INTERNATIONAL STANDARD

ISO 28258

First edition
2013-10-01

Soil quality — Digital exchange of soil-related data

Qualité du sol — Échange numérique de données relatives au sol

Reference number
ISO 28258:2013(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 1, *Evaluation of criteria, terminology and codification*.

Introduction

Concerns about the future of soils are increasing. The quality of soils and the needs for soil protection are an issue of ever-increasing importance, in all countries. Whether it be for matters of land development, recycling of waste, for assessing the consequences of the way of use of soils on the quality of water or, more generally, the maintaining of their ability to guarantee the functions expected of them by society, it is becoming more and more necessary to know soils, to describe them and to analyse them. A large number of standards indicate how to carry out these descriptions and analyses. However, soil-related studies are usually conducted by specialized departments and their results have then to be forwarded to the requesting parties or to the administration. Furthermore, as regards the availability of environmental data for the public, the official services are solicited to put them online, including information related to soils.

Soil data are produced during projects which involve the description of soil and — often, but not necessarily — sampling and analysis. Soil properties are estimated for parts of a soil, which can be genetic horizons or depth classes. This vertical sequence composes a soil profile. The intensity of soil description, sampling and analysis varies greatly among projects. In addition, available metadata, sampling and analytical designs and nomenclatures vary as well.

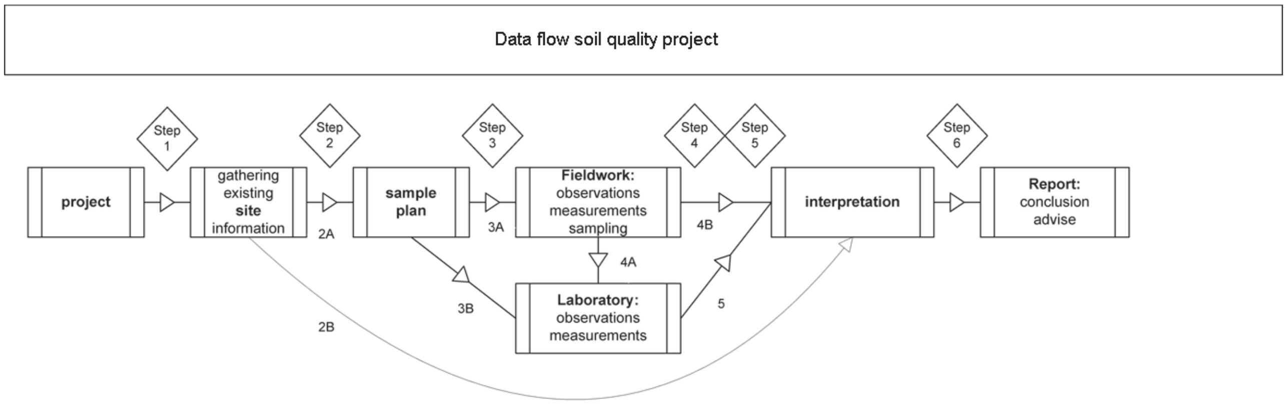
Due to this wide diversity of data and uses, the hardcopy (paper) form is nowadays rarely suitable, particularly when we consider that soil studies do not generally constitute an end in themselves but are only a part of the data required for the taking of land developmental or environmental-related decisions. Thus, soil data need to be crossed with other environmental, land-use or statistical data sources; the use of geographical information systems (GIS) is therefore essential. The purpose of this International Standard is to provide a general procedure to record all kinds of soil-related data in order to exchange them, while being consistent with relevant International Standards, but without any prerequisite for a given information system.

This International Standard proposes an eXtensible Markup Language (XML)-based format. XML consists of a set of rules for encoding information which is platform- and software-independent. A major advantage of using XML is that it is the standard for data transfer over the Internet. Most existing software tools and programming interfaces are designed to process and query XML files, to transform XML

into other data formats for further processing or display, and to transform XML to/from relational databases, whatever the purpose and the needs of the users. Moreover, a specific form of XML called GML is used for geographic information, promoting its exchange and use in combination with other environmental data.

Consequently, this International Standard contains information on how to encode soil data (metadata, soil description as well as geographic and temporal ones), including specifications and XML codes. In addition, and to make this International Standard "future-proof" between revisions, guidelines are provided for encoding of additional information not yet considered. These basic principles allow also the recipient system/user to read and/or decode information provided in a clear, safe and retrievable manner.

Figure 1 shows the fluxes of soil data, generic to many kinds of applications that can be organized using this International Standard.



Data exchange can be analog or digital, in maps, documents or raw data.

The boxes represent soil quality activities.
The arrows represent data exchange steps between the activities.
The figure shows that in an avarage soil quality project there might easily be 9 main stages where data is exchanged or stored.

Figure 1 — Common data exchanges in soil quality

Soil quality — Digital exchange of soil-related data

1 Scope

This International Standard describes how to digitally exchange soil-related data. It aims to facilitate the exchange of valid, clearly described and specified soil-related data between individuals and organizations via digital systems, and enables any soil data producer, holder or user to find and transfer data in an unambiguous way.

This International Standard contains definitions of features, several parameter specifications and encoding rules that allow consistent and retrievable data exchange. It also allows the explicit geo-referencing of soil data by building on other International Standards, thus facilitating the use of soil data within geographical information systems (GIS). Because soil data are of various origins and are obtained according to a huge variety of description and classification systems, this International Standard provides no attribute catalogue, but a flexible approach to the unified encoding of soil data by implementing the provisions of ISO 19156 observations and measurements (OM) for use in soil science.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11074, *Soil quality — Vocabulary*

ISO 15903, *Soil quality — Format for recording soil and site information*

ISO 19106:2004, *Geographic information — Profiles*

ISO 19109, *Geographic information — Rules for application schema*

ISO 19118, *Geographic information — Encoding*

ISO 19136, *Geographic information — Geography Markup Language (GML)*

ISO 19156:2011, *Geographic information — Observations and measurements*

ISO 25177:2008, *Soil quality — Field soil description*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11074 and in ISO 19109, and the following, apply.

3.1
analysis
process by which a sample is tested for composition or state according to a described procedure

Note 1 to entry: Most analyses are carried out on dislocated samples, but analyses can also be carried out on material *in situ*.

3.2
analytical result
qualitative or quantitative characteristic of a material obtained by an analysis

3.3
application schema
conceptual schema for data required by one or more applications

[SOURCE: ISO 19101.]

3.4
attribute
characteristic of a feature

Note 1 to entry: Objects and entities (see ISO 11179) are features in the context of this International Standard.

3.5
borehole
boring
bore
penetration into the subsurface with removal of soil/rock material by using, e.g. a hollow tube-shaped tool

Note 1 to entry: Generally, it is a vertical penetration.

[SOURCE: ISO 11074.]

3.6
class
description of a set of objects that share the same attributes, operations, methods, relationships, and semantics

[SOURCE: ISO/IEC 19501.]

3.7
code
member of a code list

3.8
code list
defined set of valid values of an attribute parameter

3.9
data model
description of the organization of data in a manner that reflects an information structure

3.10
extensible mark-up language
XML
subset of SGML (standard generalized markup language) which uses semantic tags in a structured format

Note 1 to entry: SML offers a flexible way to create information formats and to share both data and metadata with other applications and users.

Note 2 to entry: See ISO 13374-2.

3.11
feature
abstraction of a real world phenomenon

[SOURCE: ISO 19101.]

Note 1 to entry: A feature has identity and properties (it can be described with attributes).

Note 2 to entry: Any feature is an instantiation of a feature type, e.g. several described real-world soil profiles are all features of the feature type SoilProfile.

3.12
feature catalogue
catalogue(s) containing definitions and descriptions of feature types

3.13
feature type
class of features having common characteristics

[SOURCE: ISO 19156.]

Note 1 to entry: For this International Standard, it is considered that both geographic and soil quality related real-world and abstract objects can be features.

3.14
geography markup language
GML
XML encoding in compliance with ISO 19118 and, more specifically, ISO 19136 for the transport and storage of geographic information modelled according to the conceptual modelling framework used in the ISO 19100 family of International Standards and including both the spatial and non-spatial properties of geographic features

3.15
horizon
domain of a soil with a certain vertical extension, which is more or less parallel to the surface and is homogeneous for most morphological and analytical characteristics, developed in a parent material through pedogenic processes or made up of *in situ* sedimented organic residues of up-growing plants (peat)

3.16
layer
domain of a soil with a certain vertical extension developed through non-pedogenic processes, displaying an unconformity to possibly over- or underlying adjacent domains

Note 1 to entry: In the framework of soils deeply modified by human activity, artificial layers may be due to different kinds of deposits (concrete, bricks, etc.).

Note 2 to entry: Layers may be part of a horizon.

3.17
metadata
data that defines and describes other data

[SOURCE: ISO/IEC 11179-1:2004]

Note 1 to entry: Metadata are data, and data become metadata when they are used as defined. This happens under particular circumstances, for particular purposes, and with certain perspectives. The set of circumstances, purposes or perspectives for which some data are used as metadata is called the *context* (see ISO/IEC 11179-1).

Note 2 to entry: In turn, some metadata may provide the context for the interpretation of the data they are related to, e.g. units of measurement give an idea how to interpret the measurement value.

Note 3 to entry: This definition is similar to that of “data about data”, as defined in ISO 19115, among other International Standards.

3.18
non-destructive investigation
application of a set of procedures or techniques to obtain observations on a material without lastingly changing its physical structure and chemical characteristics

3.19
observation
act of observing a property, with the goal of producing an estimate of the value of the property

Note 1 to entry: This definition is conformant with the definition of *observation* in ISO 19156.

3.20
plot
elementary area where individual observations are made and/or samples are taken

Note 1 to entry: All types of plots only provide locality, but not soil information itself. For example, a borehole is the location where you gather the information to abstract a profile information from.

3.21
profile element
general term for both horizons and layers

3.22
project
unique process, consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including the constraints of time, cost and resources

Note 1 to entry: An individual project may form part of a larger project structure.

Note 2 to entry: In some projects, the objective(s) is (are) refined and the product characteristics defined progressively as the project proceeds (see IEC 62198).

Note 3 to entry: The data can be existing or new.

Note 4 to entry: For the purposes of this International Standard, the objective is the collection or interpretation of soil data (see also 3.23).

[SOURCE: ISO 9000:2000, definition 3.4.3 — modified. Notes 2 to 4 are particular to this International Standard.]

3.23
project
<digital exchange of soil-related data>activity that leads to the collection of soil data

3.24
sample
solid, liquid, gaseous or living material extracted from the soil, soil solution, sewage water, interflow water or soil air to be described or analysed

3.25
sampling
process by which a sample is obtained

3.26
site
defined area which is subject to a soil quality investigation

Note 1 to entry: A site provides the area around a plot.

3.27
soil feature types
specific set of feature types specified in this International Standard

3.28
soil body
artificial but recognizable tridimensional entity in a soil continuum

3.29
soil map
two- or three-dimensional representation of soil or its properties for a geographic extent

3.30
soil mapping unit
aggregate of all soil delineations which are identified by a unique symbol, colour, name or other representation on a map

3.31
soil profile
describable representation of the soil that is characterized by a vertical succession of horizons or at least one or several parent material layers

Note 1 to entry: The soil profile is abstracted from observations in a trial pit or a boring.

3.32
subclass
class that inherits attributes, operations, methods, relationships and semantics from another class, with some restrictions or extensions

Note 1 to entry: An instance of subclass can be always considered as an instance of the parent class

3.33
trial pit
test pit
trench
excavation prepared to carry out profile descriptions, sampling, and/or field tests

[SOURCE: ISO 11074.]

3.34
URL
Uniform resource locator
mechanism for identifying resources on the Internet (such as Web pages) by specifying the address of the resource and the access protocol used

[SOURCE: ISO 9241-151:2008.]

3.35
URN
universal resource name
code identifying a service or a resource on the Internet

[SOURCE: ISO 5127:2001.]

3.36
UML
unified modelling language
type of modelling element that extends the semantics of the metamodel

[SOURCE: ISO/IEC 19501.]

3.37
XSD
XML schema definition
extensible schema definition
set of rules to which an XML document shall conform in order to be considered "valid" according to that schema

Note 1 to entry: Where XML is the language, XSD is a specific definition using the XML language.

Note 2 to entry: XSD is sometimes called: "XML schema".

4 Rationale

4.1 General

This International Standard is specifically made for the exchange of soil quality data. It does not deal with the nevertheless very common use and exchange data from other disciplines, like geotechnics, geo-information, or groundwater investigation and management.

Sometimes, soil data exchange is successful or not determined by the interpretation of the incoming data by the receiving system. Basically, the receiving system can only successfully interpret incoming data when the feature types described by the data and the parameters themselves are known prior to the data exchange.

To get a handle on the problem that a huge number of systems exist for the description of soils with different parameters, parameter names, and parameter value code lists, this International Standard defines a set of features with which soils are described and that is complete, i.e. cannot be extended within the framework of this International Standard.

If soil quality data defined according to this International Standard are combined with other kinds of data, the soil quality part shall be performed, using the XML namespace “ISO 28258”.

Additionally, very few, inherent properties of these features are defined as well. This feature catalogue enables the data receiving system to allocate any data to a known feature class.

The flexibility needed to consider soil-related data of various origins is maintained by not defining any other part of the soil description, i.e. the attributes for any of these features and — if needed — the list of their valid values (code lists). Instead, a structure is provided how to define them and how to relate to these definitions from data exchange files.

When exchanging data, the sender and receiver shall both refer to the same attribute parameters and code lists and interpret them in the same way. When pieces of data are exchanged, a reference should be made to its definition in a definition file; when a coded value is exchanged, a reference shall be made to the relevant code list using URN. For data exchange, a code list can be included completely or not at all. If included, the code list shall be provided as a separate file.

It is recommended that attributes parameters and code lists according to Clause 5 are made publicly available by the producer or publisher of the soil-related data in digital form.

In order to make use of advantages of data modelling with a wider, more generic scope, this International Standard is based on the rules and requirements of ISO 19156 and ISO 19136.

To provide a good reference for soil quality data, all soil quality items of ISO 25177 are worked out as an example soil quality data list in Annex A.

The codes of the soil attributes examples in Annex A are given in Annex B.

Clause 5 provides the information model for soil quality data exchange used in this International Standard. All soil quality information shall (eventually) refer to a specific place (point, location, mapping unit) in or under the surface of the earth. For all geographical information, the ISO 19100 family of International Standards is used.

All analytical results shall refer to an appropriate standard, if available.

4.2 Requirements worked out

This International Standard requires that soil quality data exchange is based on an information model itself based on ISO 19156. Thus, this International Standard provides a basis for soil quality data exchange, while maintaining flexibility (“extend the model according to your own needs”).

Another way of maintaining flexibility is using parameters that can be added and filled in according to particular needs.

Qualitative values for attributes are usually standardized in lists ("code lists", "domain tables"). For example, the values for attribute "land use" might be from the list:

— "agriculture";

— "forest";

— "snow or ice cover";

— ....

ISO 25177 provides several such lists. Again, in different types of investigation different code lists may be used. For example, the code list for soil types may differ among countries. This International Standard does not prescribe which code lists are to be used. However, when qualitative soil data are exchanged, it should be done with reference to a data source where the qualitative value is defined. For example, two parties agree to exchange data on land use using the codes provided in ISO 25177:2008, 4.2. The data exchange should contain at least the value itself (e.g. "18; Snow or ice cover") and a reference, for example, to "ISO 25177:2008, 4.2 land use". Preferably, such a reference is given using an URL so that the reference can be found easily by either man or machine.

4.3 Introduction main soil quality data set

ISO 25177 and ISO 15903 provide standards for the description of attributes of soil data. When exchanging soil quality data in a particular context, additional attributes shall be considered that do not occur in ISO 25177 and ISO 15903. Additional attributes may differ in a particular context — for example, a country or a project. In order to make it possible to exchange all types of relevant soil data attributes, this International Standard prescribes only general rules for soil data exchange with a suggestion on how to exchange the most common soil data attributes as listed in ISO 25177 and ISO 15903.

Clause 5 provides the information model for soil quality data exchange used in this International Standard. The model may be extended or modified in specific situations, according to rules provided in this International Standard.

5 Soil features information model

5.1 Principles from observations and measurements

This International Standard inherits principles from ISO 19156, but specializes in features of interest and the description of observations and measurements for soil domain artefacts.

Figure 2 describes the relationship between this International Standard and other International Standards.

