

Validation Checks – Introduction and Structure

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Document History

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

Version Number	Date	Author/Editor	Purpose
0.1.0	Aug 2024	RM	Initial draft
0.2.0	Nov 2024	RM	Applied review comments and S-100 WG9 decisions; revised wording for check classification; revisions to maintenance regime for S-158:1xx
1.0.0 Draft 1	Feb 2025	RM	Updated references and specification metadata
1.0.0	Feb 2025	HSSC17	First implementation and testing Edition of S-158 – Introduction and Structure.

Summary of Substantive Changes in Edition x.x

Bold references in the Clauses Affected column indicate the principal sections/clauses that are affected by the described change.

Change Summary	Clauses Affected
(To be populated for editions following Edition 1.0.0)	

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1 Introduction

This document describes a common foundation for the structure and content of specifications which define validation checks for S-100 data products. It also describes the basic structure of such validation checks.

1.1 Scope

This document, designated as “S-158” by the IHO, defines a framework for the structure and content of a series of publications which specify validation checks for different S-100 data products. Publications in this series are identified by S-158:1xx designators, where “1xx” represents the official number assigned to an S-100-based data product by the IHO (for example, S-158:101 includes the validation checks specific to the S-101 ENC Product Specification). Any specification designated “S-158:1xx” must conform to the S-158 specification.

1.2 References

1.2.1 Normative references

- | | |
|------------------|--|
| CLE93 | <i>Clementini, E., Di Felice, P., Van Oostrom, P. A Small Set of Formal Topological Relationships Suitable for End-User Interaction, in D. Abel and B. C. Ooi (Ed.), Advances in Spatial Databases — Third International Symposium. SSD 1993. LNCS 692, pp. 277-295. Springer Verlag. Singapore (1993)</i> |
| ISO 19107:2003 | <i>Geographic Information – Spatial Schema</i> |
| ISO 19125-1:2004 | <i>Geographic information – Simple Feature Access – Part 1 Common Architecture</i> |
| OGC 99-049 | <i>OpenGIS Simple Features Specification for SQL, Revision 1.1 (OpenGIS Project Document 99-049, Release Date: May 5, 1999)</i> |
| S-98 | <i>S-100 ECDIS and Interoperability Specification, IHO Publication S-98, Edition 2.0.0, ??? 2025. In Preparation.</i> |
| S-100 | <i>IHO Universal Hydrographic Data Model, Edition 5.2.0, June 2024</i> |
| S-101 | <i>Electronic Navigational Chart (ENC) Product Specification, Edition 2.0.0, December 2024.</i> |
| S-102 | <i>Bathymetric Surface Product Specification, Edition 3.0.0, December 2024.</i> |
| S-104 | <i>Water Level Information for Surface Navigation Product Specification, Edition 2.0.0, December 2024.</i> |
| S-111 | <i>Surface Currents Product Specification, Edition 2.0.0, December 2024.</i> |
| S-124 | <i>Navigational Warnings, Edition 2.0.0, ??? 2025. In preparation.</i> |
| S-128 | <i>Catalogue of Nautical Products, Edition 2.0.0, ??? 2025. In preparation.</i> |
| S-129 | <i>Under Keel Clearance Management Product Specification, Edition 2.0.0, December 2024.</i> |

1.2.2 Informative references

- | | |
|----------------|---|
| ISO 19157:2013 | <i>Geographic information – Data Quality. As amended by Amendment 1, 2018</i> |
|----------------|---|

1.3 Terms, definitions and abbreviations

1.3.1 Terms and definitions

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

application schema

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

boundary

set that represents the limit of an entity [ISO 19107]

NOTE Boundary is most commonly used in the context of geometry, where the set is a collection of points or a collection of objects that represent those points.

class

description of a set of objects that share the same attributes, operations, methods, relationships, and semantics [ISO/TS 19103:2005]

NOTE 1 A class represents a concept within the system being modelled. Depending on the kind of model, the concept may be real-world (for an analysis model), or it may also contain algorithmic and computer implementation concepts (for a design model). A classifier is a generalization of class that includes other class-like elements, such as data type, actor and component.

NOTE 2 A class may use a set of interfaces to specify collections of operations it provides to its environment. See: interface (S-100 Annex A)..

conformance

fulfilment of specified requirements [ISO 19105]

coordinate

one of a sequence of numbers designating the position of a point in N-dimensional space

NOTE: In a **coordinate reference system**, the **coordinate** numbers are qualified by units.

coordinate reference system

coordinate system that is related to an **object** by a **datum**

NOTE: For geodetic and vertical datums, the **object** will be the Earth.

coverage

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

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

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

curve

1-dimensional geometric primitive, representing the continuous image of a line [ISO 19107]

NOTE The boundary of a curve is the set of points at either end of the curve. If the curve is a cycle, the two ends are identical, and the curve (if topologically closed) is considered to not have a boundary. The first point is called the start point, and the last is the end point. Connectivity of the curve is guaranteed by the "continuous image of a line" clause. A topological theorem states that a continuous image of a connected set is connected.

curve segment

1-dimensional geometric object used to represent a continuous component of a curve using homogeneous interpolation and definition methods [ISO 19107]

NOTE The geometric set represented by a single curve segment is equivalent to a curve.

data product

dataset or **dataset series** that conforms to a **data product specification**

NOTE: The S-111 data product consists of metadata and one or more sets of speed and direction values.

data quality

a set of elements describing aspects of quality, including a measure of quality, an evaluation procedure, a quality result, and a scope

data quality element

quantitative component documenting the quality of a dataset [ISO 19101:2002]

NOTE: The applicability of a data quality element to a dataset depends on both the dataset's content and its product specification, the result being that all data quality elements may not be applicable to all datasets

data quality measure

an evaluation of a data quality sub-element [ISO 19113]

data quality overview element

the non-quantitative component documenting the quality of a dataset. Information about the purpose, usage, and lineage of a dataset is non-quantitative quality information

NOTE Information about the purpose, usage and lineage of a dataset is non-quantitative quality information. [ISO 19101]

data quality scope

the extent or characteristic(s) of the data for which quality information is reported [ISO 19113]

NOTE: A data quality scope for a dataset can comprise a dataset series to which the dataset belongs, the dataset itself, or a smaller grouping of data located physically within the dataset sharing common characteristics. Common characteristics can be an identified feature type, feature attribute, or feature relationship; data collection criteria; original source; or a specified geographic or temporal extent. [S-100 Annex A]

data quality sub-element

a component of a data quality element describing a certain aspect of that data quality element [ISO 19103]

dataset

identifiable collection of data [ISO 19115]

NOTE A dataset may be a smaller grouping of data which, though limited by some constraint such as spatial extent or feature type, is located physically within a larger dataset. Theoretically, a dataset may be as small as a single feature or feature attribute contained within a larger dataset. A hardcopy map or chart may be considered a dataset.

dataset series

collection of datasets sharing the same product specification [ISO 19115:2003]

domain

well-defined set. **Domains** are used to define the **domain** set and **range** set of **attributes**, operators, and **functions**

NOTE: *Well-defined* means that the definition is both necessary and sufficient, as everything that satisfies the definition is in the set and everything that does not satisfy the definition is necessarily outside the set.

feature

abstraction of real-world phenomena

EXAMPLE: The phenomenon named *Eiffel Tower* may be classified with other similar phenomena into a **feature type** named *tower*.

