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OGC GeoPackage Extension for Tiled Gridded Coverage Data

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Abstract

The "GeoPackage Extension for Tiled Gridded Coverage Data” extension (previously titled Elevation Extension)" defines how to encode and store tiled regular gridded data, such as a digital elevation model, in a GeoPackage. In the ISO 19123 Schema for Coverage Geometry standard and in the OGC Coverage Implementation Schema, this type of regular gridded data is classed as grid-regular[[1]](#footnote-1). The tiles contain values, such as elevation, temperature or pressure, and may be stored as 16-bit PNG files or 32-bit TIFF files. The extension defines two ancillary data tables: one for regular gridded coverages and one for tiles. When using the PNG encoding, a scale and offset may be applied. The extension also allows for a TIFF encoding but constrains many of the TIFF options that are available to simplify development.

Keywords

The following are keywords to be used by search engines and document catalogues.

ogcdoc, OGC document, geopackage, cis, coverage, grid

Preface

"GeoPackage Extension for Tiled Gridded Coverage Data” was initially documented in the GeoPackage 1.2 draft standard as Annex F.11 Tiled Gridded Elevation Data. In 2016, the GeoPackage Elevation Extension was tested and refined as part of the OGC GeoPackage Elevation Extension Interoperability Experiment[[2]](#footnote-2). Based on the results of the Interoperability Experiment, the candidate extension was edited and submitted to the OGC Architecture Board for review and consideration. The OGC Architecture Board recommended that the Elevation extension not be an Annex of the core GeoPackage standard but instead should be a separate document. This document is the result of implementing that recommendation. As part of the work, the scope of the extension was expanded from just elevation data to any regular gridded coverage data.

NOTE and WARNING: Any implementations of the candidate standard prior to August 2017 may need to be revised to comply with changes to Table 1: Coverage Ancillary Table Definitions. Specifically, “pixel\_encoding” has been changed to “grid\_cell\_encoding” and additional columns have been added to the Table.

The following information is provided in compliance with the GeoPackage Extension template as defined in Annex E: GeoPackage Extension Template of the GeoPackage Standard. These additional introductory clauses are not elements in the standard OGC document template.

* Extension Author: GeoPackage SWG, author\_name gpkg.
* Extension Name or Template: gpkg\_elevation\_tiles.
* Extension Type:This extension has a dependency on [Clause 2.2](http://www.geopackage.org/spec/#tiles)[[3]](#footnote-3) of the core GeoPackage standard.
* Applicability: This GeoPackage Gridded Coverages extension can be used to store any gridded coverage in a GeoPackage data store. This extension specifies requirements and optional clauses for additional GeoPackage tables as well as requirements for extensions to [tile pyramid user data tables](http://www.geopackage.org/spec/#tiles_user_tables) (Clause 2.2.8 of the GeoPackage core) that can be used to hold tiled, gridded coverage data.
* Scope: read-write.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

*Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.*

Submitting organizations

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

The OGC GeoPackage Standards Working Group:

<http://www.opengeospatial.org/projects/groups/geopackageswg>

Submitters

All questions regarding this submission should be directed to the editor or the submitters:

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| --- | --- |
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| Chris Clarke | Compusult |
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| Jeff Yutzler | Image Matters |

# Scope

This extension defines the rules for encoding and storing 16-bit and 32-bit tiled regular grid coverages composed of regular gridded data, such as elevation and temperature, in a GeoPackage. This capability may be used to support use cases such as the following:

* Visualization
  + 2d and 3d Draping and Texture mapping
  + 2d (hill shade, color relief, slope, aspect)
  + 3d (supporting changing view angles and level of detail)
* Analysis
  + Contouring of any continuous coverage
  + Volume computations
  + Slicing for 3d printers and other applications
  + Viewshed and line-of-sight
  + Cross-country mobility (off-road routing)
  + Site suitability and planning (slope analysis such as helicopter landing zones)
  + 3d geometry representations of features (ground-based, airspace)
  + Terrain association (associating images to mapped locations)
  + Augmented reality training
  + Mesh generation
  + Ancillary data for classification tools
  + Trend Analysis
  + “Heat” maps
  + Drainage calculations
  + Profiling

This extension was designed to be relatively easy to implement and to be suitable for a wide variety of computing environments, including the mobile/handheld computing environment[[4]](#footnote-4).