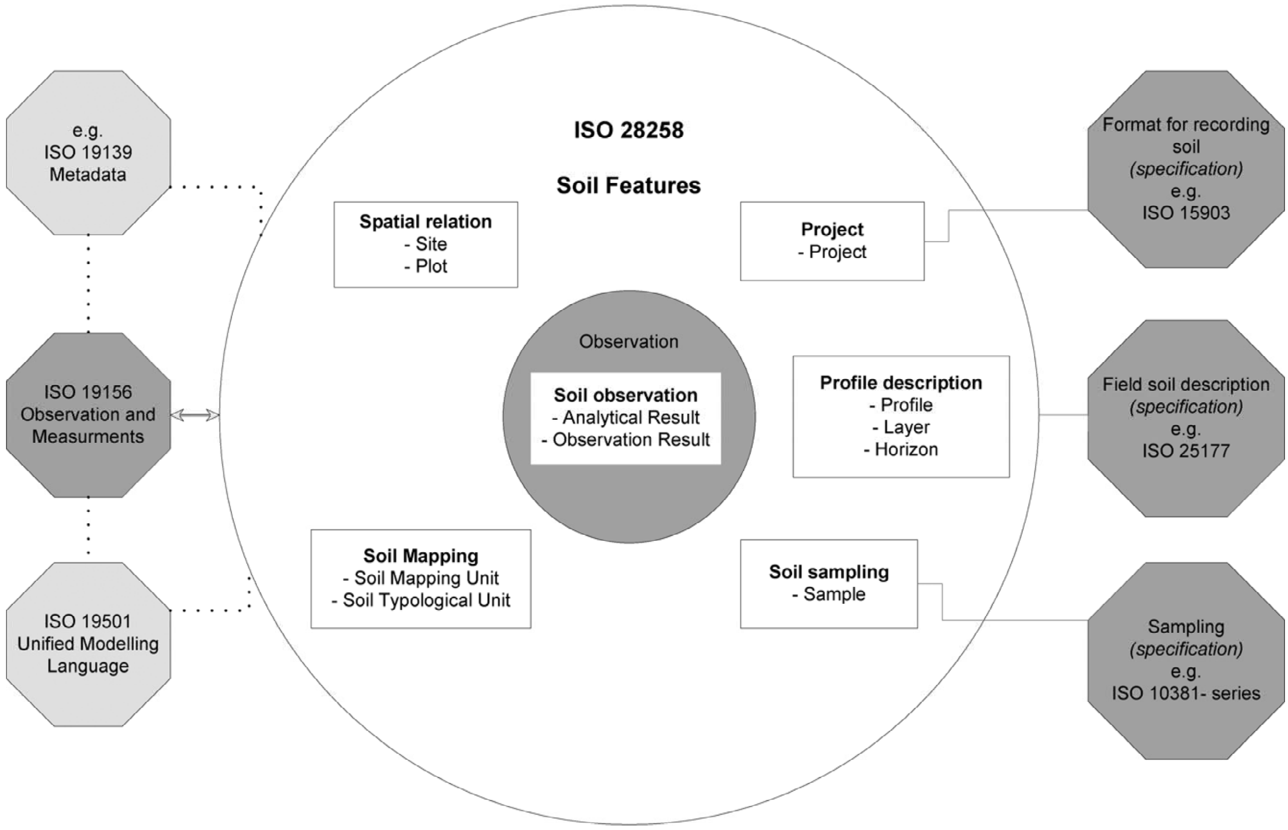


Figure 2 — Inner structure of soil information and its setting within other standards

5.2 General model for soil quality data exchange

5.2.1 General

As stated in Clause 4, soil quality data exchange shall be performed through an information model that is based on observations and measurements according to ISO 19156, which provides a generic way to exchange observations and measurements of any kind. With its general features and links to other International Standards it provides a logical and technical framework. This International Standard is an implementation of ISO 19156 in the field of soil science. Technically speaking, the UML model for soil data exchange is a profile, in accordance with ISO 19106, of ISO 19156. That means it concretizes the more general model of ISO 19156, particularly with the following restrictions.

a) The OM_Observation is restricted to *SoilObservation*.

b) The OM_Process is restricted to *ObservationProcess*.

c) The SF_SamplingFeature is restricted to *SoilSpecimen* (subclass of SF_Specimen) and *Plot* (subclass of SF_SpatialSamplingFeature).

d) The SF_Process is restricted to *PreparationProcess*.

e) FeatureType of Observation:featureOfInterest is restricted to *Site*, *Plot*, *Profile*, *ProfileElement*, and *SoilSpecimen* including all their subclasses. It means that only properties of these feature types may be observed.

f) FeatureType of SF_SamplingFeature: *sampledFeature* is restricted to *Site*, *Plot*, *Profile*, and *ProfileElement* including all their subtypes.

g) OM_ObservationContext and SF_SamplingFeatureCollection are not used.

The resulting model is an application schema of ISO 19156 for soil data exchange.

NOTE Names in UML models cannot have spaces. To make the names more readable the first character of every word in each name is written as a capital.

EXAMPLE required procedure in the submodel in 5.2.3 is written as RequiredProcedure.

5.2.2 Metadata

Information could be data or metadata, or both. For example, the information on projects as described in Figure 4 could be data or metadata.

In such a case, it is strongly recommended to at least describe the information as data in accordance with this International Standard.

5.2.3 Feature types and properties

The feature types listed in Table 1 are considered to be the soil feature types of this International Standard. Within the application schema no other feature types except those listed in Table 1 and their subtypes should be used. Nevertheless, it is possible to extend any of these domain feature types by adding properties specific to the data provider.

Table 1 — Domain feature types

Soil feature type	Origin
AnalysisRequest	Soil Quality
Borehole	Soil Quality, subtype of Plot
Horizon	Soil Quality
Layer	Soil Quality
ObservationProcess	Subtype of OM_Process
Plot	Subtype of OM_SpatialSamplingFeature
PreparationProcess	Subtype of OM_Process
Profile	Soil Quality
ProfileElement	Soil Quality
Project	Soil Quality
Site	Soil Quality
SoilMap	Soil Quality
SoilMappingUnit	Soil Quality
SoilMappingUnitCategory	Soil Quality
SoilObservation	Subtype of OM_Observation
SoilSpecimen	Subtype of SF_Specimen
SoilTypologicalUnit	Soil Quality
Surface	Soil Quality, subtype of Plot
TransportAndStorage	Soil Quality, subtype of PreparationProcess
TrialPit	Soil Quality, subtype of Plot

Each property, regardless of being introduced by this model or added by the data provider, shall be considered as being either observable or exact (see ISO 19156:2011, 6.1.1). It is generally possible that one feature has several values for each observable property. On the other hand, one feature has only one value for each exact property.

An observation may be done only on observable properties of any feature of interest; however, features of interest are restricted to Site, Plot, Profile, ProfileElement, and SoilSpecimen, including all their subtypes. General observable properties introduced by this model are listed in Table 2. Additional observable properties may be introduced by a data provider. Any other properties introduced by this model except for those listed in Table 2 are considered to be exact.

Table 2 — General observable properties

Feature type	Observable property
Layer	developedHorizon
Plot	profile
Profile	element
ProfileElement	order upperDepth lowerDepth
Site	position extent typicalProfile
SoilSpecimen	depth

5.2.4 Observation results

The result of a soil observation shall be of the same type as the observed property or one of its subtypes.

EXAMPLE 1 If an observation is made on the property profile of a plot, the result type is a Profile.

EXAMPLE 2 If an observation is made on the property element of a profile, the result could be Layer or Horizon.

The result type of an observation made on a provider-specific property depends on the type of the property.

Using this International Standard, parameter names and values for the soil attributes of the soil features shall be defined and the definition or reference to a definition list shall be part of the data set that is exchanged.

It is recommended that the parameter names and values be described in accordance with ISO 25177 (see Annex A).

5.3 Packages

Soil features are modelled on the basis of generic OM features and split up into different packages for convenience (see Figure 3). For each package a UML submodel is provided. The submodels are described in 6.1 to 6.8. For each submodel, normative attributes are defined in a definition table. Such attributes are general in nature and describe properties of the features that are inherent to their definition (e.g. top and bottom depth of a soil horizon). Other attributes are optional and are not further defined by this International Standard. Figure 3 shows a general model for Soil data exchange.

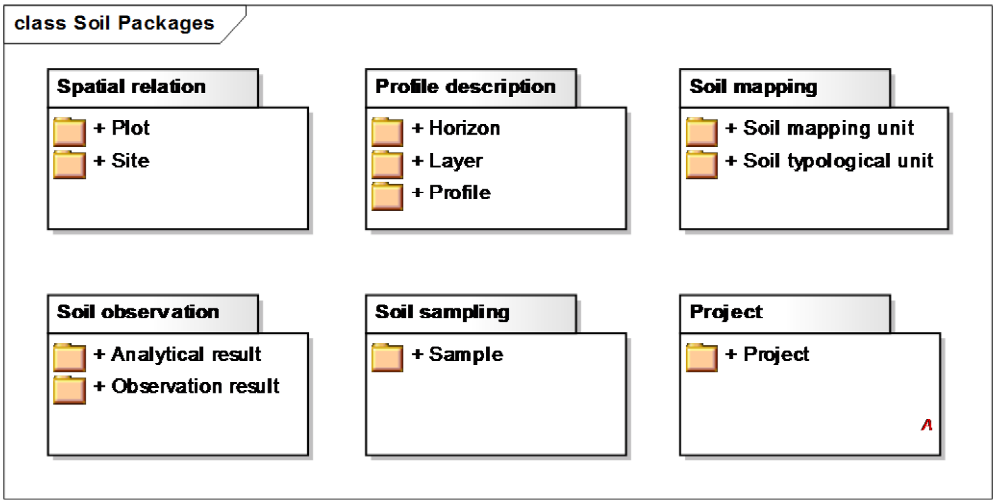


Figure 3 — General SoilQuality packages

The packages used to describe soil features are:

— Project (see 6.1),

— Spatial relation (see 6.2),

— Soil mapping (see 6.5),

— Soil observation (see 6.6),

— Soil sampling (see 6.7), and

— Profile description (see 6.8).

5.4 Model

The packages are a simplified presentation of the data model. The model presented in Figure 4 gives an overview of the submodels given in Clause 6.

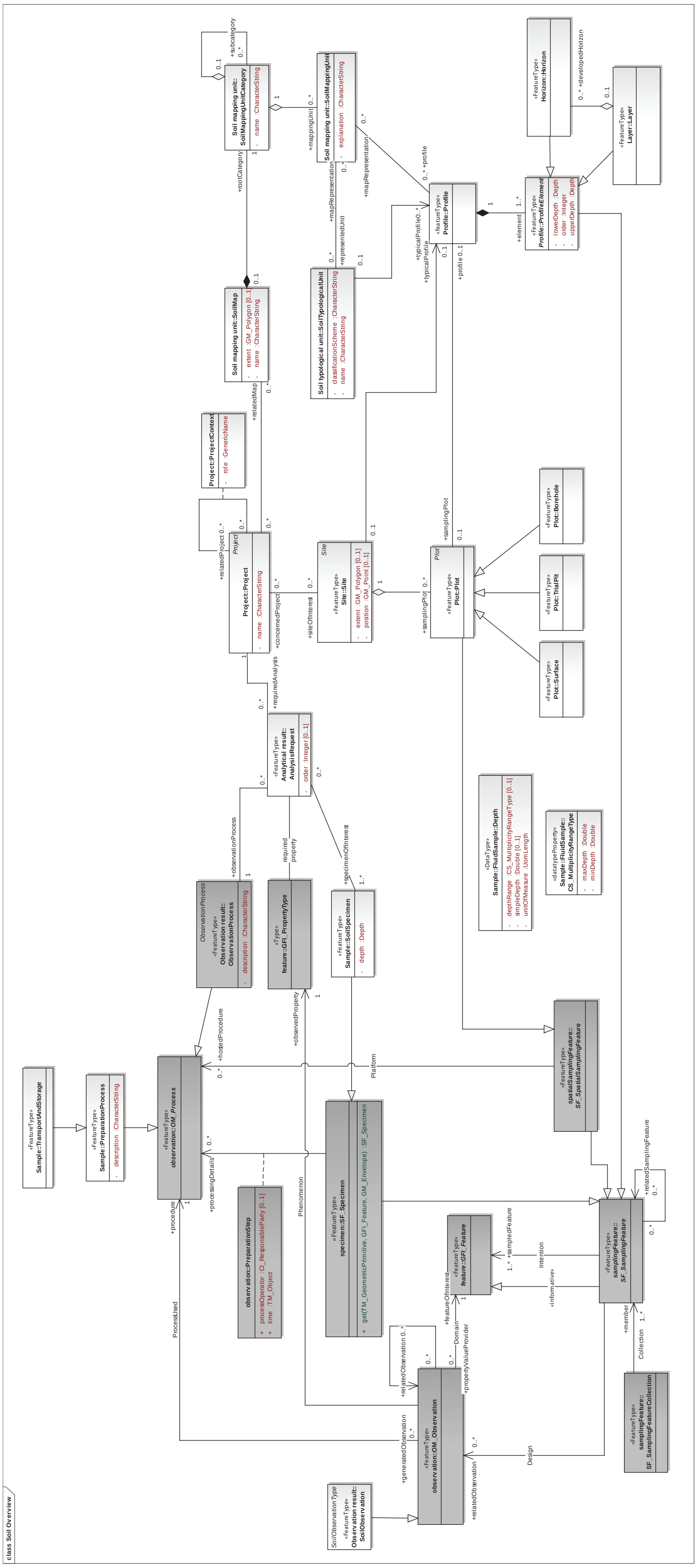


Figure 4 — Overview of sub-models (see Figures 5 to 10 for details)

6 Description of submodels

6.1 Project

The project submodel holds the background information for soil studies. A project does not describe the soil as such. It is of importance to exchange project data along with other soil quality data in order to know the aim and circumstances of data collection. The project provides the context of the data collection as a prerequisite for the proper use or reuse of these data.

The project information also may be the starting point to retrieve further information that cannot be exchanged using soil quality. For example, the name of an author or the project number may be the key for finding a report or decision document. See Table 3 and Figure 5.

Table 3 — Attributes of feature type project

Property	Property type	Type	Multiplicity
name	attribute	CharacterString	1
requiredAnalysis	association	AnalysisRequest	0..*
siteOfInterest	association	Site	0..*
relatedProject	association	Project	0..*
relatedMap	association	SoilMap	0..*

Name is a title of the project.

Required analysis is a description of a required analysis of soil specimens.

Site of interest is a site observed within this project.

Related Map is a map produced in the framework of this project.

Related project is a project related to this project. Related project has always some role, e.g. „subproject".

A project may have to be carried out according to certain standards (RequiredProcedure). Also certain laboratory analyses may have to be carried out (RequiredAnalysis). The RequiredProcedure and the RequiredAnalysis may differ from the procedures actually followed and the analysis that was actually carried out.

NOTE The data fields "Author" and "Organization" according to ISO 15903 could be added for the project using the rules for defining attribute parameters.

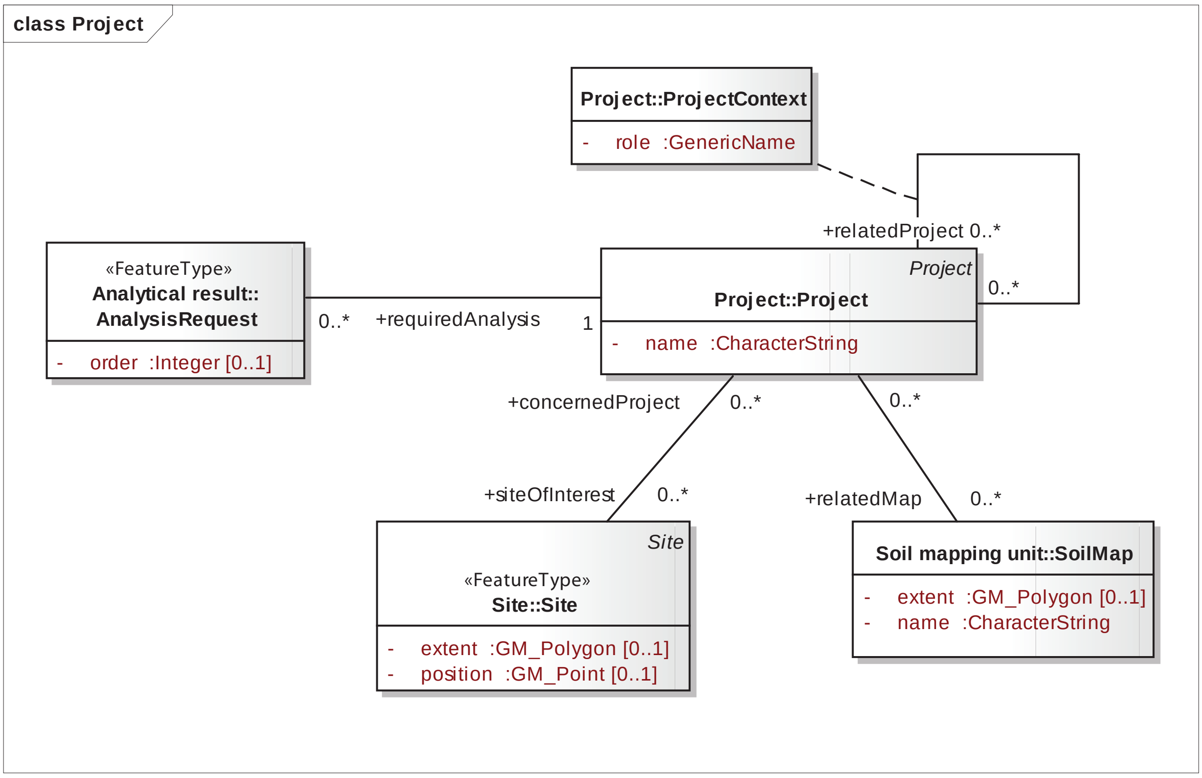


Figure 5 — Details — Project

6.2 Spatial relation

Spatial relation holds the feature types site and plot. The explanation of the submodel (Figure 6) is given in 6.3 and 6.4.

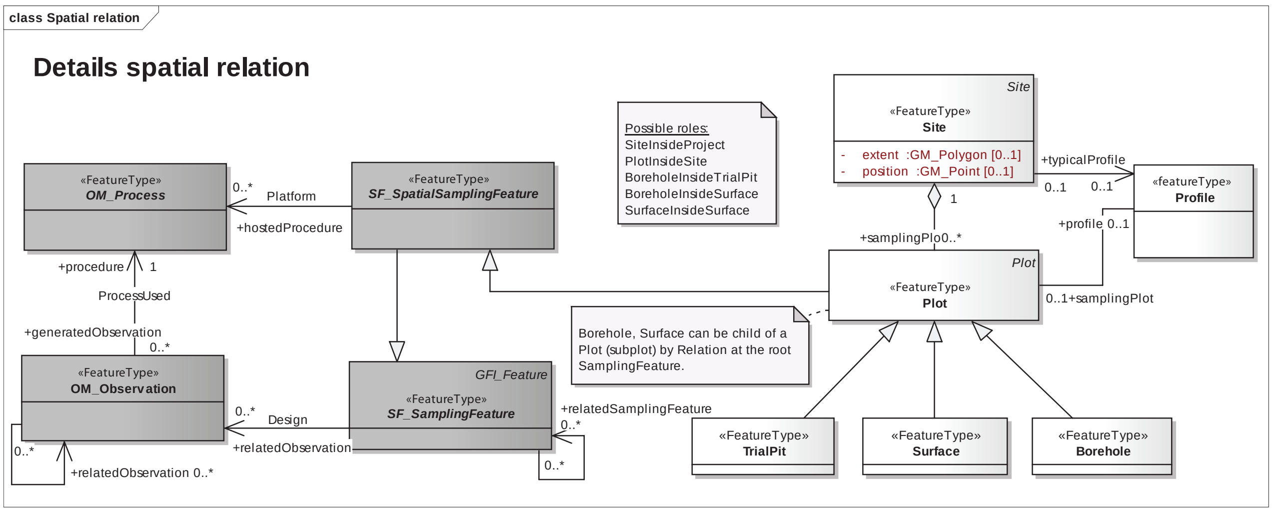


Figure 6 — Details — Spatial relation

6.3 Site

The site within the submodel spatial relation is to hold the data of any spatially extended information that is of interest for a soil-related study. As a real-world spatial object, it needs specification of its geographical position.