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

NOTE 2: In UML 2, a **feature** is a property, such as an operation or **attribute**, which is encapsulated as part of a list within a classifier, such as an interface, **class**, or **data type**.

feature attribute

characteristic of a **feature**

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

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

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

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

NOTE 3: In a **Feature Catalogue**, a **feature attribute** may include a value **domain** but does not specify **attribute** values for **feature** instances.

feature catalogue

a catalogue containing definitions and descriptions of the feature types, feature attributes, and feature associations occurring in one or more sets of geographic data [ISO 19110]

geometric object

spatial **object** representing a geometric set

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

instance

entity to which a set of operations can be applied and which has a state that stores the effects of the operations [ISO 19103]

NOTE See: object.

measurement

The (detailed) dimensions of a physical quantity [S-32]

object

entity with a well-defined boundary and identity that encapsulates state and behaviour

NOTE State is represented by attributes and relationships, behaviour is represented by operations, methods, and state machines. An object is an instance of a class. See: **class**, **instance**. [S-100 Annex A]

observation

The act or practice of noting and recording facts and events as for some scientific study. The measure of a quantity whose value is desired. The DATA so noted and recorded. A single measure, at a single setting of an apparatus [S-32]

point

zero-dimensional geometric primitive, representing a position

NOTE: The boundary of a point is the empty set [ISO 19107]

record

finite, named collection of related items (**objects** or values)

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

surface

connected 2-dimensional geometric primitive, representing the continuous image of a region of a plane [ISO 19107]

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

type

stereotype of class that is used to specify a domain of instances (objects) together with the operations applicable to the objects [S-100 Annex A]

NOTE A type may have attributes and associations.

1.3.2 Abbreviations

This Product Specification adopts the following convention for symbols and abbreviated terms:

CRS	Coordinate Reference System
CNP	Catalogue of Nautical Products
DCEG	Data Classification and Encoding Guide
ECDIS	Electronic Chart Display Information System
ENC	Electronic Navigational Chart

EPSG	European Petroleum Survey Group
HDF	Hierarchical Data Format
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
IHO	International Hydrographic Organization
ISO	International Organization for Standardization
S100WG	S-100 Working Group
TWCWG	Tides, Water Levels, and Currents Working Group
UML	Unified Modelling Language
UTC	Coordinated Universal Time

1.3.3 Symbols

The following symbols are used in logical and spatial expressions:

I	interior of a geometric object
E	exterior of a geometric object
B	boundary of a geometric object
$\cap$	the set theoretic intersection
$\cup$	the set theoretic union
$\wedge$	logical AND
$\vee$	logical OR
$\neq$	not equal
$\emptyset$	the empty or null set
a	first geometry, interior and boundary (the topological definition)
b	second geometry, interior and boundary (the topological definition)
dim	geometric dimension – 2 for Polygons (Surfaces), 1 for Curves or Composite Curves and 0 for Points dim(x) returns the maximum dimension (-1, 0, 1, or 2) of the geometric objects in x, with a numeric value of -1 corresponding to dim($\emptyset$).

NOTES:

- 1) Neither interior nor exterior include the boundary (that is I, E and B are mutually exclusive).
- 2) The boundary of a Polygon or Surface includes its set of outer and inner rings.
- 3) The boundary of a Curve is its end points except for a closed Curve, which has no boundary; the rest of the Curve is its interior.
- 4) A Point does not have a boundary.

1.4 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.

1.5 General description

Since S-158 is a foundational specification on which specifications describing validation checks for S-100 and Product Specifications based on S-100 are based, there are no data products based directly on S-158 and therefore no general information applicable to data products conforming to it.

1.6 Specification metadata and maintenance

1.6.1 Specification metadata

This information uniquely identifies this Specification and provides information about its creation and maintenance.

Title: Validation Checks – Information and Structure

Version: 1.0.0

Date: February 2025

Language: English

Classification: Unclassified

Contact: International Hydrographic Organization.
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Role: Owner

URL: <https://registry.iho.int>

Identifier: S-158

Maintenance: Changes to this Specification are coordinated by the S-100 Working Group (S-100 WG) of the IHO and made available via the IHO Publications website. Maintenance of the Product Specification must conform to IHO Technical Resolution 2/2007 (revised 2010). For reporting issues which need correction, use the contact information.

1.6.2 Specification maintenance

1.6.2.1 Introduction

Changes to S-158 will be released by the IHO as a New Edition, revision, or clarification.

S-158 is a framework document describing the content and basis for derived specifications containing validation checks for S-100 level, cross product validation and for individual Product Specifications. The descriptions of new editions, revisions, and clarifications in this clause reflect its special role.

S-158 is not accompanied by separate artefacts such as an XML Schema, Feature or Portrayal Catalogue and therefore this clause does not address the question of changes to such derived artefacts.

1.6.2.2 New Edition

New Editions of S-158 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, or significant changes to the basic information or check structure required to be used by derived specifications. *New Editions* are likely to have a significant impact on either existing users or future users of S-158 and its derived specifications. All cumulative *revisions* and *clarifications* must be included with the release of approved New Editions.

1.6.2.3 Revision

Revisions are defined as substantive semantic changes to S-158. Typically, *revisions* will change S-158 to correct factual errors or 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-158 or its derived specifications. All cumulative *clarifications* must be included with the release of approved revisions.

Changes in a revision are minor and ensure backward compatibility of derived specifications with their previous versions within the same Edition. New revisions, for example, introduce new optional structural elements or additional recommendations for derived documents.

1.6.2.4 Clarification

Clarifications are non-substantive changes to S-158. Typically, *clarifications*: remove ambiguity; correct grammatical and spelling errors; amend or update cross references; and insert improved graphics. A *clarification* must not cause any substantive semantic change to S-158 or its derived specifications.

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

1.6.2.5 Version numbers

The associated version control numbering to identify changes (n) to S-158 must be as follows:

New Editions denoted as **n.0.0**

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

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

2 Structure of S-158 Publication Series

2.1 Overview of S-158 specification series

The S-158 series of publications defines checks for verifying the correctness, completeness and integrity of S-100-based datasets and exchange sets. It consists of the following:

1. A framework publication (S-158 – this document), which explains the roles of the different publications belonging to the S-158 series, defines a basic structure for specifying validation checks, and provides foundational material shared by publications specifying validation checks for different data products.
2. A specification (S-158:100) containing a set of common checks derived from the S-100 standard itself, defining a set of validation checks which are applicable to all S-100 based data products which conform to Product Specifications based on a particular version of the S-100 standard. (Not all checks will apply to every S-100 product, for example checks relating to the GML data format will not apply to data products like S-101 which use the ISO 8211 data format.) Generic checks for feature catalogues are defined in this document, except for product-specific checks deriving from constraints in individual Product Specifications
3. Specifications containing product-specific checks (designated S-158:1xx, where “1xx” denotes the data product according to the official number assigned by the IHO). Each S-158:1xx specification defines validation checks for verifying conformance to constraints defined in individual Product Specifications. For example, S-158:101 specifies validation checks for the S-101 (ENC) Product Specification.

