×600 will remain below the 10 MB. Figure D.1 depicts the maximum grid size for 10MB.

Table D.1 — Calculated File Size for 10 MB (Uncompressed Dataset)

BathymetryCoverage					
Records					
Name	**Type**	**Size (bytes)**			
depth	Float	4			
uncertainty	Float	4			
	Total Size	**8**			
Sizes (bytes)					
KB		**MB**		**GB**	
1,024		1,048,576		1,073,741,824	
File Options					
Max Size Options (MB)		10			
Header Size (MB)		3			
BathymetryCoverage Size					

BathymetryCoverage Size(MB)	7
Total Number of BathymetryCoverage Records	366,902
Square Dimensions (BathymetryCoverage)	606

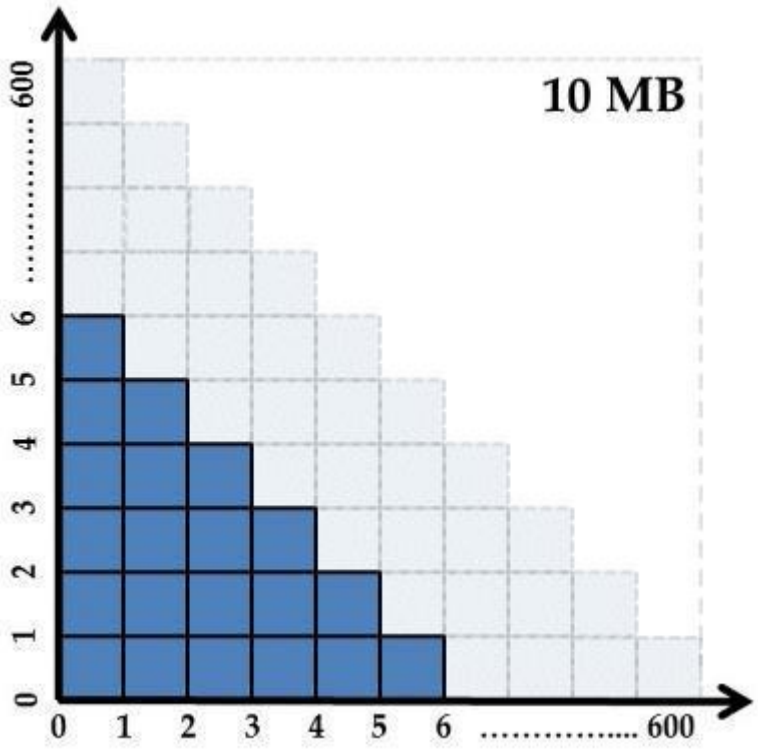

Figure D.1 — Informative grid extents for a 10 MB Uncompressed Dataset

Annex E
Multi-Resolution Gridding

NOTE Multi-Resolution gridding to be addressed in a future version of S-102.

Annex F
Gridding Full Resolution Source Bathymetry and its Relationship to a Charted Sounding

F.1. Modern High-Resolution Hydrographic Multibeam Sonars

As stated in Chapter 4, the majority of modern hydrographic surveys are conducted using high-resolution multibeam sonar systems. These systems provide great target detection capability and allow for the production of highly detailed images of the seafloor. It must be understood that this capability comes at a price. These systems collect a tremendous amount of information which requires sufficient processing power and data storage to reduce an overwhelming quantity of depth estimates to a manageable number for charting production. The following example describes one method to grid high-resolution multibeam sonar data. This example additionally shows the relationship of a product scale grid to the actual charted sounding.

F.1.1. Example collection scenario

Environmental Characteristics	Relatively Flat Seafloor Average Water Depth: 20 metres
Charting Parameters	Intended charting scale: 1:22,000
Survey Plan	Survey Length: 30 days Daily Collection Window: 12 hours each day Collection Speed: 8 kts.
Collection Sonar Characteristics	Sonar Frequency: 400kHz Beam Width: 0.5° X 0.5° Number of Beams Across Swath: 400 soundings per ping Swath Coverage: 5 times water depth Sonar Max Ping Rate: 20 Hz

F.2. Survey Metrics

F.2.1. Ping rate and number of depth estimates

In 20 metres of water the system described above would collect 400 individual depth estimates each ping. If maximum ping rate of 20 Hz is realized the sonar has the ability to collect 8,000 individual depth estimates every second.

400 depth estimates per ping X 20 Hz = 8000 depth estimates / second
-OR-
28.8 million depth estimates each hour.
345.6 million depth estimates every day.
10.4 billion depth estimates at the end of the survey.