A site is a defined, spatially extended area and provides the real world object to which soil data are related. It represents the spatial link between point and soil observations on the one hand and their environment (e.g. the landscape or larger spatial objects) on the other. As such, it provides the possibility to connect data of spatially extended phenomena, e.g. vegetation, with one- or two-dimensional sampling features (plots). It also allows for the possibility to combine the results of (quasi-)synchronous repetitions of observations of the same kind. The site is furthermore the time link between repeated soil observations, e.g. in the framework of soil monitoring. Generally, within a single project, a site is spatially invariant, but contains all plots for single or repeated observations and samplings, both related to one point in time or several points in time. See Table 4.

Table 4 — Attributes of feature type site

Property	Property type	Type	Multiplicity
extent	attribute	GM_Polygon	0..1
position	attribute	GM_Point	0..1
samplingPlot	association	Plot	0..*
typicalProfile	association	Profile	0..1
Extent is a map polygon delineating the boundaries on the earth's surface. **Position** is a point coordinate providing the location on earth. **SamplingPlot** is a plot observed within this site. **TypicalProfile** is the most typical soil profile to characterize the site.			

6.4 Plot

There are three types of plots: trial pits, surfaces or boreholes (Figure 6).

The plot provides the connection between the discrete location of a sampling or an observation and the site. The plot is therefore modelled as a spatial sampling feature. Properties of the plot describe the direct vicinity of the investigation; e.g. if a soil profile pit is investigated, the plot may receive information from the attribute parameter "local slope". Plots might locate different types of spatial sampling features which also inherit their structure and properties from SF_SpatialSamplingFeature. In the soil scientist's view, they describe the geometrical form that is projected at the soil surface, the dimension of the plot geometry might be reduced by one compared with that of the sampling feature associated with it.

Note that a plot can only be combined with one type of spatial sampling features, but of these, it might contain several (in the sense of subplots, as inherited from the feature type SF_SamplingFeature).

EXAMPLE Earthworm abundance is investigated on six subplots within a rectangle plot on the soil surface. The geographic position of the rectangle plot could define the position of the subplots because of a defined rule for how to set up the investigation, so that subplots could hold only a relative position to the (centre) coordinates of the rectangle plot.

NOTE The feature type plot does not have properties to be described here, so there is no table on plot properties.

6.5 Soil mapping

Soil mapping includes all features and their relations used in soil maps. Soil typological units (STU) are non-spatial and integrate data of similar soils. Soil mapping units (SMU) may be attributed by one or more STUs described by one or more soil profiles (with their respective site information). One polygon of a map is assigned to one SMU, and one SMU is represented by one or several polygons.

The possible relations between the features Soil Profile, STU, SMU and Map Sheet may depend on the scale and on principles or conditions for creating the map legend (e.g. top-down or bottom-up). See Table 5 and Figure 7.

Table 5 — Attributes of feature type soil mapping

Feature type	Property	Property type	Type	Multiplicity
SoilTypologicalUnit	name	attribute	CharacterString	1
SoilTypologicalUnit	classification-Scheme	attribute	CharacterString	1
SoilTypologicalUnit	mapRepresentation	association	SoilMappingUnit	0..*
SoilMappingUnit	explanation	attribute	CharacterString	1
SoilMappingUnit	representedUnit	association	SoilTypologicalUnit	0..*
SoilMappingUnitCat-egory	name	attribute	CharacterString	1
SoilMappingUnitCat-egory	mappingUnit	association	SoilMappingUnit	0..*
SoilMappingUnitCat-egory	subcategory	association	SoilMappingUnitCat-egory	0..*
SoilMap	rootCategory	association	SoilMappingUnitCat-egory	1
SoilMap	extent	attribute	GM_Polygon	0..1
SoilMap	name	attribute	CharacterString	1

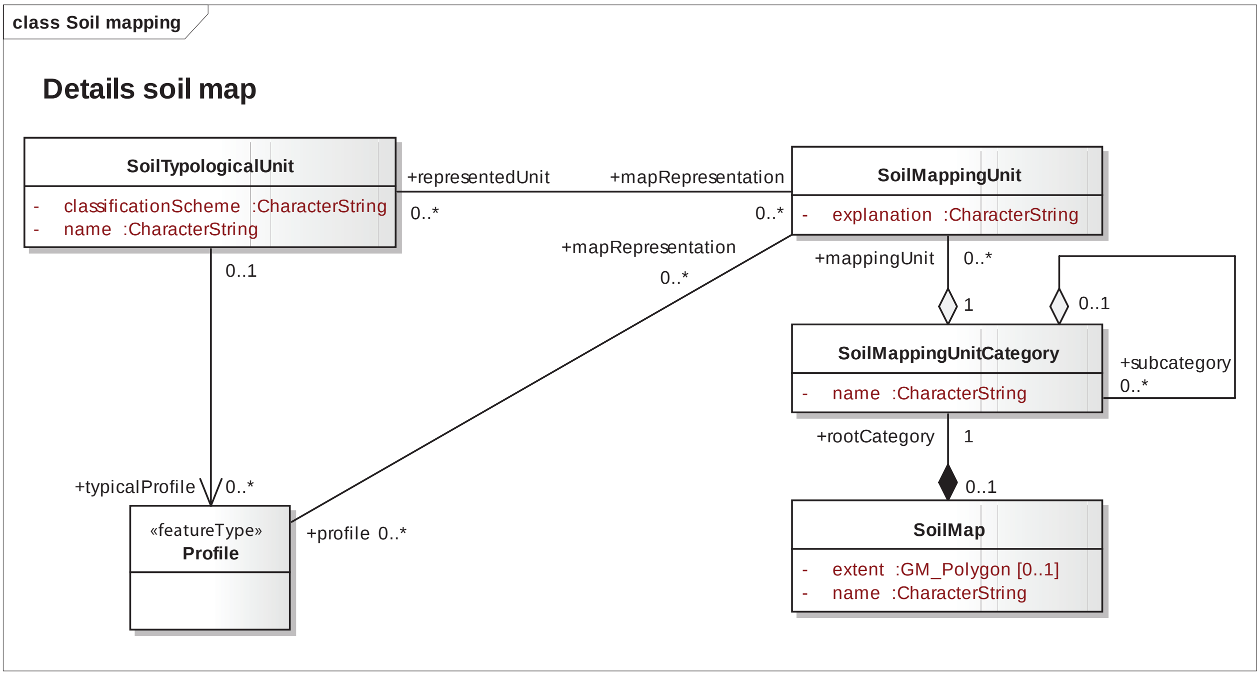


Figure 7 — Details — Soil mapping

6.6 Soil observation

The submodel soil observation provides the framework for any observation (be it in trial pits, borings, on samples, etc.) related to one of the features.

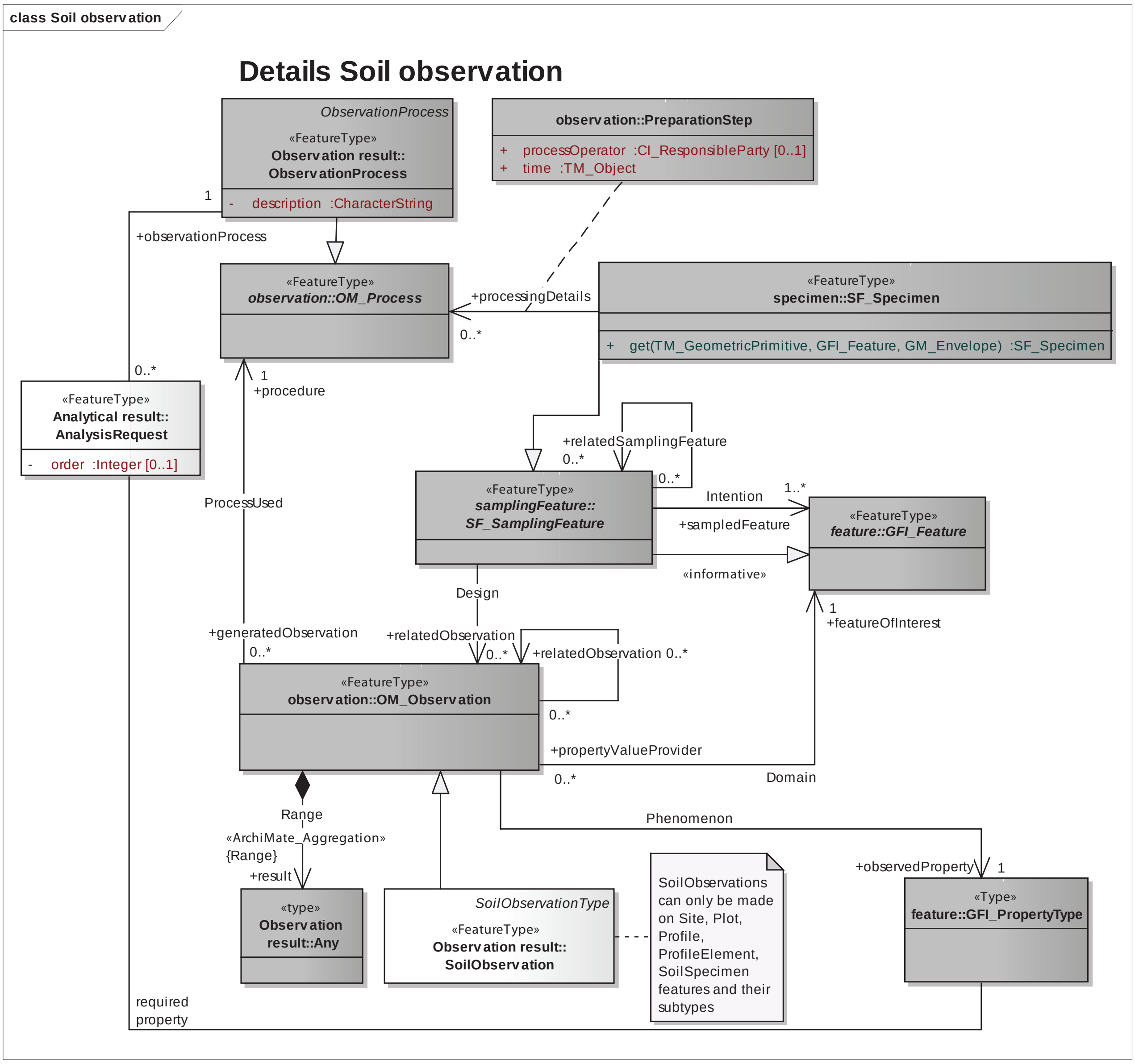


Figure 8 — Details — Soil observation

AnalysisRequest feature type, as shown in Figure 8, is a description of an analysis which should be carried out on soil specimens. As such, AnalysisRequest is associated to ObservationProcess and GFI_PropertyType types as depicted in Table 6.

Table 6 — Attributes of feature type soil observation

Feature Type	Property	Property Type	Type	Multiplicity
AnalysisRequest	observationProcess	association	ObservationProcess	1
AnalysisRequest	order	attribute	integer	0..1

EXAMPLE 1 Soil texture

When exchanging information about the texture of a soil sample, the model may be used in the following way:

To SoilObservation, a parameter is added with the name ObservationType and the value “Texture”. The source of this value shall be provided since it is a Codetype, for example “www.sikb.nl/ObservationTypes”.

The texture is provided as a QualitativeResult with a value from a code list, for example “Silty loam”. Again, the source of this value shall be provided as well.

6.7 Soil sampling

It is recommended that ISO 10381 be used for describing the attributes. See Table 7 and Figure 9.

Table 7 — Attributes of feature type sample

Feature Type	Property	Property Type	Type	Multiplicity
SoilSpecimen	Depth	attribute	Depth	1..2
PreparationPro-cess	description	attribute	CharacterString	1

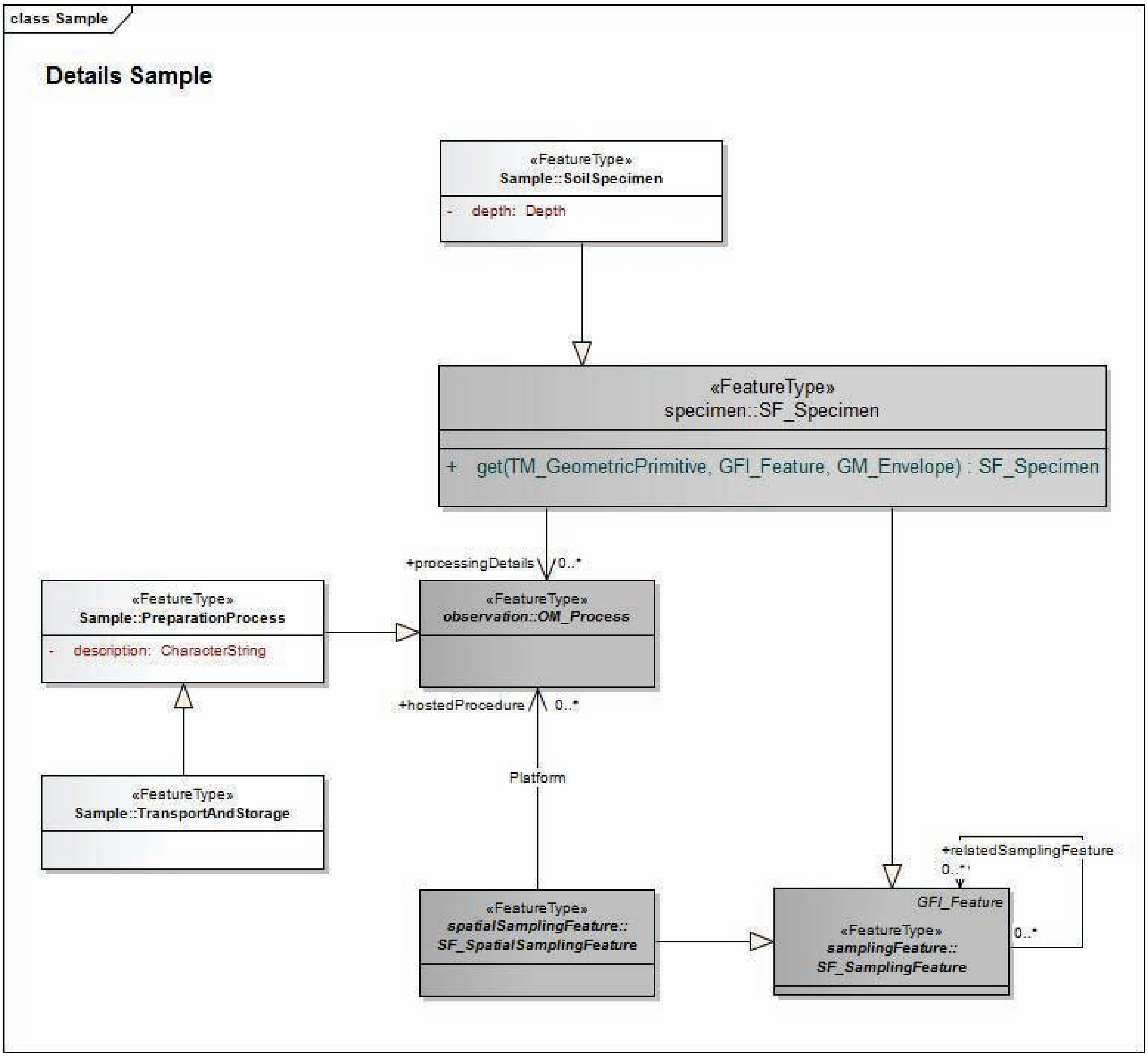


Figure 9 — Details — Sample

6.8 Profile description

The submodel profile description contains and relates the typical soil scientific concepts of soil profile, layer and soil horizon. The soil profile is an abstract, ordered set of soil horizons and/or layers. Horizons develop in layers which in turn have been developed through geogenesis or anthropogenic action. Furthermore, layers can be used to describe common characteristics of a set of adjoining horizons. Horizons may be associated with the layer in which they have been developed through pedogenesis. Because layers and horizons share the same basic properties (i.e. both have upper and lower depth information and have a position in the order within the profile), both are subclasses of the feature type ProfileElement. See Table 8.

Table 8 — Attributes of feature type soil profile

Feature Type	Property	Property type	Type	Multiplicity
Profile	samplingPlot	association	Plot	0..1
Profile	element	association	ProfileElement	1..*
ProfileElement	lowerDepth	attribute	Depth	1
ProfileElement	order	attribute	integer	1
ProfileElement	upperDepth	attribute	Depth	1
Layer	developedHorizon	association	Horizon	0..*

ProfileElement feature type is considered as the sampling feature according to ISO 19156, OM, shown in Figure 10.