The product-specific validation check specifications only contain checks that are not mandated by S-100, for example, checks that constrain application schemas and feature catalogues in ways not specified in S-100.

4. Interoperability and cross-product validation checks (S-158:98). These checks are derived from considerations for interoperability of different S-100 data products as described in S-98.

Each of the above specifications is a separate publication maintained by the appropriate responsible group. The S100WG maintains S-158 and S-158:100. Specifications for different S-1xx products are maintained by the 'owner groups' responsible for the corresponding Product Specification.

S-158 and the S-158:1xx publications are published separately by the IHO. Each publication has its own maintenance and update regime.

2.2 Specification title and cover page

The title of each S-158:1xx publication must be of the form: "S-158:1xx (Name of Product as in PS title) Validation Checks". It is not necessary that "(Name of Product)" replicate the entire title of the Product Specification – the name of the product suffices.

The cover page of each validation check publication corresponding to a Product Specification must contain the statement "Aligned to S-1xx Edition x.x.x".

2.3 Conformance statement

Each S-158:1xx specification must contain a conformance statement according to the template below (replacing "1.0.0" with the appropriate edition):

X.Y Conformance

This specification conforms to Edition 1.0.0 of IHO specification S-158 (Validation Checks – Introduction and Structure).

For Edition 1.0.0 of any S-158:1xx specification, and later editions preceding the first operational edition (which will normally be Edition 2.0.0) the following statement must also be included (replacing "1.0.0" with the appropriate edition):

Edition 1.0.0 is an Implementation version in accordance with IHO TR 2/2007 and there may be revisions issued by the Working Group prior to the Operational Edition 2.0.0 being published.

2.4 Specification maintenance

The S-158:1xx specifications must use the criteria for new editions, revisions, and clarifications described according to the template below. Additional product-specific details may be added where appropriate but the basic principles for classifying releases as new editions, revisions, and clarifications must be followed.

X.Y.Z Specification maintenance

X.Y.Z.1 Introduction

Changes to S-158:1xx will be released by the IHO as a New Edition, revision, or clarification.

The list of checks, which accompanies this document is considered part of this Specification and changes to it are considered changes to this Specification.

S-158:1xx is not accompanied by separate artefacts such as an XML Schema, Feature or Portrayal Catalogue and therefore this clause does not address the question of changes to such derived artefacts.

[OR]

S-158:1xx includes the following separate artifacts, which form an integrated part of the Specification.

- Artifact A (describe)
- Artifact B (describe)

X.Y.Z.2 New Edition

New Editions of S-158:1xx include at least one of the following changes:

- introduce a new validation check (of any classification);
- remove an existing validation check (of any classification);
- change the classification of a validation check, whether upgrade (such as Error to Critical) or downgrade (such as Error to Warning);
- extend a validation check to include new features, conditions, etc., in a way that requires validation software manufacturers to change their software;

New Editions are likely to require validation software manufacturers to change their software or invalidate datasets which passed validation according to the previous Edition of S-158:1xx.

All cumulative revisions and clarifications must be included with the release of approved New Editions.

X.Y.Z.3 Revision

Revisions are defined as substantive semantic changes to S-158:1xx. Typically, revisions will change S-158:1xx to correct factual errors or introduce necessary changes that have become evident as a result of practical experience or changing circumstances. Revisions include corrections of misinterpretations of S-100 or the relevant Product Specification, or extensions to checks that do not require changes to validation software..

A revision must not be classified as a clarification. All cumulative clarifications must be included with the release of approved revisions.

X.Y.Z.3 Clarification

Clarifications are changes to S-158:1xx arising from non-substantive reasons.

Typically clarifications for non-substantive reasons remove ambiguity; correct grammatical and spelling errors; amend or update cross references; revise check messages or clarify check descriptions without requiring manufacturers to change their software.

3 Check Structure

Validation checks are specified in a columnar format with at least the columns listed in Table 3-1. All S-158:... validation checks publications must include at least the columns specified in the table below. The columns must follow the order in Table 3-1. Additional columns may be added following these columns at the discretion of the responsible group or project team.

The first column in Table 3-1 also defines recommended XML tags for potential XML formulations of the validation checks.

Table 3-1 - Structure of checks

Column Name (Tag)	Description
Dev ID (Dev_ID)	Temporary number for checks under development. This column may be included for tracking of checks under development but should be deleted from finalized documents, when no longer required. May be structured as decided by the development team for the specification. Must consist only of alphanumeric characters in the ISO basic Latin alphabet, hyphen and underscore characters (A-Z, a-z, 0-9, - and _ characters). EXAMPLES: S101_Dev_0029, P1-4, 1, 100_Dev0001

Column Name (Tag)	Description
Check ID (Check_ID)	Identifier for check. Must be structured as 1XX_nnnn where “1XX” is the Product Specification number and “nnnn” a four digit number assigned by the development team for the specification. An optional single-letter lower-case alpha suffix in the range a-z may be added when a check is split into two or more checks. Check identifiers are unique and are not reused after a check is deleted, but may be re-introduced if the original check is revived either with or without modification EXAMPLES: 101_1005, 102_2012, 102_2012a
Classification (Classification)	Whether check failure is a critical, error, or warning issue. See clause 7
Check message (Check_Message)	Message to emit if the dataset or exchange set fails the check. This must be a message that provides the user with meaningful information.
Check description (Check_Description)	Check description written in a defined syntax (wherever feasible) as defined in this document (see clause 4).
Check solution (Check_Solution)	Suggested action to rectify a warning or error
Standards document reference (Document)	Reference to the S-100 standard or a Product Specification. Must include the Part, Annex or component, if any. EXAMPLES: S-100 Part 10a; S-101 PS; S-101 Annex A; S-129 DCEG
Clause reference (Reference)	The clause number in the cited document. If derived from a numbered table, the table number may be cited instead (with the “Table” prefix). Examples: 15.9.1; Table 10.2
Data quality measure (DQMeasure) Optional	Quality measure from the Data Quality clause of the PS or S-97 Part C if not identified in the PS. This column is optional. EXAMPLES: “Thematic accuracy”; “Logical consistency/Format consistency”
Introduced (Introduced)	The earliest edition of the cited standard or PS from which the check is derived.
Modified (Modified)	The latest edition of the cited standard or PS in which the requirement or recommendation on which the check is based was modified. Empty if no modifications.
Deleted (Deleted)	The earliest edition of the cited standard or PS in which the requirement or recommendation on which the check is based was removed or modified so as to no longer require the check. Empty if the check is still applicable.

The columnar structure is designed to be “machine-readable” in the limited sense that it can be automatically transformed into other formats which distinguish between the elements of the validation checks set forth in Table 3-1. Note that a such transformation would require pre- or post-processing to restructure or rearrange multiple “Document/Reference” entries or combinations applying to the same

validation check to produce correct results in the transformed artifact (for example, an XML document conforming to an XML schema or DTD devised by the implementer).

4 Check Syntax

In order to ensure that checks can be interpreted clearly and consistently a defined syntax must be used wherever possible.