F.2.2. Sonar footprint

Sonar footprint is a function of water depth (20 metres) and beam angle ($0.5° \times 0.5°$). Computed footprint at nadir:

$\text{Footprint @ Nadir} = 2 \times ((\text{Depth}) \times (\tan\frac{\emptyset}{2}))$, where $\emptyset = \text{Beam Width}$

$$\text{Footprint} = 2 \times ((20\text{ m}) \times (\tan.25)) = 0.17\text{ metres}$$

Since this is a $0.5° \times 0.5°$ system, the total footprint at Nadir is: $0.17\text{m} \times 0.17\text{m}$

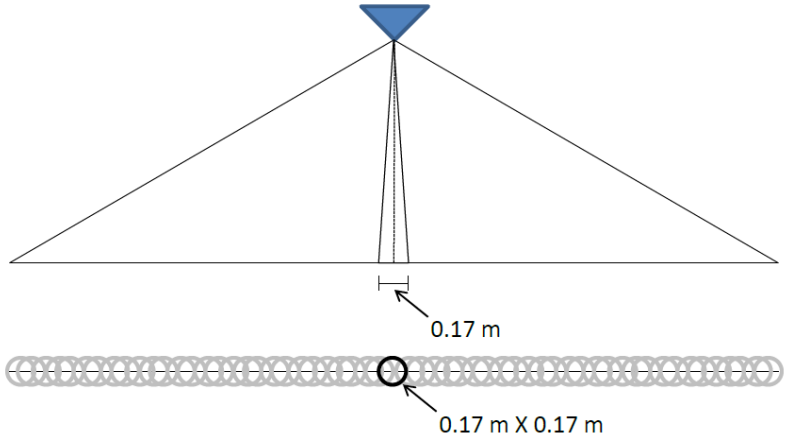

Figure F.1 — Sonar Footprint at Nadir

F.2.3. Sonar coverage

A benefit of multibeam sonars is the ability to collect a swath of depth estimates with each ping. The example sonar lists swath coverage as 5 times water depth. In 20 metres of water this system will ensonify 100 metres of seafloor every ping. This results in a 100-metre swath (50 metres to port and starboard) along the entire length of the survey line. See Figure F.2.

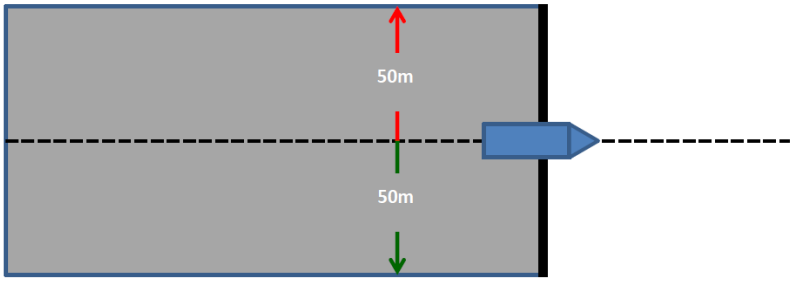

Figure F.2 — Swath Coverage of survey vessel

Total coverage:

17.8km^2 *of coverage each day.*

533.4km^2 *of total coverage after 30 days.*

F.3. Post Survey Process

F.3.1. High-density processing grid

Throughout the survey or at its completion hydrographers will process collected bathymetry, removing gross outliers and erroneous depth estimates. The current trend for processing large quantities of multibeam bathymetry is to generate grids to aid in this process. Generation of a grid improves visualization of the survey and allows for the use of statistics to clean collected data. For the purpose of this example, the described process will produce a high-density seafloor model, selecting a grid resolution representative of twice the sonar footprint at nadir. Since twice the footprint is ~0.3 metres the processing resolution has been increased to 0.5 metres.

NOTE The reason for gridding at such a high resolution is to eliminate the need to revisit the full source data point cloud (10.4 Billion Depth Estimates) every time a production effort is initiated. Production and archival of a high-density grid allows the HO to defocus the high-density surface to a coarser resolution more applicable to the intended charting product.

Results: A 0.5-metre grid for the example survey area: 2.1 Billion depth nodes, or < 20% of the total collected depth estimates.

F.3.2. Generation of a production grid

Referencing the beginning of this Annex, the intended product is a 1:22,000 ENC. Reduction of the “high-density” grid to a 6-metre grid reduces the number of grid nodes from 2.1 Billion to 14.6 million. The resulting 6-metre grid serves as an example of soundings extracted to support chart production. **In total, less than 1% of collected depth estimates make it on a charting product**.

NOTE If the 6-metre surface serves as the source for a complimentary S-102 dataset there will be ~169 nodal depths underneath a single charted sounding. See Figure F.3.

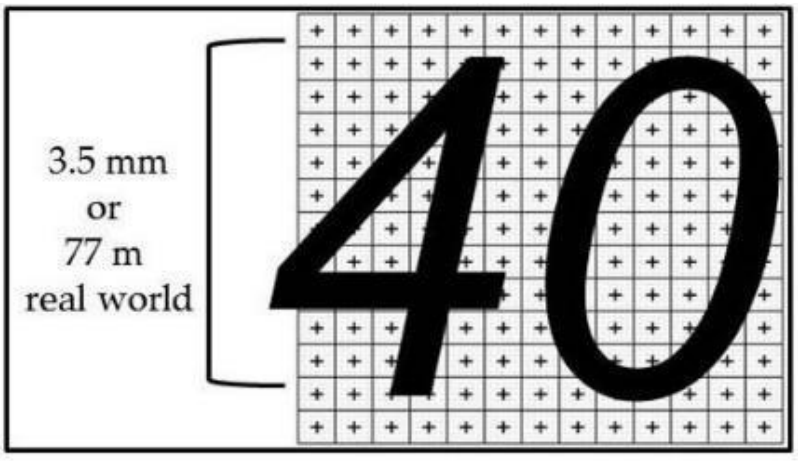

Figure F.3 — Charted Soundings vs 6-metre S-102 Grid