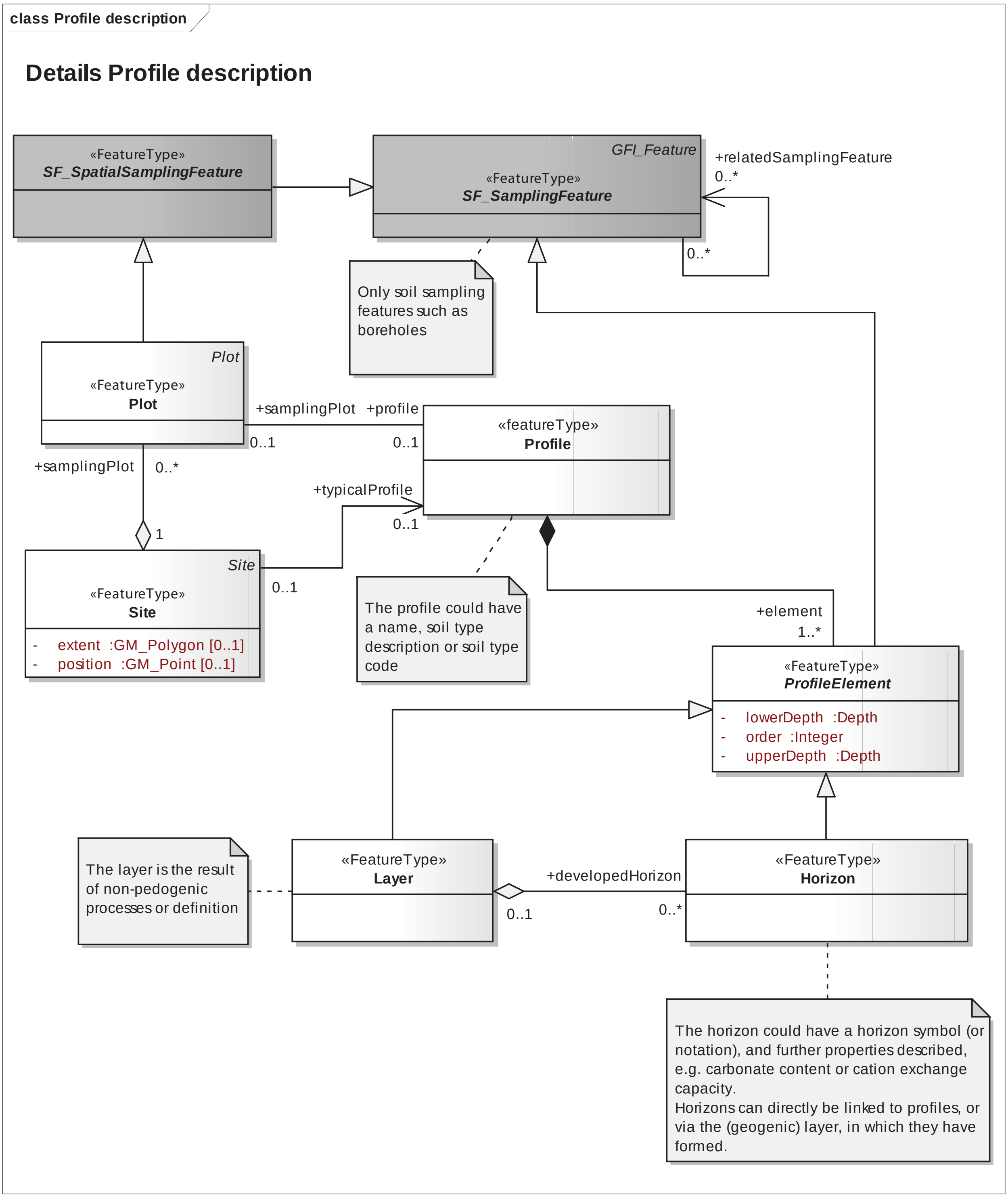


Figure 10 — Details — Soil profile

6.9 GML implementation

An example GML implementation of the data model described in Clauses 5 and 6 is provided in Annex C.

7 Software keys

If data from two different sources are exchanged, it can be helpful to make software to support the changes that are to be made.

EXAMPLE 1 The electric conductivity of source 1 uses $mS \cdot m^{-1}$, source 2 $\mu S \cdot cm^{-1}$.

Key software can change the data with factor 10 and give the other units just before implementing the data from the other source.

EXAMPLE 2 Estimated humus content in percent is called, in another source, estimated organic matter content in percent.

Key software can change the name of the parameter just before implementing the data, so it is recognized.

8 Validating software (control tools)

If data sets from different sources are often sent to one database, special software can be made to check if a data set is compliant. The report can shortly be: compliant or non-compliant. Often it is more useful to receive a detailed report of the parts that are not compliant.

Annex A
(informative)

Soil attribute examples from ISO 25177

ISO 25177:2008 **clause/subclause**	**Title**	**Feature type**	**Field**	**Example**
3	**General references**			
3.1	Site/profile numbers	Site	User defined parameter	site0123
3.2	Location	Site	User defined parameter	Hannover
3.3	Geographical coordinates	Site	Defined in extend or position	
3.4	Date of observation or sampling or visit	Soilobservation	Defined in ISO 19156	
3.5	Author and organization	Diverse	User defined parameter	Hannes Bond
4	**Profile environment**			
4.1	Previous precipitation	Diverse	User defined parameter	0;No precipitation in the last month
4.2	Land use at plot level (checked by detailed field survey)	Site or Profile	User defined parameter	18;Snow or ice cover
4.3	Type of cultivation or vegetation or human utilization (at the plot level)	Site or Profile	User defined parameter	grazing
4.4	Geomorphology of the site	Site or Profile	User defined parameter	rocky outcrop
4.5	Slope length (in metres)	Site	User defined parameter	100 (m)
4.6	Slope value	Site or Profile	User defined parameter	6 %
4.7	Orientation (aspect) of the slope	Site or Profile	User defined parameter	NE
4.8	Nature of parent material	Profile or Layer or Horizon	User defined parameter	“glacial till”
4.8.1	Modified or artificial material	No parameter		
4.8.2	Natural material	No parameter		
4.9	Presence and depth of water table	Profile	User defined parameter	present
4.9.1	General	No parameter		
4.9.2	Depth	Profile	User defined parameter	65 cm
4.9.3	Minimum depth of water table	Profile	User defined parameter	45 cm
4.9.4	Maximum depth of water table	Profile	User defined parameter	87 cm
4.9.5	Nature of the water	Profile	User defined parameter	brackish
5	**Surface appearance**			
5.1	Percentage of land surface occupied by rock outcrops or surface exposures of non-natural material (e.g. on industrial site)	Site	User defined parameter	5 abundant
5.2	Evidence of erosion	Site	User defined parameter	1.1 sheet erosion
6	**General designation — Soil type**			
6.1	General	No parameter		WRB1998: Albic Luvisol

ISO 25177:2008 clause/subclause	Title	Feature type	Field	Example
6.2	Type of soil classification used	Profile	User defined parameter	
6.3	Soil type with reference to the soil classification used			
6.4	Type of horizon designation used	Soilobservation	User defined parameter	FAO2006
6.5	Sequence of horizons	Profile	User defined parameter	Ah-E-Bt-C
7	Horizon or layer description	Feature type	Field	EXAMPLE
Missing from ISO 25177	Horizon designation	Horizon	User defined parameter	FAO2006: Ah
7	**Horizon or layer description**			
7.1	General	No parameter		
7.2	Horizon or layer number	Profileelement	Order	1
7.3	Depth	Profileelement	Lower depth, Upper depth	27cm
7.4	Estimation of moisture status	Profileelement	User defined parameter	slightly moist
7.5	Colour of the horizon or layer matrix	Profileelement	User defined parameter	brown
7.6	Mottles	No parameter		
7.6.1	General	No parameter		
7.6.2	Abundance	Profileelement	User defined parameter	2 few
7.6.3	Colour	Profileelement	User defined parameter	7.5R4/6
7.7	Estimated organic matter content	Profileelement	User defined parameter	0 absent
7.8	Texture	No parameter		
7.8.1	Description of texture diagram	Soilobservation	User defined parameter	USDA triangle
7.8.2	Estimation	Profileelement	User defined parameter	silty loam
7.9	Coarse element	No parameter		
7.9.1	General	No parameter		
7.9.2	Abundance (% volume fraction)	Profileelement	User defined parameter	3 common
7.9.3	Maximum size of the most frequently observed coarse elements	Profileelement	User defined parameter	4 > 12 and ≤ 25 cm
7.9.4	Nature	Profileelement	User defined parameter	granite
7.10	Carbonates and effervescence	No parameter		
7.10.1	Intensity of effervescence	Profileelement	User defined parameter	1 weak effervescence
7.10.2	Location of effervescence	Profileelement	User defined parameter	2 localized in the matrix
7.11	Main categories of structure	Profileelement	User defined parameter	4 blocklike
7.12	Compactness	Profileelement	User defined parameter	1 loose
7.13	Total estimated porosity	Profileelement	User defined parameter	1 low
7.14	Roots	No parameter		
7.14.1	Size (diameter) of most frequently observed roots	Profileelement	User defined parameter	2 fine
7.14.2	Abundance	Profileelement	User defined parameter	0 no roots
7.15	Density of worm channels (usually an average over a number of square decimetres)	Profileelement	User defined parameter	2 common
7.16	Nature of lower horizon boundary	Profileelement	User defined parameter	2 wavy

Annex B
(informative)

Code list examples from ISO 25177

ISO 25177:2008 **sub-clause**	**Code**	**Subject/code**
4.1		**Previous precipitation**
4.1	0	No precipitation within the last month.
4.1	1	No precipitation within the last week.
4.1	2	No precipitation within the last three days.
4.1	3	Rainy but no intense precipitation within the last three days.
4.1	4	Moderate rain for several days or intense rainfall the day before the observation.
4.1	5	Extreme precipitation or snow melt or inundation just before the observation.
4.1	6	Not recorded.
4.2		**Land use at plot level (checked by detailed field survey)**
4.2	01	Buildings and industrial infrastructures
4.2	02	Mining site (current or past).
4.2	03	Metal processing sites
4.2	04	Chemical processing sites
4.2	05	Oil and gas production sites
4.2	06	Metal manufacturing sites
4.2	07	Food processing sites
4.2	08	Waste disposal sites
4.2	09	Cultivated Lands
4.2	10	Horticulture
4.2	11	Grazing.
4.2	12	Orchards, fruit plantations or grapevines.
4.2	13	Forest, woodlands.
4.2	14	Mixed land use (agroforestry or agropastoral).
4.2	15	Gathering/hunting-fishing (exploitation of natural vegetation, hunting or fishing).
4.2	16	Nature protection (for EXAMPLE nature reserve, protected area, erosion control by terracing).
4.2	17	Wetland (for EXAMPLE marsh, swamp, mangrove, etc.).
4.2	18	Snow or ice cover.
4.2	19	Bare rock or rocky surface.
4.2	20	Natural lands
4.2	21	Natural grasslands
4.2	22	Recreation land
4.2	23	Other type of unutilized and unmanaged site.
4.7		**Orientation (aspect)**
4.7	AA	Flat
4.7	VV	Variable
4.9.2		**Depth**
4.9.2	a	Observed or measured

ISO 25177:2008 **sub-clause**	**Code**	**Subject/code**
4.9.2	b	Estimated
4.9.2	c	Not observed
4.9.3		**Minimum depth of water table**
4.9.3	a	Observed or measured
4.9.3	b	Estimated
4.9.3	c	Not observed
4.9.4		**Maximum depth of water table**
4.9.4	a	Observed or measured
4.9.4	b	Estimated
4.9.4	c	Not observed
4.9.5		Nature of the water
4.9.5	**S**	**Saline**
4.9.5	B	Brackish
4.9.5	F	Fresh
4.9.5	P	Polluted or contaminated
4.9.5	SP	Combination S and P
4.9.5	BP	Combination B and P
4.9.5	FP	Combination F and P
5.1		**Percentage of land surface occupied by rock outcrops or surface exposures of “non-natural”**
5.1	0	None: 0 %.
5.1	1	Very few: > 0 % and ≤ 2 %.
5.1	2	Few: > 2 % and ≤ 5 %.
5.1	3	Common: > 5 % and ≤ 15 %.
5.1	4	Many: > 15 % and ≤ 40 %.
5.1	5	Abundant: > 40 % and ≤ 80 %
5.1	6	Dominant: > 80 %.
5.1	7	Not observed.
5.2		**Evidence of erosion or accumulation**
5.2	0	No visible evidence.
5.2	1	Visible evidence of soil loss
5.2	1.1	Sheet erosion.
5.2	1.2	Rill erosion.
5.2	1.3	Gully erosion.
5.2	1.4	Wind erosion.
5.2	1.5	Landslides.
5.2	2	Visible evidence of accumulation
5.2	2.1	Deposition by water.
5.2	2.2	Wind deposition.
7.4		**Estimation of moisture status**
7.4	a	Dry
7.4	b	Slightly moist
7.4	c	Moist
7.4	d	Very wet
7.4	e	Saturated
7.4	f	Inundated

ISO 25177:2008 **sub-clause**	**Code**	**Subject/code**
7.6.2		**Mottles — Abundance**
7.6.2	0	None: 0 %.
7.6.2	1	Very few: > 0 % and ≤ 2 %.
7.6.2	2	Few: > 2 % and ≤ 5 %.
7.6.2	3	Common: > 5 % and ≤ 15 %.
7.6.2	4	Many: > 15 % and ≤ 40 %.
7.6.2	5	Abundant: > 40 %.
7.7		**Estimated organic matter content**
7.7	0	Absent or not detectable
7.7	1	Sufficient to darken the soil
7.7	2	Considerable organic matter giving the soil a very dark colour and a low density
7.7	3	Only organic matter detectable
7.7	4	Undetermined.
7.9.2		**Coarse element — Abundance (in % volume fraction)**
7.9.2	0	0 None: 0 %.
7.9.2	1	1 Very few: > 0 % and ≤ 2 %.
7.9.2	2	2 Few: > 2 % and ≤ 5 %.
7.9.2	3	3 Common: > 5 % and ≤ 15 %.
7.9.2	4	4 Many: > 15 % and ≤ 40 %.
7.9.2	5	5 Abundant: > 40 % and ≤ 80 %.
7.9.2	6	6 Dominant: > 80 %.
7.9.3		**Maximum size of the most frequently observed coarse elements**
7.9.3	1	0 cm to ≤ 2 cm.
7.9.3	2	> 2 cm and ≤ 7,5 cm.
7.9.3	3	> 7,5 cm and ≤ 12 cm.
7.9.3	4	> 12 cm and ≤ 25 cm.
7.9.3	5	> 25 cm.
7.10.1		**Carbonates and effervescence — Intensity of effervescence**
7.10.1	0	No effervescence
7.10.1	1	Weak effervescence
7.10.1	2	Moderate effervescence
7.10.1	3	Strong effervescence
7.10.1	4	Extreme effervescence
7.10.2		**Location of effervescence**
7.10.2	1	Generalized
7.10.2	2	Localized in the matrix
7.10.2	3	Localized on coarse elements
7.11		**Main categories of structural aggregation**
7.11	0	Continuous or massive
7.11	1	Single grain
7.11	2	Fibrous or layered
7.11	3	Spheroidal
7.11	4	Blocklike
7.11	5	Prismatic or columnar
7.11	6	Planar or platy

ISO 25177:2008 **sub-clause**	**Code**	**Subject/code**
7.11	7	Rock
7.12		**Compactness**
7.12	1	Loose — Uncompacted material; a knife penetrates easily up to the hilt.
7.12	2	Slightly compacted — A slight effort is required to insert a knife into the soil.
7.12	3	Compacted — A knife does not penetrate completely, even with considerable effort.
7.12	4	Very compacted — It is impossible to insert a knife more than a few millimetres.
7.13		**Total estimated porosity**
7.13	0	0 Nonporous: 0 % to ≤ 2 %.
7.13	1	1 Low: > 2 % and ≤ 5 %.
7.13	2	2 Medium: > 5 % and ≤ 15 %.
7.13	3	3 High: > 15 % and ≤ 40 %.
7.13	4	4 Very high: > 40 %.
7.13	5	5 Visible porosity, but not quantified.
7.13	6	6 Porosity not recorded.
7.14.1		**Roots — Size (diameter) of most frequently observed roots**
7.14.1	1	Very fine: ≤ 0,5 mm.
7.14.1	2	Fine: > 0,5 mm and ≤ 2 mm.
7.14.1	3	Medium: > 2 mm and ≤ 5 mm.
7.14.1	4	Coarse: > 5 mm.
7.14.2		**Abundance**
7.14.2	0	No roots.
7.14.2	1	Very few: 1 root/dm2 to 20 roots/dm^2, or less than 4 on a line 50 cm long.
7.14.2	2	Few: 20 roots/dm2 to 50 roots/dm^2, or 4 to 8 on a line 50 cm long.
7.14.2	3	Common: 50 roots/dm2 to 200 roots/dm^2, or 8 to 16 on a line 50 cm long.
7.14.2	4	Many: > 200 roots/dm^2, or more than 16 on a line 50 cm long.
7.15		**Density of worm channels (usually average over number of square decimetres)**
7.15	0	No worm channels.
7.15	1	Few: ≤ 1/dm^2 on the vertical face of the horizon.
7.15	2	Common: 1 to 2/dm^2.
7.15	3	Abundant: > 2/dm^2.
7.16		**Nature of lower horizon boundary**
7.16	1	Smooth
7.16	2	Wavy
7.16	3	Irregular
7.16	4	Broken

Annex C
(informative)

Construction of XML files

C.1 XML implementation

C.1.1 Overview

The UML model as described in 5.4 and Clause 6 has to be translated into a form in which it supports the physical exchange of soil data. This International Standard encodes soil data using the eXtended Markup Language (XML) developed by the World Wide Web consortium (W3C). XML provides a way to encode data in simple text files. In order to make these data files better operational, XML files shall be encoded according to some structure. This structure is defined in an XML schema definition file (XSD). XSD is a specification also developed by W3C. These XSD files are themselves XML encoded text files that conform to strict rules. It is a very sophisticated mechanism widely used in many standards (e.g. ISO 19118 or ISO 19136) and can be processed with and by many software solutions.

This International Standard provides an XSD called **soilml.xsd** which is the XSD file for SoilML data files (i.e. any soil data file encoded with and complying with soilml.xsd or an extension of it does comply with this International Standard).

Soilml.xsd is based on existing Geography Markup Language (GML) XSD files, because the GML schemas represent ISO 191xx models on which the model of this International Standard is based.

This International Standard expects that every data provider extends SoilML classes with properties which are suitable for his or her data model, or simply fill the attributes for which (s)he has data. This extension of the SoilML UML model shall also appear in the XSD. Therefore, the data provider has to create two different kinds of files:

a) an extended **soilml.xsd** (XSD file).

b) the file that holds the soil data (XML file, data file).

The rules for creating an extension of SoilML (soilml.xsd) are described in C.3. The encoding of soil data are described in C.2 (according to basic SoilML) and C.4 (according to an extended SoilML).

C.1.2 SoilML XML schema soilml.xsd

The soilml.xsd is presented in C.6. The schema imports existing schemas of the GML and of OM, on which the SoilML application schema is based. SoilML corresponds with GML principles, so an at least basic understanding of GML principles enhances the understanding of SoilML XML schema. As in any xsd file, the generic W3C XML schema has to be imported into soilml.xsd as well.

The SoilML XML schema contains definition of following feature types:

— AnalysisRequest;

— Borehole;

— Horizon;

— Layer;

— ObservationProcess;

— Plot;

— PreparationProcess;

— Profile;

— ProfileElement;

— Project;

— Site;

— SoilMap;

— SoilMappingUnit;

— SoilMappingUnitCategory;

— SoilObservation;

— SoilSpecimen;

— SoilTypologicalUnit;

— Surface;

— TransportAndStorage;

— TrialPit.

Every feature type is represented by the following.

— One global GML element named after the feature type (e.g. Site or TrialPit) which represents the feature instance (e.g. an instance of the feature type site is one specific site).

  This element contains local sub-elements representing feature properties.

— One global GML type named after the feature type with the suffix “Type” (e.g. SiteType or TrialPitType).

— One global GML property type named after the feature type with “PropertyType” suffix (e.g. SitePropertyType or TrialPitPropertyType).