4.1 Syntax for generic S-100 checks

Generic checks (S-158:100) have their descriptions stated in one of two ways:

- 1) As either positive requirements (“must”, “shall”) or negative requirements (“must not”, “shall not”, etc.) which must be satisfied by the subject of the test; that is, the check generates a Critical Error, Error, or Warning if the statement in the check description is not satisfied by the dataset or exchange set.
- 2) As non-imperative conditions (“For each X where Y”; “IF P and Q...”) where the check is triggered if the condition is satisfied.

The syntax of S-100 checks is explained in S-158:100.

4.2 Syntax for product-specific checks

Each check is a statement which generates a Critical Error, Error or Warning if the condition described in the check description returns ‘true’.

In the example below the check would return true and give an error for each **Building** feature instance that is in or overlaps a **DepthArea** or **UnsurveyedArea** feature instance and which does not have the attribute *inTheWater=true*.

Table 4-1 - Example of check syntax

Check message	Check description	Check solution
Building over navigable water does not have attribute in the water equal to TRUE.	For each Building feature object which OVERLAPS OR is COVERED_BY a DepthArea or UnsurveyedArea feature object and the attribute inTheWater is Not equal to TRUE.	Set attribute inTheWater = TRUE

The elements of the syntax are defined next.

4.2.1 Comparison and Logical Operators

The following comparison and logical operators are used:

1. Equal
2. Not equal
3. Less than
4. Less than or equal to
5. Greater than

6. Greater than or equal to
7. AND
8. OR (inclusive OR)

4.2.2 Spatial Operators

Within this document the spatial operators (EQUALS, DISJOINT, TOUCHES, WITHIN, OVERLAPS, CROSSES, INTERSECTS, CONTAINS, and COINCIDENT), based on those laid out in the ISO standard 19125-1, are used to describe spatial relationships tested within the checks. They are described in clause 8.

For all spatial operators a default tolerance specified in the S-158:1xx document should be applied in validation software.

4.2.3 Values

The following terms are used for types of values:

1. Present – The attribute is present and may or may not be populated with a value.
2. Known – The attribute is Present and has been populated with a value.
3. Unknown – The attribute is Present, but has not been populated with a value.
4. Optional – The encoding of the attribute is optional. It may be Present or not Present.

The following terms may be used to combine the above terms for brevity:

1. Missing: The attribute is either not present, or present and either null or nilled (cf. clause 4.2.3.2)
2. Populated: The attribute is present and has been assigned a value conforming to its datatype.

4.2.3.1 Conventions for value descriptors in Part 10a formats

The following terms are used in relation to ISO 8211 unsigned 8-bit integer sub-fields (i.e., datasets using the S-100 Part 10a data format).

1. Null – The sub-field has a value of null (255).
2. notNull – The sub-field value is not Null.

Note that in the ISO 8211 format, “unknown” is distinguished from “Null”. “Unknown” values for thematic attributes are represented by the empty string (S-100 10a-5.1.3).

4.2.3.2 Conventions for value descriptors in exchange catalogues and Part 10b (GML) formats

The following terms are used in relation to XML element content or for values of instance attributes in datasets (thus applying to both Part 10b GML data formats and Part 17 exchange catalogues):

1. Whitespace: One or more of the characters defined as white space in the W3C XML specification: space, tab, carriage return or line feed.
2. Null: The XML element or XML attribute has no content or value, or the content/value is the empty (0-length) string.
 1. String type attributes consisting of only whitespace characters are not considered to be empty.
 2. URI, URL, or URN type attributes consisting of only whitespace characters are considered to be empty.
 3. Numeric, enumeration, date, time, dateTime, or Boolean types consisting of only whitespace characters are considered to be empty. This situation is an error (unless the attribute is declared nillable in the GML application schema). Such errors should be detected by XML validation software when the file is validated against its XML schema.

3. Nilled: The XML element has no content and the element has the XML attribute `xsi:nil="true"`. A nillable attribute is one which the GML application schema or GML profile allows to be nilled.
4. notNull: The XML element content or XML attribute value is not Whitespace or Null.

4.2.3.3 Conventions for value descriptors in Part 10c (HDF5) formats

HDF5 array elements (used for coverage data in S-100 coverage products) use “fill values” when the value is unknown or missing. Fill values are values conforming to the basic datatype but specially designated as signifying “no data”. Product Specifications using the HDF5 format define the fill values for attributes. Different attributes may have different fill values.

S-158:1xx publications for data products using the S-100 Part 10c format use the following conventions:

1. Null: The value of the field is the designated fill value, or null/empty if allowed by the datatype
2. notNull: The value of the field is not Null and is not equal to the fill value designated for the field in the Product Specification.

4.2.4 Statements

The checks must be structured using the following statements:

1. If – A conditional statement which determines whether a further statement should be executed.
2. For – Repeat a statement until a statement is met (evaluates to “true”). For the purposes of the checks the statement being met generates the error or warning specified.

Conditions beginning with “For each <item>...” are applied to every instance of the designated item. Items may be features, information type, attributes, associations, roles, etc. Box brackets are used for grouping phrases where the interpretation may be ambiguous (for example, “X AND [Y OR Z]”).

5 Outline of Validation

Validation consists of the following discrete groups of activities.

- Intra-dataset validation – validation checks to ensure a dataset is intrinsically valid. Validation for this group of activities consists of checking datasets in isolation.
- Inter-dataset, intra-product validation – checks to ensure the dataset validates against those it spatially intersects, touches or joins with. Validation for this group of activities consists of checking datasets against other datasets for the same data product.
- Inter-product validation – checks to ensure the dataset is compatible with other products. Validation for this group of activities will compare datasets from different data products.
- Package validation – checks to ensure the packaging is consistent with the dataset. This group of activities checks the structure and integrity of exchange sets and discovery metadata in CATALOG.XML files.

In addition, the contents of product catalogue datasets – specifically, S-128 (Catalogue of Nautical Products) datasets must match the datasets they describe.

Figure 5-1 depicts the validation activities as connections between data product components and the specification or product components against which they are validated. Specifications are depicted in red; data product components in black. The validation activities are labelled with lower-case letters, and described in Table 5-1. The S-100 feature catalogue and portrayal schemas, portrayal specification, S-98 interoperability, user experience guidelines and data management influence validation checks indirectly, via requirements which are captured in different components of the Product Specifications (feature catalogue, DCEG, and portrayal catalogue).

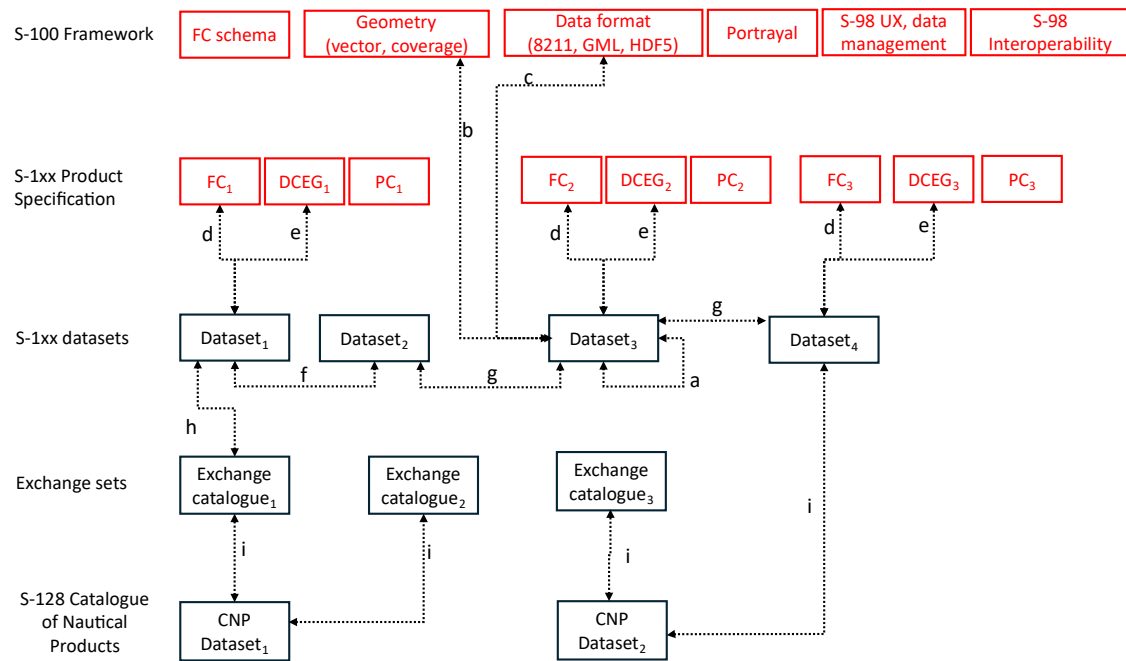


Figure 5-1 - Outline of Validation

Table 5-1 - Validation activities

Validation Activity	Thing Validated	Controlling Specification or Artifact	Validator(s)	Examples
a	Dataset in isolation	S-1xx PS S-100 generic structuring in Parts 10a, 10b, 10c (e.g., 10a-4-7)	dataset producer	Non-conformant file names, incorrect ordering of features
b	Dataset in isolation	S-100 Part 7 S-100 Part 10c	dataset producer	Things which contravene the geometry model, e.g., CCW exterior rings, unused curves
c	Dataset in isolation	S-100 Data Format (Parts 10a, 10b, 10c)	dataset producer	Formatting problems with encodings, non-conformant GML, incorrect HDF5 group names, incorrectly formatted attributes (e.g., dates, Booleans, unknowns)
d	Dataset in isolation	S-1xx feature catalogue	dataset producer	Presence of attributes or features not defined in the FC, missing mandatory attributes
e	Dataset in isolation	S-1xx DCEG	dataset producer	Bad combination of attributes
f	Dataset against other datasets for same product	S-1xx PS	dataset producer, aggregator	Horizontal/vertical datum consistency, excessive overlap

Validation Activity	Thing Validated	Controlling Specification or Artifact	Validator(s)	Examples
g	Datasets for different products	S-98	dataset producer, aggregator, application	Vertical datum compatibility between S-101, S-102, S-104 and S-129; ENC land area features partially of wholly obscured by S-102 data
h	Exchange catalogue, exchange set structure, signatures	S-100 Part 17, S-100 Part 15	dataset producer, aggregator, application	Bad digital signatures, extent of dataset does not match bounding box or data coverage in exchange catalogue discovery metadata, incorrect encoding or mismatch of producer code, missing support files, mis-located files in exchange set
i	Corresponding S-128 dataset	S-128	distributor, aggregator, producer of CNP dataset	Mismatch of coverage or dataset name.

6 Check Application Sequence

A dataset is validated using generic checks derived from S-100, product-specific checks derived from the relevant Product Specification, and interoperability checks derived from the interoperability specification S-98. Further, after datasets which pass validation are packaged into exchange sets, the structure of the exchange sets, accompanying metadata, and signatures must also be validated. The following sequence of validation checks is therefore suggested:

Table 6-1 - Suggested application order of validation checks

Order	Check Collection	Defined in	Apply to
1	S-100 generic checks for datasets	S-158:100	Dataset, in isolation
2	Product-specific checks for datasets	S-158:1xx	Dataset, in isolation
3	Interoperability checks for single S-1xx dataset	S-158:98	Dataset, in isolation
4	Inter-dataset, intra-product checks	S-158:1xx	Adjacent or intersecting datasets for the same data product
5	Inter-version checks(?)	S-158:1xx	Related datasets for different versions of the same Product Specification
6	Interoperability checks for combinations of datasets from different products	S-158:98	Dataset in combination with relevant datasets from other products
7	S-100 generic checks for exchange sets	S-158:100	Exchange set
8	Product-specific checks for exchange sets	S-158:1xx	Exchange set
9	Product catalogue checks	S-158:128	S-128 datasets with other S-1xx products

S-158:1xx publications may recommend a check application order for different subsets of product-specific checks. Developers of validation software may use a different check application order.

7 Check Classification

All S-158:1xx specifications must use the check classifications and minimum check standard described in this clause. Specifications need not reproduce this clause but must include a statement that this classification and minimum standard described here apply to the checks defined in the S-158:1xx specification.

The check classification is intended to ensure that published data products are free of errors which would affect their use in an end-user system such as ECDIS. In some cases it may be necessary to diverge from the strength of wording used in the S-100 Universal Hydrographic Data Model or its derived Product Specifications. In such cases the impact on the user should be the overriding factor for consideration. The classifications have the following meanings:

Table 7-1 - Classification of checks

Indicator	Type	Description
C	Critical Error	An error which would make an S-100 based dataset or exchange set unusable in the end-user system through not loading; or causing an end-user system to crash; or presenting data which is unsafe or unintelligible for the intended purpose of the product, for example navigation.
E	Error	An error which may degrade the quality of the S-100 based dataset or exchange set through appearance or usability but which will not pose a significant danger when used to support the intended purpose of the product.
W	Warning	An error which may be duplication or an inconsistency which will not noticeably degrade the usability of the S-100 based dataset or exchange set in the end-user system.

At a minimum validation software must group validation reports using these categories. They may also support sub-grouping of related checks such as those relating to geometric validity or attribute consistency. Software may allow checks of type Error or Warning to be deselected completely or by such categories.

7.1 Minimum check standard

The critical checks included in S-158:100 and associated S-158:1xx constitute the minimum check standard for S-100 based data products. All published S-100 based data products must conform to the checks classified as Critical within these documents.

8 Geometry and Spatial Operators in Checks for Vector Products

8.1 Definitions for ISO 19125-1:2004 Geometry

This Section defines ISO 19125-1:2004 geometric terms used in this document.

Note that these definitions are for the primitives defined by ISO 19125-1:2004 which are single Point, single Line and single Area geometry objects.

- *Polygon* – A Polygon has a geometric dimension of 2. It consists of a boundary and its interior, not just a boundary on its own. It is a simple planar surface defined by 1 exterior boundary and 0 or more interior boundaries. The geometry used by an Area feature is equivalent to a Polygon. The ISO 19125-1 Polygon corresponds to the S-100 *surface* spatial primitive type in S-100 feature catalogues.