Furthermore, the Depth data type is represented in very similar way as the feature types. Depth data type is in detail described in C.2..

C.2 Encoding soil data according to basic SoilML

According to this International Standard, soil data should be encoded in an XML file — here called a **data file** — which shall be conformant to the following rules.

— The XML file shall be valid to the XML schema recommended for this International Standard (**soilml.xsd**) or an extension of it.

— The XML file shall comply with general GML 3.2.1 principles.

The following paragraphs should be considered as an informal introduction to basic GML principles.

In GML, every feature is represented by one element named by its feature type. Every feature shall also have a gml:id identifier which should be unique within the whole XML document. Object properties are represented by sub-elements named exactly as in the UML model.

```
<Project gml:id=”project1”>
  <name>Sulingen</name>
```

```
    <siteOfInterest xlink:href="#site1"/>
  </Project>
```

A property can be an expression of an attribute, but also a relation to another object. The latter is called an association. If a property is an association, the associated object is represented by reference (see in the example above) or can be inserted inline:

```
  <Project gml:id="project1">
    <name>Sulingen</name>
    <siteOfInterest>
      <Site gml:id="site1">
        <concernedProject xlink:href="#project1"/>
        <position>
          <gml:Point gml:id="point1" srsName="urn:x-ogc:def:crs:EPSG::4326">
            <gml:pos>17.45820 58.45656</gml:pos>
          </gml:Point>
        </position>
        ...
      </Site>
    </siteOfInterest>
  </Project>
```

Every soil database consists of many objects, but the GML schema allows to store only one GML feature. Therefore, it is suitable to use gml:FeatureCollection as the root element for storing more than one object in one file. Then every object is nested within one gml:featureMember property (e.g. Project, Site, or Plot in the following example) of the collection or is nested as a value of an inline property within another object (e.g. Borehole inside Site's samplingPlot property in the following example).

EXAMPLE A complete data file encoded according to this International Standard basic XML schema soilml.xsd: One project with one site on which two plots are located.

```
<?xml version="1.0" encoding="UTF-8"?>
<gml:FeatureCollection gml:id="coll1"
xmlns="http://www.iso28258.org"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:om="http://www.opengis.net/om/2.0"
xmlns:sam="http://www.opengis.net/sampling/2.0"
xmlns:sams="http://www.opengis.net/samplingSpatial/2.0"
xsi:schemaLocation="http://www.iso28258.org http://iso28258.org/0.1/soilml.xsd">
  <gml:description>Collection of Soil Features</gml:description>
  <gml:name>Soil Collection</gml:name>

  <gml:featureMember>
    <Project gml:id="project1">
      <name>Sulingen</name>
      <siteOfInterest xlink:href="#site1"/>
    </Project>
  </gml:featureMember>

  <gml:featureMember>
    <Site gml:id="site1">
      <concernedProject xlink:href="#project1"/>
      <position>
        <gml:Point gml:id="point1" srsName="urn:x-ogc:def:crs:EPSG::4326">
          <gml:pos>17.45820 58.45656</gml:pos>
        </gml:Point>
      </position>
      <samplingPlot xlink:href="#plot1"/>
      <samplingPlot>
        <Borehole gml:id="plot2">
          <sam:type xlink:href="http://www.opengis.net/def/samplingFeatureType/OGC.
```



```
OM/2.0/SF_SamplingPoint" />
          <sam:sampledFeature xlink:href="#site1"/>
          <sams:shape xlink:href="#point1" />
        </Borehole>
      </samplingPlot>
    </Site>
  </gml:featureMember>


  <gml:featureMember>
    <Plot gml:id="plot1">
      <sam:sampledFeature xlink:href="#site1"/>
      <sams:shape>
        <gml:Point gml:id="point2" srsName="urn:x-ogc:def:crs:EPSG::4326">
          <gml:pos>17.05835 59.54635</gml:pos>
        </gml:Point>
      </sams:shape>
    </Plot>
  </gml:featureMember>


</gml:FeatureCollection>
```

Remember to specify also a complete and correct list of namespaces used.

Spatial reference system (SRS) is defined for each object through the srsName = "**urn:x-ogc:def:crs:EPSG::4326**" attribute (see listing above). The part srsName = "**urn:x-ogc:def:crs:EPSG:** remains the same for all SRS definitions while the numeric code (with typically four digits) defines the spatial reference system itself. The list of relevant code values and corresponding spatial reference systems may be found at http://www.epsg-registry.org/.

EXAMPLE 1 The definition srsName = "**urn:x-ogc:def:crs:EPSG::4326**" indicates the World Geodetic System 1984 (WGS84), i.e. longitude and latitude in decimal degrees.

It is common to use a technique called *xlink* in XML documents. This technique enables almost any part of an XML to be connected with almost any part of the same or different XML. The *xlink* attribute in XML shall include the *href*, i.e. specification of the link's destination.

EXAMPLE 2 See the xlink:href = "**#plot1**" listing that enables linking the *plot1* from the *project1.*

Finally, it is important to validate the data file against the XML schema of this International Standard to an extension of it.

C.3 Extending SoilML

C.3.1 Motivation

SoilML is a quite general application schema to be sufficiently universal for most of the existing and future soil quality data and applications. The model introduces many classes (especially feature types) related to soil quality data with special focus on the spatiotemporal aspect of soil. On the other hand, the model introduces a quite limited set of properties. This is because it is expected that **every data provider extends SoilML classes with properties which are suitable for his or her data model**. The conceptual level of this extensibility mechanism is described in C.3.2, whereas the implementation level (XML schema) is described in C.3.3.

Before elaborating such an extension, it is advisable for the data provider to consider whether he or she wants (or needs) or does not want to use **SoilObservation** in the extended application schema. Using SoilObservation does mean making higher effort, but gives opportunities to transfer many object-level meta-data (e.g. observation process for each observation independently). The decision-making process is described in detail in Clause 5.

C.3.2 Extending the application schema

SoilML provides the possibility to extend every class (feature type, data type, or type) with one or more properties. Such an added property can be an attribute (simple or complex) or an association role. A simple attribute holds one simple value, e.g. one character string or one numerical value, while a complex attribute holds two or more simple or further complex attributes. The extended application schema shall conform to ISO 19109 rules for application schemas. Respecting following steps ensures that the extended application schema meets all ISO 19109 rules.

NOTE It is reasonable, but not necessary, to make the extension in some UML modelling tool. However, the extension can also be made directly on the implementation level (by only producing an xsd file) without modelling it on the conceptual level (see C.3.3).

The extension of the SoilML application schema typically consists of the following steps.

a) Consider which properties are added to which classes.

This depends primarily on what the data provider would like to describe.

EXAMPLE 1 Data provider XY has soil data which contain plot elevation and humus content and colour of horizons. Those properties are not part of the SoilML application schema, so XY needs to extend it. XY extends Plot class with the property elevation and the Horizon class with the properties humus content and colour. (In the following example phrases, this is related to as the XY example.)

b) Choose extended class names.

Extended class names shall be unique within the application schema and shall meet following conditions: alphanumeric characters only, no number at first position, upper first letter, and camel case (i.e. any new word within the name starts again with uppercase, e.g. CamelCase). The name typically (but not necessarily) consists of the parent class name with a prefix related to the data provider or the database.

EXAMPLE 2 Class names could be *XYPlot* and *XYHorizon*.

c) Choose property names

Property names shall be unique within the class and shall meet the following conditions: alphanumeric characters only, no number at first position, lower first letter, and camel case (e.g. CamelCase).

EXAMPLE 3 Property names could be e.g. *elevation*, *humusContent*, and *colour*.

d) Choose property multiplicity

Multiplicity is the specification of the number of property values related to one object. It can be one number or a range. Typically it is 0 to 1, exactly 1, 0 to several (many), and 1 to several/many. Also any natural number (positive integer numbers) can be used.

EXAMPLE 4 In the XY schema there was chosen multiplicity 1 for all added properties.

NOTE In UML, giving no multiplicity means 1, several or many is expressed with a star *, Zero with 0. In the UML diagrams, a range consists of its two boundary values, separated by two dots, e.g. 0..1 or 0..*.

e) Choose the value domain of the property

In this step, the data provider shall consider and precisely determine the character of the property values to choose the right value domain. The most typical and preferable domains are:

— Integer

Integer typically represents count of some elements. Possible values are all integer numbers.

EXAMPLE 5 Possible values are e.g. –278, 0, 1, or 3542.

— Measurement

Measurement represents a real number having some unit of measurement. Values are real numbers with unit.

EXAMPLE 6 Possible values are e.g. 128 m, 0.25 kg, 100 km/h, or 20 %.

EXAMPLE 7 In the XY example, property elevation is definitely a measurement.

NOTE For dimensionless measurements, the unit of measurement stays empty, e.g. for pH values.

— Enumeration

Enumeration represents a set of named values. In the case of evaluation, the data provider needs to make a list all of possible values.

EXAMPLE 8 Day of the week is an enumeration of the values “Monday”, “Tuesday”, Wednesday”, “Thursday”, “Friday”, “Saturday”, and “Sunday”.

EXAMPLE 9 In the case of humus content, the XY database contains only few possible values: h0 – h7. Therefore the humus content can be considered as an enumeration of the values h0, h1, h2, h3, h4, h5, h6, h7.

— Boolean

Boolean represents true/false values.

— Free text

Free text represents a character string without fixed structure, typically a name or descriptive information.

— Record

Record represents types having a value composed of one or more simple (of the types listed above) sub-values.

EXAMPLE 10 XY Horizon colour is represented by up to three values from the same code list, and their order is part of the information (like grey, blue, and green for greyish blue-green), and can be considered a record.

— Object (Feature Type or Type)

This domain represents all properties which are considered as associations (links between objects). In this case, the data provider shall determine the feature type (or type) this association relates to. It can be the feature type of this International Standard’s specification or it can be any other feature type of the ISO 191xx family of International Standards (e.g. ISO 19107 for spatial types and ISO 19108 for date and time types).

f) Choose property data type according to its domain

In the last step, the data provider needs to determine the property data types holding the property values. The property data type depends on the property domain specified in previous step. In the case of **Integer**, **Measurement**, **Boolean**, and **Free text** domains, property data type should be represented by data types listed in Table C.1.

Table C.1 — Domains and suitable ISO 19103 data types

Property domain	**Suitable** ISO 19103 **data type**
Integer	Integer
Measurement	Measure (and its subtypes Angle, Length, Weight, Volume, Area)
Boolean	Boolean
Free text	CharacterString

In the case of **Enumeration** and **Record**, the property data type is also a data type, but choosing the latter one is more complicated.

Preferably, a data provider should try to find existing suitable data types in this International Standard (e.g. “Depth” data type) or in one of the ISO 191xx family of International Standards (e.g. ISO 19103 for basic data types).

This International Standard defines new data types on the top of the data types originating from the other International Standards. Following data types were defined to cover the aspects of horizons and layers, including the ones with not strictly horizontal boundaries:

— Depth;

— CS_MultiplicityRangeType.

Depth data type consists of two ways of expressing the depth of a soil horizon or a layer. The first option enables description of information on depth in one single number, e.g. 60 cm. The latter option supports the information on depth range through the CS_MultiplicityRangeType data type. CS_MultiplicityRangeType consists of two elements:

— maxDepth (maximum depth of a soil horizon/layer)

— minDepth (minimum depth of a soil horizon/layer)

Both ways of expression incorporate definition of units of measure, i.e. the *uom* concept similarly to other International Standards (e.g. ISO/TS 19139). In other words, each depth element presented above contains the mandatory *uom* attribute.

EXAMPLE Minimum depth 23.7 cm would be encoded in the following way:

```
<sq:minDepth uom="cm">23.7</sq:minDepth>
```

If the data provider did not find a suitable data type, a new one is to be defined. This is very likely in the case of special enumerations or records. In this phase, it is necessary to choose the enumeration or record name. The name shall meet the following conditions: alphanumeric characters only, no number at first position, upper first letter, and camel case. Furthermore, the name shall be unique within the application schema classes. The implementation phase of defining new data types is described in the following part.

EXAMPLE In the XY example, the data type names can be “*HumusContentEnumeration*” for humus content enumeration and “*Colour*” for colour record.

In the case of **Objects (Feature Types** or **Types)**, the property data type is the feature type (or type) itself that was determined in the previous step.

C.3.3 Extending the XML schema

Whereas C.3.2 describes the extension of the SoilML application schema on the conceptual level, this section describes how to create extended SoilML XML schemas. For every extended SoilML application schema, one extended XML schema definition file is needed. The extended XML schema definition shall conform to following rules:

a) The document is a valid XML schema.

b) The document namespace is set to “ISO 28258” namespace.

c) The basic XML schema for this International Standard (SoilML) or one of its extensions is included using the “include” element.

d) Every extended class shall be defined according to GML 3.2.1 principles.

The mechanisms described in this sublause comply with GML 3.2.1 principles, so it is advisable that those not familiar with GML 3.2.1 follow it.

EXAMPLE A complete example of the extension mechanism is available in **soilmlXY.xsd** (extended SoilML Schema) and **soilmlXY.xml** (data file).

C.3.3.1 Extending classes

The extension mechanism described below complies with GML 3.2.1 principles (see GML 3.2.1, E.2.4.3–E2.4.10). Other possibilities provided by XML schema (e.g. extension only by type or type redefinition) probably do not correspond with GML 3.2.1 principles, and hence are deprecated here.

A class extension meets following requirements. Two global elements shall be created for every class:

a) For every class, one global “complexType” element is created with

— the mandatory attribute “name” set to extended class name with the suffix “Type” appended,

— inner elements “xsd:complexContent/xsd:extension/xsd:sequence” with “base” attribute of the second element set to parent class GML type. Within these elements, every added property is defined according to GML 3.2.1 principles (see C.3.3.3).

This element represents the class type.

b) For every class, one global “xsd:element” element is created with

— the mandatory attribute “name” set to extended class name,

— the mandatory attribute “substitutionGroup” set to name of parent class instance element,

— the mandatory attribute “type” set to name of parent class type.

This element represents the class instance.

The documentation should be written inside “xsd:annotation/xsd:documentation” elements.

EXAMPLE According to these rules, XYPlot class should be represented as

```
<xsd:complexType name="XYPlotType">
  <xsd:annotation>
    <xsd:documentation>Extension of a Plot type.</xsd:documentation>
  </xsd:annotation>
  <xsd:complexContent>
    <xsd:extension base="PlotType">
      <xsd:sequence>
        ...{added properties}...
      </xsd:sequence>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
<xsd:element name="XYPlot" substitutionGroup="Plot" type="XYPlotType" />
```

This extension mechanism changes the element name of the class. Therefore, every encoded object of the extended class in the data file shall use the new class name as element name (e.g. “XYPlot” instead of “Plot”).

NOTE Extending a class in this way does not affect its subclasses (if existing). This means that if e.g. the Plot class is extended with the property “elevation”, its subclasses (Borehole, TrialPit, and Surface) are not automatically extended with this property.

A complete example of this extension mechanism is available in **soilmlXY.xsd** (extended XML schema according to this International Standard) and **soilmlXY.xml** (data file).

C.3.3.2 GML type

Before adding a new property to the extended class, the data provider needs to determine the GML type of the property. The GML type depends on the property domain and property data type (see last steps in C.3.2).

In the cases of **Integer**, **Measurement**, **Boolean**, **CharacterString**, and **Enumeration**, there exist plenty of predefined GML types (see Table C.2). The data provider should choose one of them.

Table C.2 — Suitable GML types

Property data type	Suitable GML type	Suitable GML nillable type
Integer	xsd:integer, xsd:nonPositiveInteger, xsd:negativeInteger, xsd:nonNegativeInteger, xsd:positiveInteger	
Measure	gml:MeasureType, gml: AngleType, gml:LengthType, gml: WeightType, gml:VolumeType, gml:AreaType	
Enumeration	xsd:enumeration, gml:CodeType + gml:Dictionary	
Boolean	xsd:boolean	gml:booleanOrNilReason
CharacterString	xsd:string	gml: stringOrNilReason

In the case of **Enumeration** defined by the data provider, the xsd:enumeration is simpler and a local solution, because the enumeration is defined inside the XML schema (see GML 3.2.1, E.2.4.8). On the other hand, gml:CodeType shall refer to the external gml:Dictionary which represents the enumeration; in this case, the dictionary can be referred to from more than one exchange file (see GML 3.2.1, E.2.4.8, Example 2).

In the case of **xsd:enumeration**, a new GML type shall be created by the data provider inside the extended XML schema. The new type shall conform to the following rules:

a) Every enumeration type is represented by one global “xsd:simpleType” element with

— the mandatory attribute “name” set to enumeration type name with suffix “Type” (the name was determined in the last step of C.3.2),

— the inner element “xsd:restriction” with the attribute “base” specifying the name of the GML type suitable for the enumeration values (typically “xsd:string”),

— an optional attribute “id” set to enumeration type name. See C.5.3.1 for the rationale of the attribute.

This element represents the data type itself.

b) Every enumeration value is represented by “xsd:enumeration” element located inside “xsd:restriction”. The enumeration value is specified in attribute “value”.

The documentation of the enumeration type should be written inside “xsd:annotation/xsd:documentation” elements, where as the documentation of any enumeration value should be written inside “xsd:annotation/xsd:appinfo/gml:description” elements (see GML 3.2.1, E.2.4.9, Example 1).

EXAMPLE 1 According to enumeration encoding rules, XY humus content can be encoded as follows:

```
<xsd:simpleType name="HumusContentEnumerationType" id="HumusContentEnumeration">
  <xsd:annotation>
    <xsd:documentation>Enumeration for humus content.</xsd:documentation>
  </xsd:annotation>
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="h0">
      <xsd:annotation>
        <xsd:appinfo>
```



```
          <gml:description>No humus at all.</gml:description>
        </xsd:appinfo>
      </xsd:annotation>
    </xsd:enumeration>
    <xsd:enumeration value="h1"/>
    <xsd:enumeration value="h2"/>
    <xsd:enumeration value="h3"/>
    <xsd:enumeration value="h4"/>
    <xsd:enumeration value="h5"/>
    <xsd:enumeration value="h6"/>
    <xsd:enumeration value="h7"/>
  </xsd:restriction>
</xsd:simpleType>
```

In the case of a **Record** defined by the data provider, a new GML type shall be created by the data provider inside the extended XML schema. Three global elements shall be created:

a) For every record type, one global “xsd:complexType” element is created with

— the mandatory attribute “name” set to record type name with “Type” suffix (the name was determined in the last step given in C.3.2),

— an optional attribute “id” set to record type name (see C.5.3.1 for the rationale of the attribute), and

— an inner element “xsd:sequence” in which the structure of sub-values is specified.