- *Polygon boundary* – A Polygon boundary has a geometric dimension of 1 and is equivalent to the outer and inner rings used by an S-100 Area feature.
- *LineString* – A LineString is a Curve with linear interpolation between Points. A LineString has a geometric dimension of 1. It is composed of one or more segments – each segment is defined by a pair of points. The geometry used by an S-100 Curve feature is equivalent to a LineString.
- *Line* - An ISO 19125-1:2004 line is a LineString with exactly 2 points. Note that the geometry used by an S-100 Curve feature is equivalent to a LineString, not a line in ISO 19125-1:2004 terms. In this document the term Line refers to an S-100 Curve feature or a LineString which can have more than two points.
- *Point* – Points have a geometric dimension of 0. The geometry used by an S-100 Point feature is equivalent to an ISO 19125-1:2004 point.
- *Reciprocal* – inversely related or opposite.

The following table matches 19125-1:2004 geometric terms to S-100 geometry terms:

ISO 19125-1:2004	S-100 dataset
Polygon	Area feature geometry OR Surface
Polygon boundary	Exterior and interior boundaries
LineString	Curve OR Composite Curve
Point	Point feature geometry

8.2 ISO 19125-1:2004 Geometric Operator Relationships

For symbols used in the relationships, see clause 1.3.3 (Symbols).

In ISO 19125-1:2004, the dimensionally extended nine-intersection model (DE-9IM) defines 5 mutually exclusive geometric relationships between two objects (Polygons, LineStrings and/or Points). One and only one relationship will be true for any two given objects (see CLE93):

1. WITHIN
2. CROSSES
3. TOUCHES
4. DISJOINT
5. OVERLAPS

There are others that help further define the relationship:

6. CONTAINS
 - the reciprocal of WITHIN
 - within is the primary operator; however, if **a** is not within **b** then **a** may contain **b** so CONTAINS may be the unique relationship between the objects
7. EQUALS
 - a special case of WITHIN / CONTAINS
8. INTERSECTS
 - reciprocal of DISJOINT
 - have at least one point in common
9. COVERS and is COVERED_BY
 - reciprocal operators
 - extends CONTAINS and WITHIN respectively
10. COINCIDENT

Note that COVERS, COVERED_BY and COINCIDENT relational operators are not described in the ISO 19125-1:2004 document.

The formulas given in this Section (for example $a.\text{Disjoint}(b) \Leftrightarrow a \cap b = \emptyset$) are the generalized ones given for ISO 19125-1:2004, not the more specific DE-9IM formulas (that is, DE-9IM predicates). The generalized formulas use topologically closed notation (that is, geometry includes the interior and boundary unless otherwise stated), whereas the DE-9IM formulas refer to the interior and boundary of geometry separately. Note that different versions of documents describing ISO 19125-1 give different generalized formulas – this Section is using the formulas that are the most consistent with the DE-9IM predicates. If a generalized formula appears to contradict a DE-9IM predicate as defined in ISO 19125-1:2004, the DE-9IM predicate takes precedence. Software is expected to be consistent with DE-9IM predicates.

8.3 How the Relationships Apply to S-100 Feature Geometry

Geometric relationships will be tested on an entire feature object as a single geometric entity. Note that Point, Curve and Area feature geometry is equivalent in ISO 19125-1:2004 terms to Point, LineString and Polygon geometry respectively.

A Curve feature in S-100 datasets may be made up of several individual curves. The geometric relationship operators used with a curve feature will consider the sequence of edges as a single geometry (LineString).

A test on an Area feature will operate on the entire Polygon (Surface).

In an S-100 dataset a Curve or Surface feature may be split into pieces as a result of a cutting operation from a data source. In that case each feature record in the dataset is treated as a separate Curve (LineString) or Surface (Polygon) when testing geometric relationships.

If a test intends to operate only on a feature's specific components (Polygon boundary (all rings), Polygon outer ring, Polygon inner rings, edges, vertexes or nodes) then it must make this explicit in the description of the test. When a specific linear portion is specified in a test (Polygon boundary, edge) then it is treated as a Curve while individual vertexes or points will be treated as points.

For example a test to look for cases where object class A OVERLAPS object class B would operate on the entire geometry. While a test to see if boundary of Area object class A OVERLAPS an edge of Line class B will be comparing Area boundaries to edges using Line to Line comparisons.

8.4 Geometric Operator Definitions

The ISO 19125-1:2004 definitions referenced in this section, refer to section 6.1.14.3 entitled “Named spatial relationship predicates based on the DE-9IM” in the ISO 19125-1:2004 document.

(In the diagrams within this Section LineString corresponds to the S-100 *curve* spatial primitive.)

EQUALS – Geometric object **a** is spatially equal to geometric object **b**.

The two geometric objects are the same. This is a special case of WITHIN.



Figure 8-1 - Examples of the Equals relationship

Note: ISO 19107:2003 describes equality more formally as:

Two different GM_Objects are equal if they return the same Boolean value for the operation `GM_Object::contains` for every tested DirectPosition within the valid range of the coordinate reference system associated to the object.

NOTE: Since an infinite set of direct positions cannot be tested, the internal implementation of equal must test for equivalence between two, possibly quite different,

representations. This test may be limited to the resolution of the coordinate system or the accuracy of the data. Application schemas may define a tolerance that returns true if the two GM_Objects have the same dimension and each direct position in this GM_Object is within a tolerance distance of a direct position in the passed GM_Object and vice versa.

For the purposes of geometric operators in S-158, a GM_Object is any vector spatial object as described in S-100 Part 7 (Polygons, Curves, and Points – coverages and multipoints are not considered for the purposes of these geometric operators). A spatial object is always equal to itself; that is, **a EQUALS a** is always true.

DISJOINT – Geometric object **a** and geometric object **b** do not intersect.

The two geometric objects have no common points.

The ISO 19125-1:2004 definition of DISJOINT is:

$$a.Disjoint(b) \Leftrightarrow a \cap b = \emptyset$$

This translates to: **a** is disjoint from **b** if the intersection of **a** and **b** is the empty set.

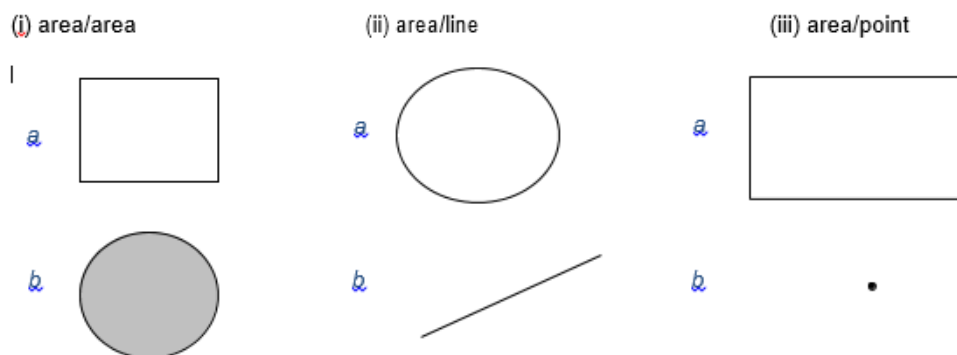


Figure 8-2 - Examples of the DISJOINT relationship

TOUCHES – Geometric object **a** intersects with geometric object **b** but they do not share interior points.

Only the boundary of one geometry intersects with the boundary of another geometry.

The only thing the geometric objects have in common is contained in the union of their boundaries.