The structure depends on the data provider).

This element represents the data type itself.

b) For every record type, one global “xsd:element” element is created with

— the mandatory attribute “name” set to record type name,

— the mandatory attribute “type” set to previous element name (record type name with suffix “Type”), and

— the mandatory attribute substitutionGroup set to “gml:AbstractObject”.

This element represents an instance of the data type.

c) For every record type, one global “xsd:complexType” element is created with

— the mandatory attribute “name” set to record type name with suffix “PropertyType”, and

— an inner element “xsd:sequence/xsd:element”.

The “xsd:element” element has the attribute “ref” set to record type name with SoilML namespace prefix.

This element represents the GML property type (see GML 3.2.1, parts 7.2.3 and E.2.4.11).

The documentation of the enumeration type can be written inside “xsd:annotation/xsd:documentation” elements for each of those three elements.

EXAMPLE 2 According to the record encoding rules, XY colour can be encoded as follows. Note that every sub-value (red, green, blue) is represented by one sub-element; this is the pattern each data type should follow:

```
  <xsd:complexType name="ColourType" id="Colour">
    <xsd:annotation>
      <xsd:documentation>Colour is a datatype which is defined by three integers, each for
one RGB band.</xsd:documentation>
    </xsd:annotation>
    <xsd:sequence>
      <xsd:element name="red">
        <xsd:simpleType>
```

```
        <xsd:restriction base="xsd:integer">
          <xsd:minInclusive value="0"/>
          <xsd:maxExclusive value="255"/>
        </xsd:restriction>
      </xsd:simpleType>
    </xsd:element>
    <xsd:element name="green">
      <xsd:simpleType>
        <xsd:restriction base="xsd:integer">
          <xsd:minInclusive value="0"/>
          <xsd:maxExclusive value="255"/>
        </xsd:restriction>
      </xsd:simpleType>
    </xsd:element>
    <xsd:element name="blue">
      <xsd:simpleType>
        <xsd:restriction base="xsd:integer">
          <xsd:minInclusive value="0"/>
          <xsd:maxExclusive value="255"/>
        </xsd:restriction>
      </xsd:simpleType>
    </xsd:element>
  </xsd:sequence>
</xsd:complexType>
<xsd:element name="Colour" substitutionGroup="gml:AbstractObject" type="ColourType" />
<xsd:complexType name="ColourPropertyType">
  <xsd:sequence>
    <xsd:element ref="sq:Colour"/>
  </xsd:sequence>
</xsd:complexType>
```

In the case of **Object** (**FeatureType** or **Type**), the data provider should find a corresponding GML type and GML property type in an existing GML schema, including SoilML.

C.3.3.3 Adding properties to extended classes

After locating (or creating) GML types for adding properties, the data provider should continue with adding properties to the extended classes (see C.3.3.1). The extension mechanism described below corresponds to GML 3.2.1 principles (see GML 3.2.1, E.2.4.11).

Property addition complies with the following rules. Every added property is represented by one local “xsd:element” which is located inside “xsd:complexContent/xsd:extension/xsd:sequence” elements of the extended class. The local property element has the following:

— a mandatory attribute “name” set to property name;

— a mandatory attribute “type”: in the case of a simple content, i.e. **Integer**, **Measurement**, **Enumeration**, **Boolean**, **CharacterString**, the attribute is set to GML type (data type with suffix “Type”); in the case of a complex content, i.e. **Record** or **Object** (**FeatureType** or **Type**), the attribute is set to GML property type (data type with suffix “PropertyType”);

— optional attributes “minOccurs” and “maxOccurs”, representing multiplicity of the property (specified in C.3.2);

— optional attribute “id” set to string composed of extended class name + “_” + property name. See C.5.3.1 for a rationale of the attribute;

— if the property is considered as nillable (not mandatory to contain a value), it shall be encoded also according to GML 3.2.1, 8.2.3.2.

EXAMPLE 1 Property *elevation* of XYPlot is a measurement, so it is specified by the respective GML type:

```
<xsd:complexType name="XYPlotType">
  <xsd:annotation>
    <xsd:documentation>Extension of a Plot type.</xsd:documentation>
```

```
    </xsd:annotation>
    <xsd:complexContent>
      <xsd:extension base="PlotType">
        <xsd:sequence>
          <xsd:element id="XYPlot_elevation" name="elevation" type="gml:MeasureType"
minOccurs="1" maxOccurs="1"/>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
```

EXAMPLE 2 Property *humusContent* of XYPlot is an Enumeration, so it is specified by the respective GML type. Property *colour* is a Record, so it is specified by the respective GML property type:

```
  <xsd:complexType name="XYHorizonType">
    <xsd:annotation>
      <xsd:documentation>Extension of a Horizon type.</xsd:documentation>
    </xsd:annotation>
    <xsd:complexContent>
      <xsd:extension base="HorizonType">
        <xsd:sequence>
          <xsd:element id="XYHorizon_humusContent" name="humusContent" type="HumusContentE
numerationType" minOccurs="1" maxOccurs="1" />
          <xsd:element id="XYHorizon_colour" name="colour" type="ColourPropertyType"
minOccurs="1" maxOccurs="1"/>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
```

C.4 Encoding soil data according to extended SoilML

Encoding soil data according to an extended SoilML schema shall follow the same rules as specified in C.2. The only additional requirement is that the data file shall be valid to the appropriate extended SoilML Schema.

EXAMPLE The root element of the data file encoded according to extended SoilML. Note the change of "xsi:schemaLocation" attribute compared to the last example in C.2.

```
<?xml version="1.0" encoding="UTF-8"?>
<gml:FeatureCollection gml:id="coll1"
    xmlns="http://www.iso28258.org"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:gml="http://www.opengis.net/gml/3.2"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:om="http://www.opengis.net/om/2.0"
    xmlns:sam="http://www.opengis.net/sampling/2.0"
    xmlns:sams="http://www.opengis.net/samplingSpatial/2.0"
    xsi:schemaLocation="http://www.iso28258.org soilmlXY.xsd">
```

C.5 SoilObservation feature type

SoilObservation is a unique feature type of SoilML which brings a special mechanism related to feature property values. It is a subtype of ISO 19156 OM_Observation feature type.

C.5.1 Motivation

The SoilObservation enables even more complex description of soil data and it should be considered very carefully whether to use it or not. There exist at least two cases for which it is suitable to use SoilObservation.

First, the data provider wants to exchange information about **when, how, by whom, etc. was obtained one (or more) property value(s)**. This is very commonly described by textual information in the metadata section, but SoilObservation enables encoding of this in a structured way and independently for each piece of data.

Second, the data provider wants to encode **more than one observation of a property of an individual feature which differ e.g. in point in time, observing procedure, etc**. This is sometimes implemented by several different properties (e.g. humusContent1980 and humusContent1990 for humus content in two different years), but SoilObservation brings a semantically correct solution.

If the data provider does not want to encode such type of information, then it is sufficient not to use SoilObservation in the data file at all. If the data provider decides to use SoilObservation, there is one more crucial decision to be made which is described in detail in C.5.2.3.

C.5.2 Concept of SoilObservation

C.5.2.1 Relation to OM_Observation

SoilObservation is a subtype of OM_Observation which is a crucial feature type of ISO 19156 (see ISO 19156:2011, 6.1.2).

An observation is an act associated with a discrete time instant or period through which a number, term or other symbol is assigned to a phenomenon. It involves application of a specified procedure, such as a sensor, instrument, algorithm, or process chain. The procedure may be applied *in situ*, remotely, or *ex situ* with respect to the sampling location. The result of an observation is an estimate of the value of a property of some feature. Use of a common model allows observation data using different procedures to be combined unambiguously.

The OM_Observation enables information to be described such as "The property elevation of the site XY-23 was measured by GPS device type NN on 2007-15-04 with the result 49m." In other words, OM_Observation enables additional information about any individual property value to be described.

— The observed property is identified through OM_Observation *observedProperty* property.

— The feature whose property it is through *featureOfInterest*.

— The way how it was measured through *procedure*.

— The time when it was measured through *phenomenonTime*.

— The observed value through *result*.

— etc.

See Figure C.1 for a detailed model of OM_Observation.

SoilObservation as a subtype of OM_Observation therefore enables additional information about any soil-related property value to be described. In comparison to OM_Observation, SoilObservation has two restrictions.

a) Property SoilObservation.**featureOfInterest** is restricted to Site, Plot, Profile, ProfileElement, and SoilSpecimen including all their subtypes.

b) Within the basic application schema of this International Standard, only the properties listed in Table C.3 may be (but not need to be) considered as observable (i.e. property SoilObservation.**observedProperty** may refer to the following properties of the basic application schema of this International Standard).

However, the set of observable properties can and should be extended with provider-specific properties related to Site, Plot, Profile, ProfileElement and/or SoilSpecimen, including their subtypes.

EXAMPLE In the XY example, all three added properties can be considered as observable and therefore described also by SoilObservation.

Observed property can be a simple attribute as well as an association role, so it is possible to observe Plot.elevation as well as Plot.profile. Observation of a Plot.profile can be considered as related not only to Profile itself, but also to its property values (elements, meaning Layers and Horizons, their order, depths, etc.).

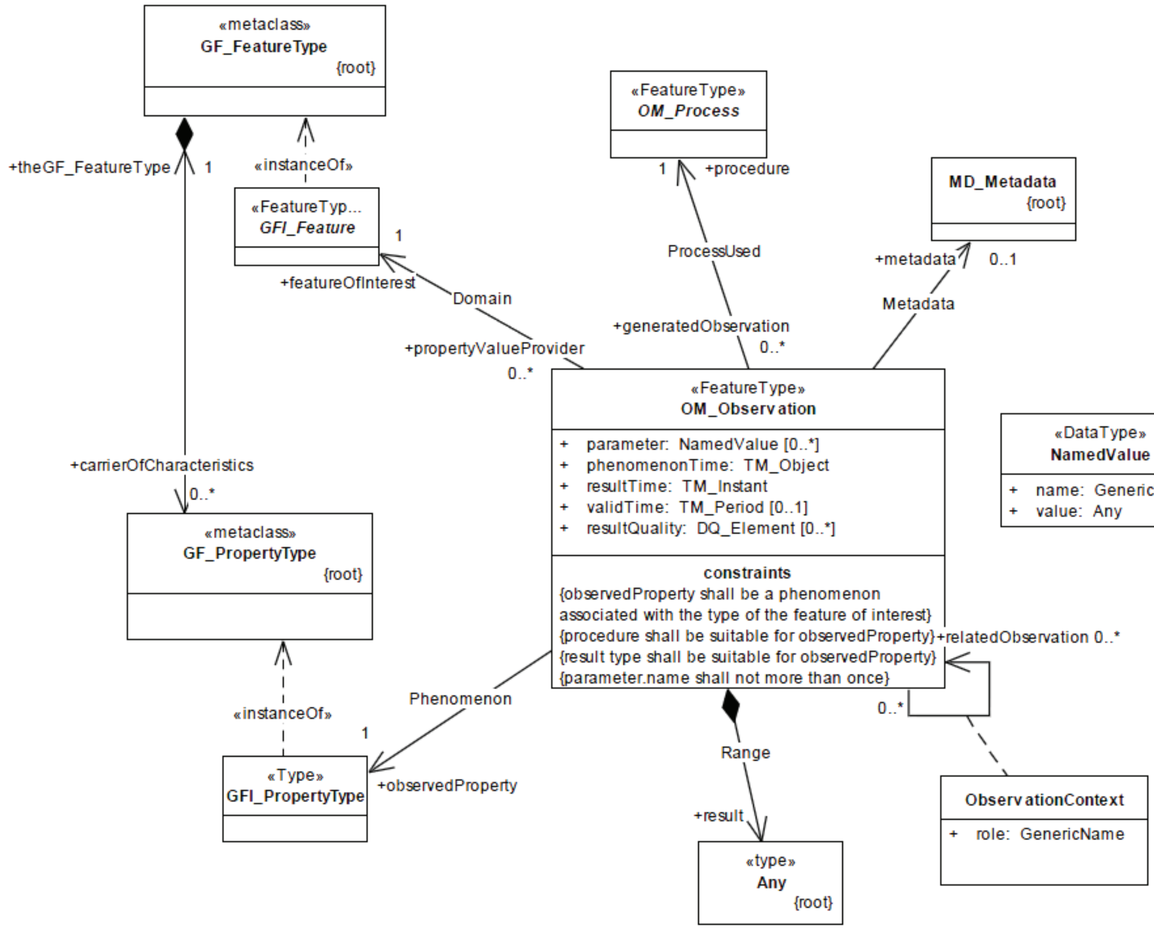


Figure C.1 — OM_Observation type (from **ISO 19156**)

Table C.3 — Observable properties according to basic application schema of this International Standard

FeatureType.Property	Result type	Suitable property type
Layer.developedHorizon	sq:Horizon	sq:HorizonPropertyType
Plot.profile	sq:Profile	sq:ProfilePropertyType
Profile.element	sq:ProfileElement	sq:ProfileElementPropertyType
ProfileElement.order	xs:integer	xs:integer
ProfileElement.upperDepth	sq:Depth	sq:DepthPropertyType
ProfileElement.lowerDepth	sq:Depth	sq:DepthPropertyType
Site.position	gml:Point	gml:PointPropertyType
Site.extent	gml:Polygon	gml:SurfacePropertyType
Site.typicalProfile	sq:Profile	sq:ProfilePropertyType
SoilSpecimen.depth	sq:Depth	sq:DepthPropertyType

C.5.2.2 Observable Property Types

All property types listed in Table C.3 are considered observable, whereas other properties from the basic SoilML application schema are considered as unobservable. All properties added by data providers in extended schemas are generally considered as observable. However, if the property type was really observed or not can differ from data file to data file.

C.5.2.3 Modelling observable property types

ISO 19156 contains a very important note concerning SoilObservation.**observedProperty** (see ISO 19156, 6.2.2.8):

NOTE An observed property may, but need not be modelled as a property (in the sense of the General Feature Model) in a formal application schema that defines the type of the feature of interest.

The meaning of this note is explained in detail in the following paragraphs.

The General Feature Model (GFM, see ISO 19109) specifies that every feature type consists of zero or more property types describing its characteristics, and every property type is always linked to exactly one feature type. Therefore every application schema consists of definitions of certain feature types, and those in turn consist of several property types definitions. The same mechanism is used in C.3, because the data provider extends a specific feature type with specific property types, so the property type is always linked to one feature type.

EXAMPLE SoilML SoilSpecimen feature type consists of five property types:

— *depth* (defined by SoilML)

— *processingDetails* (inherited from SF_Specimen, ISO 19156)

— *sampledFeature* (inherited from SF_SamplingFeature, ISO 19156)

— *relatedObservation* (inherited from SF_SamplingFeature, ISO 19156)

— *relatedSamplingFeature* (inherited from SF_SamplingFeature, ISO 19156).

All these property types are modelled as properties in the sense of the General Feature Model, because they are defined in the application schema(s) for specific feature type.

However, the note from ISO 19156 cited above enables through SoilObservation to connect a property value with a feature whose feature type does not contain a corresponding property type. It means that it is possible to encode, e.g. an observation of weight of a soil specimen even if the SoilSpecimen class does not contain the weight property (the weight property of the SoilSpecimen class is not defined nor in ISO 19156 neither in SoilML application schema nor its extension). In other words, using SoilObservation brings two options:

a) to model observed property type as property in sense of GMF, or

b) not to model observed property type as property in sense of GMF.

This raises a question as to whether to model property type as a property in the sense of GFM or not. The second option can, but need not to be suitable in the following cases:

— If the data provider wants to encode a property value of a property type which was already defined by some external authority, e.g. **soil gazetteer**.

— If the data provider knows that there usually exists **more than one observation of the property for individual features**.

Modelling property type as a property in the sense of GFM usually leads to duplication in the data file (see C.5.3.2); the second option does not lead to duplication at all.

In the case of modelling property type as a property in the sense of GFM, a data user should know about the property type from the extended SoilML application schema. However, the extended SoilML application schema does not contain any information about the existence of an observed property type in the case of the second option. In this case, the information should be described in textual metadata of the data set.

EXAMPLE A data provider needs to encode weight of a soil specimen using SoilObservation. There are two ways to do this.

— The **first** is to extend SoilSpecimen with a property *weight* in the sense of GFM according to C.3. The extended feature type, called e.g. ExtendedSoilSpecimen, now consists of six property types: *weight* plus those five from previous example. In this case, SoilObservation.observedProperty will refer to ExtendedSoilSpecimen.weight property type.

— The **second** is not to extend SoilSpecimen, but to use some external resource where meaning of “weight” is defined without connection to a specific feature type. Such resource can be e.g. soil gazetteer. The only requirement to use this way is that the property shall be identifiable by URI (see C.5.3.1). Furthermore, the data provider needs to choose or create an appropriate data type for the weight property even if it is external (see last step in C.3.2).

NOTE The weight property is defined e.g. in GEMET Thesaurus (http://www.eionet.europa.eu/gemet/). The weight URL is http://www.eionet.europa.eu/gemet/concept?cp=9286. In this case, SoilObservation.observedProperty will refer to GEMET weight definition by the URL.

C.5.3 Encoding SoilObservation

SoilObservation objects shall be encoded as any other feature according to the SoilML schema (see C.2).

EXAMPLE 1 An encoded SoilObservation object:

```
<SoilObservation gml:id="obs1">
  <om:phenomenonTime>
    <gml:TimeInstant gml:id="ot1">
      <gml:timePosition>2005-01-11</gml:timePosition>
    </gml:TimeInstant>
  </om:phenomenonTime>
  <om:resultTime xlink:href="#ot1"/>
  <om:procedure>
    <ObservationProcedure gml:id="obsproc1">
      <description>GPS eTrex Legend</description>
    </ObservationProcedure>
  </om:procedure>
  <om:observedProperty xlink:href="soilmlXY.xsd#XYPlot_elevation"/>
  <om:featureOfInterest xlink:href="#plot1"/>
  <om:result xsi:type="gml:MeasureType" uom="m">107</om:result>
</SoilObservation>
```

EXAMPLE 2 A complete example of a data file with encoded SoilObservation objects is given in C.7.

The following two sections focus on two special SoilObservation properties: observedProperty and result.

C.5.3.1 Encoding SoilObservation.observedProperty

OM 2.0 XML schema requires that every observable property is identified by a URI, because the schema uses the property identifier when referring from OM_Observation.**observedProperty**. The property URI can be an URN or URL:

URN example: urn:GSSoil:property:Weight

URL example: http://www.gssoil.eu/def/properties.xml#Weight

In any case, there shall be a document where the property is defined together with its identifier. OM does not require any specific structure of the document; it can be a simple GML dictionary or a complex OWL ontology.

NOTE The document can be used to give further information on an attribute, e.g. if the attribute value is of the enumeration type, for each value of the enumeration further details could be provided. Considering the humus content example above, for the humus content values h0 to h7 the class boundaries (% m/m organic matter) could be specified to give the data user an idea about the meaning of the values.

When a reference to property types of the basic SoilML application schema is to be made, it is recommended that an URL identifier composed of the path to the SoilML XML schema + "#" + property id be used. The "id" attribute is defined in SoilML XML schema for every observable property.

EXAMPLE 1 The property *depth* of SoilSpecimen can be referred to as

```
<om:observedProperty xlink:href="path/to/soilml.xsd#SoilSpecimen_depth"/>
```

For referring to property types of the extended application schema of this International Standard, it is recommended that an URL composed of the path to the extended SoilML application schema + "#" + property id be used. This is the reason why the data provider should define also the "id" attributes of the property elements and data types (see C.3.3.2 and C.3.3.3).

EXAMPLE 2 The property *elevation* of XYPlot can be referred to as

```
<om:observedProperty xlink:href="path/to/soilmlXY.xsd#XYPlot_elevation"/>
```

In the case of an observed property which is not modelled as a property in the sense of the General Feature Model (see C.5.2.3), there shall also exist a document where the property is defined together with its identifier (e.g. soil gazetteer). The structure of such document is not specified.

EXAMPLE 3 The property *weight* which is specified by the external GEMET thesaurus (see C.5.2.3) can be referred to as

```
<om:observedProperty xlink:href="http://www.eionet.europa.eu/gemet/concept?cp=9286"/>
```

C.5.3.2 Encoding SoilObservation.result

The property SoilObservation.result links the SoilObservation to the observed value.

In the XML schema recommended for this International Standard, which is presented in C.6, the type of the result is defined as "Any", since it may represent the value of any feature property. Nevertheless it is necessary that the result element is of the same type as the observed property element type. Therefore, in the data file the XML schema type of the result is indicated using the value of the xsi:type attribute which shall be the same as the observed property element type.

EXAMPLE 1 Consider SoilObservation encoding the XYPlot.elevation value. The XYPlot.elevation property type is of gml:MeasureType and therefore SoilObservation.result shall be of the same type:

```
<om:result xsi:type="gml:MeasureType" uom="m">107</om:result>
```

EXAMPLE 2 Consider e.g. SoilObservation encoding the XYHorizon.colour value. The XYPlot.elevation property type is of ColourPropertyType and therefore SoilObservation.result shall be of the same type:

```
<om:result xsi:type="ColourPropertyType">
  <Colour>
    <red>23</red>
    <green>68</green>
    <blue>50</blue>
  </Colour>
</om:result>
```


This mechanism leads to duplications in the case of non-object types (e.g. xsd:integer, gml:MeasureType, xsd:boolean, xsd:string, sq:Depth, sq:Colour), i.e. when the value is encoded as a result of SoilObservation and also in the observed object itself. In the case of object types (e.g. sq:Profile, sq:ProfileElement), the duplicity should be avoided using the by-reference mode.

EXAMPLE 3 Consider SoilObservation encoding the Plot.profile value. The Plot.profile property type is of the ProfilePropertyType and therefore SoilObservation.result is of the same type. By-reference mode is used:

```
<om:result xsi:type="ProfilePropertyType" xlink:href="#profile1"/>.
```

C.6 Recommended XML schema definition for SoilML (soilml.xsd)

```
<?xml version="1.0" encoding="windows-1252"?>
<schema
    xmlns="http://www.w3.org/2001/XMLSchema"
    xmlns:gml="http://www.opengis.net/gml/3.2"
    xmlns:sq="http://www.iso28258.org"
    xmlns:om="http://www.opengis.net/om/2.0"
    xmlns:sam="http://www.opengis.net/sampling/2.0"
    xmlns:sams="http://www.opengis.net/samplingSpatial/2.0"
    xmlns:spec="http://www.opengis.net/samplingSpecimen/2.0"
    elementFormDefault="qualified"
    targetNamespace="http://www.iso28258.org"
    version="0.1">
  <import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.open-
gis.net/gml/3.2.1/gml.xsd"/>
  <import namespace="http://www.opengis.net/om/2.0" schemaLocation="http://schemas.open-
gis.net/om/2.0/observation.xsd"/>
  <import namespace="http://www.opengis.net/sampling/2.0" schemaLocation="http://schemas.
opengis.net/sampling/2.0/samplingFeature.xsd"/>
  <import namespace="http://www.opengis.net/samplingSpatial/2.0" schemaLocation="http://
schemas.opengis.net/samplingSpatial/2.0/spatialSamplingFeature.xsd"/>
  <import namespace="http://www.opengis.net/samplingSpecimen/2.0" schemaLocation="http://
schemas.opengis.net/samplingSpecimen/2.0/specimen.xsd"/>


  <element name="PreparationProcess" type="sq:PreparationProcessType" substitutionGroup="g
ml:AbstractFeature">
    <annotation>
      <documentation>PreparationProcess


Preparation process is a subtype of OM_Process (also known as SF_Process). It is a process
used to prepare the specimen. It has one subtype TransportAndStorage.</documentation>


    </annotation>
  </element>
  <complexType name="PreparationProcessType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="description" type="string"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="PreparationProcessPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:PreparationProcess"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="Project" type="sq:ProjectType" substitutionGroup="gml:AbstractFeature">
    <annotation>
      <documentation>project
The project holds the background information for soil studies. A project does not describe
the soil as such. It is of importance to exchange project data along with other soil qual-
```

```
ity data in order to know the aim and circumstances of data collection. The project pro-
vides the context of the data collection as a prerequisite for the proper use or reuse of
these data.
The project information also may be the starting point to retrieve further information
that cannot be exchanged using soil quality. For example, the name of an author or the
project number may be the key for finding a report or decision document.</documentation>
    </annotation>
  </element>
  <complexType name="ProjectType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="name" type="string"/>
          <element name="siteOfInterest" type="sq:SitePropertyType" minOccurs="0"
maxOccurs="unbounded">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.
net/gml/3.2">sq:concernedProject</reversePropertyName>
              </appinfo>
            </annotation>
          </element>
          <element name="relatedMap" type="sq:SoilMapPropertyType" minOccurs="0"
maxOccurs="unbounded"/>
          <element name="relatedProject" type="sq:ProjectContextPropertyType" minOc-
curs="0" maxOccurs="unbounded"/>
          <element name="requiredAnalysis" type="sq:AnalysisRequestPropertyType" minOc-
curs="0" maxOccurs="unbounded"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="ProjectPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:Project"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <complexType name="ProjectContextPropertyType">
    <sequence>
      <element ref="sq:ProjectContext"/>
    </sequence>
  </complexType>
  <element name="ProjectContext" type="sq:ProjectContextType"/>
  <complexType name="ProjectContextType">
    <sequence>
      <element name="role" type="gml:ReferenceType"/>
      <element name="relatedProject" type="gml:ReferenceType">
        <annotation>
          <appinfo>
            <gml:targetElement>sq:Project</gml:targetElement>
          </appinfo>
        </annotation>
      </element>
    </sequence>
  </complexType>
  <element name="Depth" type="sq:DepthType" substitutionGroup="gml:AbstractObject">
    <annotation>
      <documentation>
Depth is a datatype which can both simple depth (e.g. 60cm) or depth extent (e.g.
60-70cm).
Depth is implemented as a choice of GML Quantity or GML QuantityExtent.</documentation>


    </annotation>
  </element>
  <complexType name="DepthType">
    <choice>
      <element name="extent" type="gml:QuantityExtentType"/>
      <element name="simple" nillable="true">
```

```
        <complexType>
          <simpleContent>
            <extension base="gml:MeasureType">
              <attribute name="nilReason" type="gml:NilReasonType"/>
            </extension>
          </simpleContent>
        </complexType>
      </element>
    </choice>
  </complexType>
  <complexType name="DepthPropertyType">
    <sequence>
      <element ref="sq:Depth"/>
    </sequence>
  </complexType>
  <element name="SoilSpecimen" type="sq:SoilSpecimenType" substitutionGroup="spec:SF_Spec-
imen">
    <annotation>
      <documentation>soil specimen


Soil specimen is a subtype of SF_Specimen. Soil specimen may be taken in the Site, Plot,
Profile, or ProfileElement including their subtypes.</documentation>


    </annotation>
  </element>
  <complexType name="SoilSpecimenType">
    <complexContent>
      <extension base="spec:SF_SpecimenType">
        <sequence>
          <element name="depth" id="SoilSpecimen_depth" type="sq:DepthPropertyType"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="SoilSpecimenPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:SoilSpecimen"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="SoilObservation" type="sq:SoilObservationType" substitutionGroup="om:OM_
Observation">
    <annotation>
      <documentation>soil observation


Soil observation is a subtype of OM_Observation.


[ISO 19156]


An observation is an act associated with a discrete time instant or period through which
a number, term or other symbol is assigned to a phenomenon. It involves application of a
specified procedure, such as a sensor, instrument, algorithm or process chain. The proce-
dure may be applied in situ, remotely, or ex situ with respect to the sampling location.
The result of an observation is an estimate of the value of a property of some feature.
Use of a common model allows observation data using different procedures to be combined
unambiguously.</documentation>


    </annotation>
  </element>
  <complexType name="SoilObservationType">
    <complexContent>
      <extension base="om:OM_ObservationType">
        <sequence/>
```

```
      </extension>
    </complexContent>
  </complexType>
  <complexType name="SoilObservationPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:SoilObservation"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="Site" type="sq:SiteType" substitutionGroup="gml:AbstractFeature">
    <annotation>
      <documentation>site


defined area which is subject to a soil quality investigation


A site is a defined, spatially extended area and provides the real world object to which
soil data are related. It represents the spatial link between point, linear and areal
soil observations on the one hand and its environment (e.g. the landscape or larger spa-
tial objects) on the other. As such, it provides the possibility to connect data on spa-
tially extended phenomena, e.g. vegetation, with point, linear and areal sampling features
(plots). It also allows for the possibility to combine the results of (quasi-)synchro-
nous repetitions of observations of the same kind. The site is furthermore the time link
between repeated soil observations, e.g. in the framework of a soil monitoring. Generally,
within one single project, a site is spatially invariant, but contains all plots for sin-
gle or repeated observations and samplings, both related to one point in time or several
points in time. Very often, the data obtained on a site are considered to originate from
one single point in further data processing and evaluation.


In terms of OM, each site is a sampled feature of its plots which are spatial sampling fea-
tures. Site serves also as a typical feature of interest of soil observations.</documentation>


    </annotation>
  </element>
  <complexType name="SiteType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="concernedProject" type="sq:ProjectPropertyType" minOccurs="0"
maxOccurs="unbounded">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.
net/gml/3.2">sq:siteOfInterest</reversePropertyName>
              </appinfo>
            </annotation>
          </element>
          <choice>
            <element name="extent" id="Site_extent">
              <complexType>
                <complexContent>
                  <extension base="gml:AbstractMemberType">
                    <sequence minOccurs="0">
                      <element ref="gml:Polygon"/>
                    </sequence>
                    <attributeGroup ref="gml:AssociationAttributeGroup"/>
                  </extension>
                </complexContent>
              </complexType>
            </element>
            <element name="position" id="Site_position" type="gml:PointPropertyType"/>
          </choice>
          <element name="typicalProfile" id="Site_typicalProfile"
type="sq:ProfilePropertyType" minOccurs="0"/>
          <element name="samplingPlot" type="sq:PlotPropertyType" minOccurs="0"
maxOccurs="unbounded"/>
```

```
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name=”SitePropertyType”>
    <sequence minOccurs=”0”>
      <element ref=”sq:Site”/>
    </sequence>
    <attributeGroup ref=”gml:AssociationAttributeGroup”/>
    <attributeGroup ref=”gml:OwnershipAttributeGroup”/>
  </complexType>
  <element name=”TrialPit” type=”sq:TrialPitType” substitutionGroup=”sq:Plot”>
    <annotation>
      <documentation>trial pit, test pit, trench

excavation prepared to carry out profile descriptions, sampling, and/or field tests

Trial pit is a subtype of a plot with point shape. A trial pits may have an associated soil
profile. TrialPit represents the location of a dug soil opening made to observe the soil.

[ISO 11074]

For the purposes of this International Standard, the term trial pit is used.</documentation>

    </annotation>
  </element>
  <complexType name=”TrialPitType”>
    <complexContent>
      <extension base=”sq:PlotType”>
        <sequence/>
      </extension>
    </complexContent>
  </complexType>
  <complexType name=”TrialPitPropertyType”>
    <sequence minOccurs=”0”>
      <element ref=”sq:TrialPit”/>
    </sequence>
    <attributeGroup ref=”gml:AssociationAttributeGroup”/>
    <attributeGroup ref=”gml:OwnershipAttributeGroup”/>
  </complexType>
  <element name=”Layer” type=”sq:LayerType” substitutionGroup=”sq:ProfileElement”>
    <annotation>
      <documentation>layer

domain of a soil with a certain vertical extension developed through non-pedogenic pro-
cesses, displaying an unconformity to possibly over- or underlying adjacent domains

Note 1: In the framework of soils deeply modified by human activity, artificial layers may
be due to different kinds of deposits (concrete, bricks, ů).
Note 2: Layers may be part of a horizon.</documentation>
    </annotation>
  </element>
  <complexType name=”LayerType”>
    <complexContent>
      <extension base=”sq:ProfileElementType”>
        <sequence>
          <element name=”developedHorizon” id=”Layer_developedHorizon”
type=”sq:HorizonPropertyType” minOccurs=”0” maxOccurs=”unbounded”/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name=”LayerPropertyType”>
```

```
    <sequence minOccurs="0">
      <element ref="sq:Layer"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="TransportAndStorage" type="sq:TransportAndStorageType" substitutionGroup=
"sq:PreparationProcess">
    <annotation>
      <documentation>TransportAndStorage


TransportAndStorage is a subtype of preparation process. It represents transportation and
storage of soil specimen.</documentation>


    </annotation>
  </element>
  <complexType name="TransportAndStorageType">
    <complexContent>
      <extension base="sq:PreparationProcessType">
        <sequence/>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="TransportAndStoragePropertyType">
    <sequence minOccurs="0">
      <element ref="sq:TransportAndStorage"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="AnalysisRequest" type="sq:AnalysisRequestType" substitutionGroup="gml:Abs
tractFeature">
    <annotation>
      <documentation>analysis requeset


AnalysisRequest is a description of an analysis which should be carried out on soil speci-
mens.</documentation>


    </annotation>
  </element>
  <complexType name="AnalysisRequestType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="order" type="integer" minOccurs="0"/>
          <element name="requiredProperty" type="gml:ReferenceType" nillable="true">
            <annotation>
              <appinfo>
                <gml:targetElement>xs:anyType</gml:targetElement>
              </appinfo>
            </annotation>
          </element>
          <element name="observationProcess" type="sq:ObservationProcessPropertyType"/>
          <element name="specimenOfInterest" type="sq:SoilSpecimenPropertyType"
maxOccurs="unbounded"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="AnalysisRequestPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:AnalysisRequest"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
```

```
  <element name="SoilMappingUnit" type="sq:SoilMappingUnitType" substitutionGroup="gml:Abs
tractFeature">
    <annotation>
      <documentation>SoilMappingUnit (SMU)


Soil mapping unit is a map legend category with unique map symbol within the soil map.
Each mapping unit is related exactly to one map (through category tree). Mapping unit may
represent one or more soil typological units, whereas soil typological unit may occur
within one or more mapping units.</documentation>


    </annotation>
  </element>
  <complexType name="SoilMappingUnitType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="representedUnit" type="sq:SoilTypologicalUnitPropertyType" minOc-
curs="0" maxOccurs="unbounded">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.
net/gml/3.2">sq:mapRepresentation</reversePropertyName>
              </appinfo>
            </annotation>
          </element>
          <element name="delineation" minOccurs="0" maxOccurs="unbounded">
            <complexType>
              <complexContent>
                <extension base="gml:AbstractMemberType">
                  <sequence minOccurs="0">
                    <element ref="gml:Polygon"/>
                  </sequence>
                  <attributeGroup ref="gml:AssociationAttributeGroup"/>
                </extension>
              </complexContent>
            </complexType>
          </element>
          <element name="explanation" type="string"/>
          <element name="profile" type="sq:ProfilePropertyType" minOccurs="0"
maxOccurs="unbounded">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.
net/gml/3.2">sq:mapRepresentation</reversePropertyName>
              </appinfo>
            </annotation>
          </element>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="SoilMappingUnitPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:SoilMappingUnit"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="ProfileElement" type="sq:ProfileElementType" abstract="true" substitutionG
roup="gml:AbstractFeature">
    <annotation>
      <documentation>profile element


Profile element is an abstract feature type grouping layers and horizons. Profile element
may be considered as a horizontal feature that is parallel to the earth surface and that
is part of the profile.</documentation>
```



```
    </annotation>
  </element>
  <complexType name="ProfileElementType" abstract="true">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="order" id="ProfileElement_order" type="integer"/>
          <element name="upperDepth" id="ProfileElement_upperDepth"
type="sq:DepthPropertyType"/>
          <element name="lowerDepth" id="ProfileElement_lowerDepth"
type="sq:DepthPropertyType"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="ProfileElementPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:ProfileElement"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="SoilTypologicalUnit" type="sq:SoilTypologicalUnitType" substitutionGroup=
"gml:AbstractFeature">
    <annotation>
      <documentation>SoilTypologicalUnit (STU)


Soil typological unit is a non-spatial unit of systematically similar soils. Each typo-
logical is related exactly to one map (see constraint).</documentation>


    </annotation>
  </element>
  <complexType name="SoilTypologicalUnitType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="name" type="string"/>
          <element name="classificationScheme" type="string"/>
          <element name="typicalProfile" type="sq:ProfilePropertyType" minOccurs="0"
maxOccurs="unbounded"/>
          <element name="mapRepresentation" type="sq:SoilMappingUnitPropertyType" minOc-
curs="0" maxOccurs="unbounded">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.
net/gml/3.2">sq:representedUnit</reversePropertyName>
              </appinfo>
            </annotation>
          </element>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="SoilTypologicalUnitPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:SoilTypologicalUnit"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="SoilMap" type="sq:SoilMapType" substitutionGroup="gml:AbstractFeature">
    <annotation>
      <documentation>SoilMap


SoilMap is a soil map or soil map series with unified classification of soil mapping units
and soil typological units.</documentation>
```

```
    </annotation>
  </element>
  <complexType name="SoilMapType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="name" type="string"/>
          <element name="extent" minOccurs="0">
            <complexType>
              <complexContent>
                <extension base="gml:AbstractMemberType">
                  <sequence minOccurs="0">
                    <element ref="gml:Polygon"/>
                  </sequence>
                  <attributeGroup ref="gml:AssociationAttributeGroup"/>
                </extension>
              </complexContent>
            </complexType>
          </element>
          <element name="rootCategory" type="sq:SoilMappingUnitCategoryPropertyType"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="SoilMapPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:SoilMap"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="Surface" type="sq:SurfaceType" substitutionGroup="sq:Plot">
    <annotation>
      <documentation>surface


Surface is a subtype of a plot with surface shape. Surfaces may be located within other
surfaces.</documentation>


    </annotation>
  </element>
  <complexType name="SurfaceType">
    <complexContent>
      <extension base="sq:PlotType">
        <sequence/>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="SurfacePropertyType">
    <sequence minOccurs="0">
      <element ref="sq:Surface"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="SoilMappingUnitCategory" type="sq:SoilMappingUnitCategoryType" substituti
onGroup="gml:AbstractFeature">
    <annotation>
      <documentation>SoilMappingUnitCategory


Soil mapping unit category is a map legend category used for grouping soil mapping units
or another categories. Each category is either root category of a map or subcategory of
another category. Concerning this, each category is related exactly to one map through
root category of the tree structure (see subcategory).</documentation>


    </annotation>
  </element>
```

```
  <complexType name="SoilMappingUnitCategoryType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="name" type="string"/>
          <element name="subcategory" type="sq:SoilMappingUnitCategoryPropertyType" minOc-
curs="0" maxOccurs="unbounded"/>
          <element name="mappingUnit" type="sq:SoilMappingUnitPropertyType" minOccurs="0"
maxOccurs="unbounded"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="SoilMappingUnitCategoryPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:SoilMappingUnitCategory"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="Profile" type="sq:ProfileType" substitutionGroup="gml:AbstractFeature">
    <annotation>
      <documentation>Soil profile describable representation of the soil that is character-
ised by a vertical succession of horizons or at least one or several parent material layers


Soil profile is an ordered set of soil horizons and/or layers. These are subtypes of
abstract feature type ProfileElement. Profile is also typical feature of interest of soil
observations.</documentation>


    </annotation>
  </element>
  <complexType name="ProfileType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="samplingPlot" type="sq:PlotPropertyType" minOccurs="0">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.net/gml/3.2">sq:profile</
reversePropertyName>
              </appinfo>
            </annotation>
          </element>
          <element name="element" id="Profile_element" type="sq:ProfileElementPropertyType"
maxOccurs="unbounded"/>
          <element name="mapRepresentation" type="sq:SoilMappingUnitPropertyType" minOc-
curs="0" maxOccurs="unbounded">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.net/gml/3.2">sq:profile</
reversePropertyName>
              </appinfo>
            </annotation>
          </element>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="ProfilePropertyType">
    <sequence minOccurs="0">
      <element ref="sq:Profile"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="Plot" type="sq:PlotType" substitutionGroup="sams:SF_SpatialSamplingFea-
ture">
    <annotation>
```



```
      <documentation>plot elementary area where individual observations are made and/or
samples are taken


Plot is a subtype of SF_SpatialSamplingFeature. The plot provides the connection between
the discrete location of a sampling or an observation and the site. Plot is also a typical
feature of interest of soil observations. Plot has three subtypes: Surface, TrialPit and
Borehole.</documentation>


    </annotation>
  </element>
  <complexType name="PlotType">
    <complexContent>
      <extension base="sams:SF_SpatialSamplingFeatureType">
        <sequence>
          <element name="profile" id="Plot_profile" type="sq:ProfilePropertyType" minOc-
curs="0">
            <annotation>
              <appinfo>
                <reversePropertyName xmlns="http://www.opengis.
net/gml/3.2">sq:samplingPlot</reversePropertyName>
              </appinfo>
            </annotation>
          </element>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="PlotPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:Plot"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="ObservationProcess" type="sq:ObservationProcessType" substitutionGroup="g
ml:AbstractFeature">
    <annotation>
      <documentation>observation process Observation process is a subtype of OM_Process.
It is a process used to generate the result of the observation.


Implementation note: OM_Process is modelled as FeatureType, but within OGC XML schema
(version 2.0.0) it is only anyXML. ObservationProcess should be implemented as Feature-
Type.</documentation>


    </annotation>
  </element>
  <complexType name="ObservationProcessType">
    <complexContent>
      <extension base="gml:AbstractFeatureType">
        <sequence>
          <element name="description" type="string"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>
  <complexType name="ObservationProcessPropertyType">
    <sequence minOccurs="0">
      <element ref="sq:ObservationProcess"/>
    </sequence>
    <attributeGroup ref="gml:AssociationAttributeGroup"/>
    <attributeGroup ref="gml:OwnershipAttributeGroup"/>
  </complexType>
  <element name="Borehole" type="sq:BoreholeType" substitutionGroup="sq:Plot">
    <annotation>
      <documentation>borehole
```

```
Penetration into the subsurface with removal of soil/rock material by using e.g. a hollow
tube-shaped tool. Synonyms: Boring and bore.


Borehole is a subtype of a plot with point shape. A boreholes may have an associated profile.


[ISO 11074]


Note 1: Generally, it is a vertical penetration.
Note 2: For the purpose of this International Standard, the term borehole is used.</docu-
mentation>
    </annotation>
  </element>
  <complexType name=”BoreholeType”>
    <complexContent>
      <extension base=”sq:PlotType”>
        <sequence/>
      </extension>
    </complexContent>
  </complexType>
  <complexType name=”BoreholePropertyType”>
    <sequence minOccurs=”0”>
      <element ref=”sq:Borehole”/>
    </sequence>
    <attributeGroup ref=”gml:AssociationAttributeGroup”/>
    <attributeGroup ref=”gml:OwnershipAttributeGroup”/>
  </complexType>
  <element name=”Horizon” type=”sq:HorizonType” substitutionGroup=”sq:ProfileElement”>
    <annotation>
      <documentation>horizon


domain of a soil with a certain vertical extension, which is more or less parallel to the
surface and is homogeneous for most morphological and analytical characteristics, devel-
oped in a parent material through pedogenic processes or made up of in-situ sedimented
organic residues of up-growing plants (peat)


NOTE   Horizons may be part of a layer.</documentation>
    </annotation>
  </element>
  <complexType name=”HorizonType”>
    <complexContent>
      <extension base=”sq:ProfileElementType”>
        <sequence/>
      </extension>
    </complexContent>
  </complexType>
  <complexType name=”HorizonPropertyType”>
    <sequence minOccurs=”0”>
      <element ref=”sq:Horizon”/>
    </sequence>
    <attributeGroup ref=”gml:AssociationAttributeGroup”/>
    <attributeGroup ref=”gml:OwnershipAttributeGroup”/>
  </complexType>
</schema>
```