The ISO 19125-1:2004 definition of TOUCHES is:

$$a.Touch(b) \Leftrightarrow (I(a) \cap I(b) = \emptyset) \wedge (a \cap b) \neq \emptyset$$

This translates to: **a** touches **b** if the intersection of the interior of **a** and the interior of **b** is the empty set AND the intersection of **a** and **b** is not the empty set.

Note: This operator applies to the Area/Area, Line/Line, Line/Area, Point/Area and Point/Line relationships. It does not apply to a Point/Point relationship since points do not have a boundary.

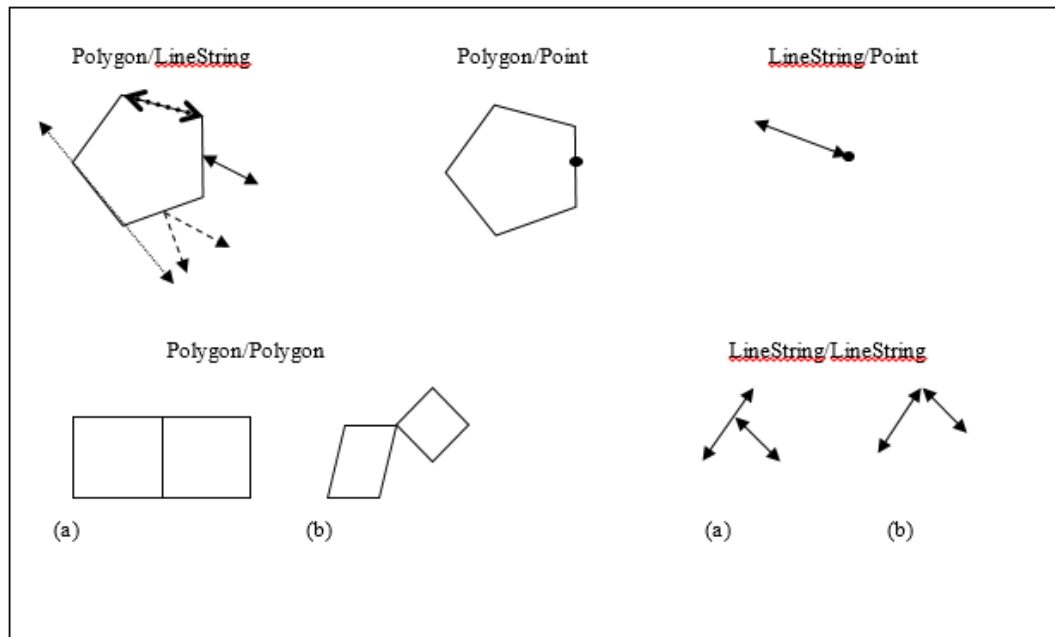


Figure 8-3 - Examples of the TOUCHES relationship

Note the Polygon touches Polygon example (a) is also a case where the Polygon boundaries are COINCIDENT. In the Polygon/LineString example two of the LineStrings that share a linear portion of the Polygon boundary are also COINCIDENT with the Polygon boundary.

WITHIN – Geometric object **a** is completely contained in geometric object **b**.

WITHIN includes EQUALS.

The definition of WITHIN is:

$$\mathbf{a} \text{ Within}(\mathbf{b}) \Leftrightarrow (\mathbf{a} \cap \mathbf{b} = \mathbf{a}) \wedge (I(\mathbf{a}) \cap I(\mathbf{b}) \neq \emptyset)$$

This translates to: **a** is within **b** if the intersection of **a** and **b** equals **a** AND the intersection of the interior of **a** and the interior of **b** is not the empty set.

Note that this formula matches the one given in the **OpenGIS Simple Features Specification for SQL, Revision 1.1 (OpenGIS Project Document 99-049, Release Date: May 5, 1999)** which is the precursor to ISO 19125-1:2004.

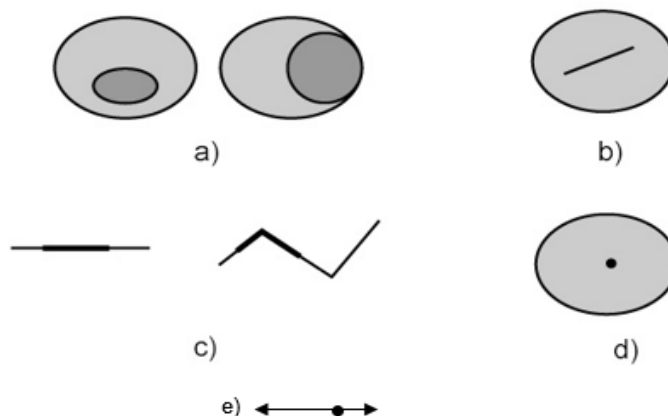


Figure 8-4 - Examples of the WITHIN relationship – Polygon/Polygon (a), Polygon/LineString (b), LineString/LineString (c), Polygon/Point (d), and LineString/Point (e)

Note that a Line that completely falls on a Polygon boundary is not WITHIN the Polygon, it TOUCHES it. In that case it would also be COINCIDENT with the Polygon boundary and COVERED_BY the Polygon.

OVERLAPS - The intersection of two geometric objects with the same dimension results in an object of the same dimension but is different from both of them.

For two Polygons or two LineStrings, part of each geometry, but not all, is shared with the other.

The OVERLAPS relationship is defined for Area/Area and Line/Line relationships. Points are either equal or disjoint.

Note that this does not include lines that cross.

The ISO 19125-1:2004 definition of OVERLAPS is:

$$a.\text{Overlaps}(b) \Leftrightarrow (\dim(I(a)) = \dim(I(b)) = \dim(I(a) \cap I(b))) \wedge (a \cap b \neq a) \wedge (a \cap b \neq b)$$

This translates to: **a** overlaps **b** if the geometric dimension of:

- (1) the interior of **a**
 - (2) the interior of **b**
 - (3) the intersection of the interiors of **a** and **b**
- are all equal AND the intersection of **a** and **b** does not equal either **a** or **b**.



Figure 8-5 - Examples of the OVERLAPS relationship

Note Lines that OVERLAP are also COINCIDENT.

CROSSES – The intersection of geometric object **a** and geometric object **b** returns geometry with a dimension less than the largest dimension between **a** and **b** but is not the same as geometric object **a** or **b**.

Two LineStrings cross each other if they meet on an interior point. A LineString crosses a Polygon if the LineString is partly inside the Polygon and partly outside.

The definition of CROSSES is:

$$a.\text{Cross}(b) \Leftrightarrow (I(a) \cap I(b) \neq \emptyset) \wedge (\dim(I(a) \cap I(b)) < \max(\dim(I(a)), \dim(I(b)))) \wedge (a \cap b \neq a) \wedge (a \cap b \neq b)$$

This translates to: **a** crosses **b** if the intersection of the interiors of **a** and **b** is not the empty set AND the dimension of the result of the intersection of the interiors of **a** and **b** is less than the largest dimension between the interiors of **a** and **b** AND the intersection of **a** and **b** does not equal either **a** or **b**.

Note that “ $(I(a) \cap I(b) \neq \emptyset) \wedge$ ” was added to the beginning of the ISO 19125-1:2004 formula so that it would not be true for disjoint geometry.