C.7 Example of an extended SoilML XML schema and data file

This is an example of an extended SoilML XML schema. The Plot is extended with elevation property becoming XYPlot, whereas the Horizon is extended with humusContent and colour properties becoming XYHorizon. The example is described in detail in C.3.

```
<?xml version=”1.0” encoding=”utf-8”?>
<xsd:schema
xmlns=”http://www.iso28258.org”
xmlns:sq=”http://www.iso28258.org”
```



```
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
targetNamespace="http://www.iso28258.org"
elementFormDefault="qualified"
xmlns:gml="http://www.opengis.net/gml/3.2"
>
  <xsd:include schemaLocation="path/to/soilml.xsd"/>
  <xsd:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.
opengis.net/gml/3.2.1/gmlBase.xsd"/>
  <xsd:import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.
opengis.net/gml/3.2.1/basicTypes.xsd"/>

  <xsd:element name="XYPlot" substitutionGroup="Plot" type="XYPlotType" />

  <xsd:complexType name="XYPlotType">
    <xsd:annotation>
      <xsd:documentation>Extension of a Plot type.</xsd:documentation>
    </xsd:annotation>
    <xsd:complexContent>
      <xsd:extension base="PlotType">
        <xsd:sequence>
          <xsd:element id="XYPlot_elevation" name="elevation" type="gml:MeasureType"
minOccurs="1" maxOccurs="1" />
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>

  <xsd:element name="XYHorizon" substitutionGroup="Horizon" type="XYHorizonType" />

  <xsd:complexType name="XYHorizonType">
    <xsd:annotation>
      <xsd:documentation>Extension of a Horizon type.</xsd:documentation>
    </xsd:annotation>
    <xsd:complexContent>
      <xsd:extension base="HorizonType">
        <xsd:sequence>
          <xsd:element id="XYHorizon_humusContent" name="humusContent" type="HumusContentE
numerationType" minOccurs="1" maxOccurs="1" />
          <xsd:element id="XYHorizon_colour" name="colour" type="ColourPropertyType"
minOccurs="1" maxOccurs="1" />
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>

  <xsd:simpleType name="HumusContentEnumerationType" id="HumusContentEnumeration">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="h0">
        <xsd:annotation>
          <xsd:appinfo>
            <gml:description>No humus at all.</gml:description>
          </xsd:appinfo>
        </xsd:annotation>
      </xsd:enumeration>
      <xsd:enumeration value="h1"/>
      <xsd:enumeration value="h2"/>
      <xsd:enumeration value="h3"/>
      <xsd:enumeration value="h4"/>
      <xsd:enumeration value="h5"/>
      <xsd:enumeration value="h6"/>
    </xsd:restriction>
  </xsd:simpleType>
```



```
  <xsd:element name="Colour" substitutionGroup="gml:AbstractObject" type="ColourType" />
  <xsd:complexType name="ColourType" id="Colour">
    <xsd:annotation>
      <xsd:documentation>Colour is a datatype which is defined by three integers, each for
one RGB band.</xsd:documentation>
    </xsd:annotation>
    <xsd:sequence>
      <xsd:element name="red">
        <xsd:simpleType>
          <xsd:restriction base="xsd:integer">
            <xsd:minInclusive value="0"/>
            <xsd:maxExclusive value="255"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="green">
        <xsd:simpleType>
          <xsd:restriction base="xsd:integer">
            <xsd:minInclusive value="0"/>
            <xsd:maxExclusive value="255"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="blue">
        <xsd:simpleType>
          <xsd:restriction base="xsd:integer">
            <xsd:minInclusive value="0"/>
            <xsd:maxExclusive value="255"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType name="ColourPropertyType">
    <xsd:sequence>
      <xsd:element ref="sq:Colour"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:schema>
```

After creating the extended SoilML XML schema, it is possible to create also the data file according to the extended schema. Compare the following example with data file encoded according to basic SoilML XML schema.

```
<?xml version="1.0" encoding="UTF-8"?>
<gml:FeatureCollection gml:id="coll1"
    xmlns="http://www.iso28258.org"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:gml="http://www.opengis.net/gml/3.2"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:om="http://www.opengis.net/om/2.0"
    xmlns:sam="http://www.opengis.net/sampling/2.0"
    xmlns:sams="http://www.opengis.net/samplingSpatial/2.0"
    xsi:schemaLocation="http://www.iso28258.org soilmlXY.xsd">
  <gml:description>Collection of Soil Features</gml:description>
  <gml:name>Soil Collection</gml:name>


  <gml:featureMember>
    <Project gml:id="project1">
      <name>Sulingen</name>
      <siteOfInterest xlink:href="#site1" />
    </Project>
  </gml:featureMember>


  <gml:featureMember>
    <Site gml:id="site1">
      <concernedProject xlink:href="#project1" />
      <position>
        <gml:Point gml:id="point1" srsName="urn:x-ogc:def:crs:EPSG::4326">
```

```
          <gml:pos>17.45820 58.45656</gml:pos>
        </gml:Point>
      </position>
      <samplingPlot xlink:href=”#plot1” />
      <samplingPlot>
        <Borehole gml:id=”plot2”>
          <sam:type xlink:href=”http://www.opengis.net/def/samplingFeatureType/OGC.
OM/2.0/SF_SamplingPoint” />
          <sam:sampledFeature xlink:href=”#site1” />
          <sams:shape xlink:href=”#point1” />
        </Borehole>
      </samplingPlot>
    </Site>
  </gml:featureMember>


  <gml:featureMember>
    <XYPlot gml:id=”plot1”>
      <sam:sampledFeature xlink:href=”#site1” />
      <sams:shape>
        <gml:Point gml:id=”point2” srsName=”urn:x-ogc:def:crs:EPSG::4326”>
          <gml:pos>17.05835 59.54635</gml:pos>
        </gml:Point>
      </sams:shape>
      <elevation uom=”m”>107</elevation>
    </XYPlot>
  </gml:featureMember>


  <gml:featureMember>
    <Profile gml:id=”profile1”>
      <samplingPlot xlink:href=”#plot1” />
      <element xlink:href=”#horizon1” />
    </Profile>
  </gml:featureMember>


  <gml:featureMember>
    <XYHorizon gml:id=”horizon1”>
      <order>1</order>
      <upperDepth>
        <Depth>
          <simple uom=”cm”>0</simple>
        </Depth>
      </upperDepth>
      <lowerDepth>
        <Depth>
          <simple uom=”cm”>10</simple>
        </Depth>
      </lowerDepth>
      <humusContent>h3</humusContent>
      <colour>
        <Colour>
          <red>23</red>
          <green>68</green>
          <blue>50</blue>
        </Colour>
      </colour>
    </XYHorizon>
  </gml:featureMember>


</gml:FeatureCollection>
```

Furthermore, it is possible to encode the extended data file containing SoilObservation objects, as it is shown in the following example:

```
<?xml version=”1.0” encoding=”UTF-8”?>
<gml:FeatureCollection gml:id=”coll1”
    xmlns=”http://www.iso28258.org”
```



```
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:gml="http://www.opengis.net/gml/3.2"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:om="http://www.opengis.net/om/2.0"
    xmlns:sam="http://www.opengis.net/sampling/2.0"
    xmlns:sams="http://www.opengis.net/samplingSpatial/2.0"
    xsi:schemaLocation="http://www.iso28258.org soilmlXY.xsd">
  <gml:description>Collection of Soil Features</gml:description>
  <gml:name>Soil Collection</gml:name>

  <gml:featureMember>
    <Project gml:id="project1">
      <name>Sulingen</name>
      <siteOfInterest xlink:href="#site1" />
    </Project>
  </gml:featureMember>

  <gml:featureMember>
    <Site gml:id="site1">
      <concernedProject xlink:href="#project1" />
      <position>
        <gml:Point gml:id="point1" srsName="urn:x-ogc:def:crs:EPSG::4326">
          <gml:pos>17.45820 58.45656</gml:pos>
        </gml:Point>
      </position>
      <samplingPlot xlink:href="#plot1" />
      <samplingPlot>
        <Borehole gml:id="plot2">
          <sam:type xlink:href="http://www.opengis.net/def/samplingFeatureType/OGC.
OM/2.0/SF_SamplingPoint" />
          <sam:sampledFeature xlink:href="#site1" />
          <sams:shape xlink:href="#point1" />
        </Borehole>
      </samplingPlot>
    </Site>
  </gml:featureMember>

  <gml:featureMember>
    <XYPlot gml:id="plot1">
      <sam:sampledFeature xlink:href="#site1" />
      <sams:shape>
        <gml:Point gml:id="point2" srsName="urn:x-ogc:def:crs:EPSG::4326">
          <gml:pos>17.05835 59.54635</gml:pos>
        </gml:Point>
      </sams:shape>
      <elevation uom="m">107</elevation>
    </XYPlot>
  </gml:featureMember>

  <gml:featureMember>
    <Profile gml:id="profile1">
      <samplingPlot xlink:href="#plot1" />
      <element xlink:href="#horizon1" />
    </Profile>
  </gml:featureMember>

  <gml:featureMember>
    <XYHorizon gml:id="horizon1">
      <order>1</order>
      <upperDepth>
        <Depth>
          <simple uom="cm">0</simple>
        </Depth>
      </upperDepth>
      <lowerDepth>
```

```
        <Depth>
          <simple uom="cm">10</simple>
        </Depth>
      </lowerDepth>
      <humusContent>h3</humusContent>
      <colour>
        <Colour>
          <red>23</red>
          <green>68</green>
          <blue>50</blue>
        </Colour>
      </colour>
    </XYHorizon>
  </gml:featureMember>


  <gml:featureMember>
    <SoilObservation gml:id="obs1">
      <om:phenomenonTime>
            <gml:TimeInstant gml:id="ot1">
                  <gml:timePosition>2005-01-11</gml:timePosition>
            </gml:TimeInstant>
      </om:phenomenonTime>
      <om:resultTime xlink:href="#ot1"/>
      <om:procedure>
        <ObservationProcedure gml:id="obsproc1">
          <description>GPS eTrex Legend</description>
        </ObservationProcedure>
      </om:procedure>
      <om:observedProperty xlink:href="soilmlXY.xsd#XYPlot_elevation"/>
      <om:featureOfInterest xlink:href="#plot1"/>
      <om:result xsi:type="gml:MeasureType" uom="m">107</om:result>
    </SoilObservation>
  </gml:featureMember>


  <gml:featureMember>
    <SoilObservation gml:id="obs2">
      <om:phenomenonTime xlink:href="#ot1" />
      <om:resultTime xlink:href="#ot1"/>
      <om:procedure>
        <ObservationProcedure gml:id="obsproc2">
          <description>observed by Mr A. N. Other</description>
        </ObservationProcedure>
      </om:procedure>
      <om:observedProperty xlink:href="soilml.xsd#Plot_profile"/>
      <om:featureOfInterest xlink:href="#plot1"/>
      <om:result xsi:type="ProfilePropertyType" xlink:href="#profile1" />
    </SoilObservation>
  </gml:featureMember>
</gml:FeatureCollection>
```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ICS 13.080.01

Price based on 63 pages