The CROSSES operator only applies to Line/Line and Line/Area relationships.

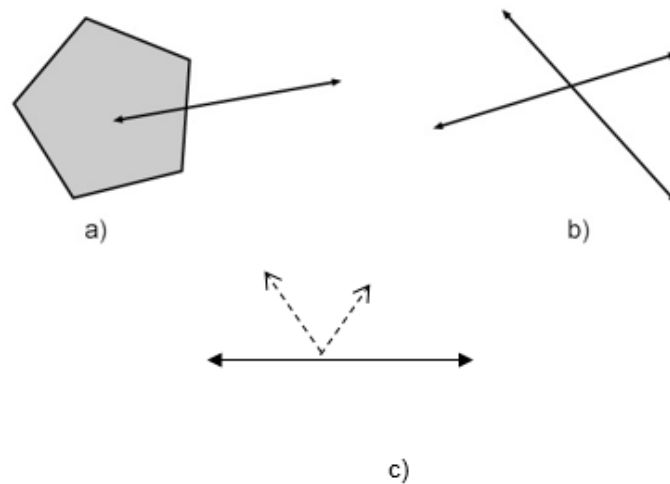


Figure 8-6 - Examples of the CROSSES relationship

Note that example c) shows one solid line and one dashed line – their interiors intersect. If any Line were split into two separate Line features at the intersection point then the relationship would be TOUCHES because a boundary would be involved.

INTERSECTS is the reciprocal of DISJOINT.

The two geometric objects cross, overlap or touch, or one is within (or is contained by) the other. They have at least one common point.

CONTAINS is the reciprocal of WITHIN.

*Given two geometric objects, **a** and **b**, if **a** is within **b** then **b** must contain **a**.*

COVERED_BY (not a standard ISO 19125-1:2004 operator)

No point of geometry **a** is outside geometry **b**.

The definition of COVERED_BY is:

$$\mathbf{a. \text{ Covered_by } (b) \Leftrightarrow (a \cap b = a)}$$

This translates to: **a** is covered_by **b** if the intersection of **a** and **b** equals **a**.

The following expressions are equivalent to **a** is COVERED_BY **b**:

1. Polygon (**a**) is COVERED_BY Polygon (**b**): Polygon **a** is WITHIN a polygon **b** (WITHIN includes EQUALS)
2. Point (**a**) is COVERED_BY Polygon (**b**): Point **a** is WITHIN or TOUCHES polygon **b**
3. Line (**a**) is COVERED_BY Polygon (**b**): Line **a** is WITHIN polygon **b** or WITHIN the boundary of Polygon **b**
4. Line (**a**) is COVERED_BY Line (**b**): Line **a** is WITHIN Line **b** (WITHIN includes EQUALS)
5. Point (**a**) is COVERED_BY Line (**b**): Point **a** is WITHIN or TOUCHES Line **b**
6. Point (**a**) is COVERED_BY Point (**b**): Point **a** EQUALS Point **b**

Note that the figure below on the left is an example of Lines that are COVERED_BY a polygon.

The figure on the right is not an example of a Line that is covered by a Polygon – it is an example of a Line that TOUCHES a Polygon. In both cases the Lines are COINCIDENT with the Polygon boundary.

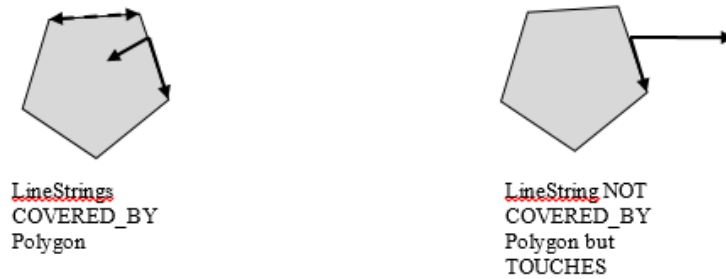


Figure 8-7 - Example and counterexample of the COVERED_BY relationship

COVERS (not a standard ISO 19125-1:2004 operator)

COVERS is the reciprocal of COVERED_BY.

*Given two geometric objects, **a** and **b**, if **a** is COVERED_BY **b** then **b** must cover **a**.*

COINCIDENT (not an ISO 19125-1:2004 operator)

Two geometric Lines OVERLAP or one geometric Line is WITHIN the other. Note that EQUAL Lines are also COINCIDENT by this definition.

The intersection of two geometric Lines results in one or more Lines.

This operator is only to be used to compare a Line with another Line. Note that normally the boundary of a Polygon is not the same as a Line but for this operation the boundary of a Polygon, exterior and interior rings, is treated as Lines for the COINCIDENT test.

The following expressions are equivalent to **a** is COINCIDENT with **b**:

1. Polygon (**a**) is COINCIDENT with Polygon (**b**): The boundary of Polygon **a** OVERLAPS or is WITHIN the boundary of Polygon **b**.
2. Line (**a**) is COINCIDENT WITH Polygon (**b**): Line **a** OVERLAPS or is WITHIN the boundary of Polygon **b**.
3. Line (**a**) is COINCIDENT WITH Line (**b**): Line **a** OVERLAPS or is WITHIN Line **b**.

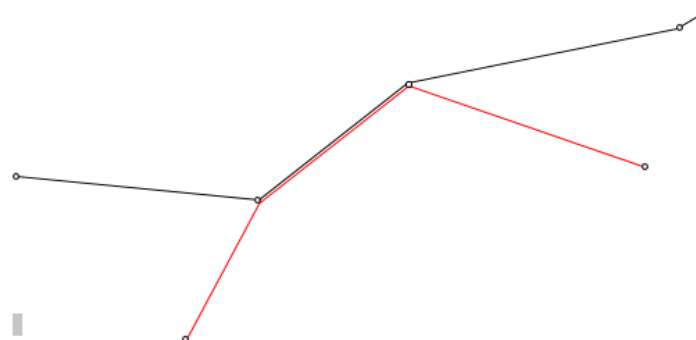


Figure 8-8 - Example of the COINCIDENT relationship

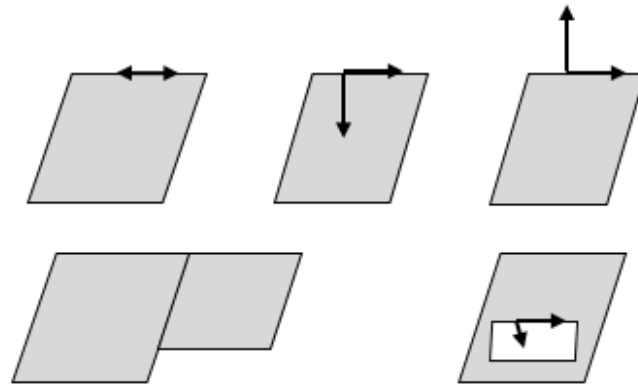


Figure 8-9 - Additional examples of COINCIDENT objects

Above are other examples of objects COINCIDENT with the boundary of a Polygon. LineStrings following a portion of a Polygon boundary or Polygons sharing a boundary portion.

Note that by definition a Line can be COINCIDENT with an interior boundary of a Polygon.

Note that other relationships may also be true such as COVERED_BY or TOUCHES since COINCIDENT is not mutually exclusive.