# Conformance

This standard defines requirements for a Regular Grid Coverage, such as an elevation matrix, to be stored in a GeoPackage.

Conformance with this standard shall be checked using all the relevant tests specified in Annex A (normative) of this document. The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in the OGC Compliance Testing Policies and Procedures and the OGC Compliance Testing web site[[5]](#footnote-5).

# References

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

ISO: ISO12639:2004, Graphic technology -- Prepress digital data exchange -- Tag image file format for image technology (TIFF/IT), 2004

ISO: ISO 19162:2015 *Geographic information -- Well-known text representation of coordinate reference systems*. Also OGC 12-063r5. <http://docs.opengeospatial.org/is/12-063r5/12-063r5.html>, 2015

OGC: OGC 01-009 *Implementation Specification: Coordinate Transformation Services Revision 1.0* <http://portal.opengeospatial.org/files/?artifact_id=999>, 2001

OGC: OGC 08-015r2, Abstract Specification Topic 2 – Spatial Referencing by Coordinates, (ISO 19111), 2010.

OGC: OGC 07-011, *Abstract Specification Topic 6: Schema for coverage geometry and functions*, (ISO 19123), 2006

OGC: OGC 15-115r3 *CDB Core Standard: Model and Physical Data Store Structure* <https://portal.opengeospatial.org/files/?artifact_id=72712>, 2016

OGC: OGC 09-146r6 *Coverage Implementation Schema* <http://docs.opengeospatial.org/is/09-146r6/09-146r6.html>, 2017

OGC: OGC 12-128r12, *GeoPackage Encoding Standard 1.1* <http://www.geopackage.org/spec110/>, 2015

OGC: OGC 06-121r9 Web Services Common Standard, version 2.0.0, 2010.

OGC: OGC 08-094r1, OGC® SWE Common Data Model Encoding Standard, version 2.0, 2011

UCUM: [The Unified Code for Units of Measure](http://unitsofmeasure.org/ucum.html). 2014.

Adobe Systems Incorporated: Adobe *TIFF ™ Revision 6.0 Final*, <ftp://download.osgeo.org/libtiff/doc/TIFF6.pdf>, 1992

# Terms and Definitions[[6]](#footnote-6)

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r9], which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

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



Continuous coverage

**coverage** that returns different values for the same feature attribute at different **direct positions** within a single spatial object, temporal objector spatiotemporal objectin its domain. [ISO 19123]

Note: A continuous (grid) coverage has values not only at the direct positions themselves, but also at any location between the direct positions. In other words, an application can apply interpolation methods to obtain values between direct positions.

Coordinate Reference System (CRS)

coordinate system that is related to the real world by a datum [ISO 19111:2007]

Coverage

A coverage is a function that describe characteristics of real-world phenomena that vary over space and/or time. Typical examples are temperature, elevation and precipitation. A coverage is typically represented as a data structure containing a set of such values, each associated with one of the elements in a spatial, temporal or spatiotemporal domain. Typical spatial domains are point sets (e.g. sensor locations), curve sets (e.g. contour lines), grids (e.g. orthoimages, elevation models), etc. A property whose value varies as a function of time may be represented as a temporal coverage or time-series [[ISO-19109](https://www.w3.org/TR/sdw-bp/#bib-ISO-19109)].NOTE: feature that acts as a function to return values from its range for any direct position within its spatiotemporal domain, as defined in OGC Abstract Topic 6 [ISO 19123]



Discrete Coverage

Coverage that returns the same feature attribute values for every direct position within any single spatial object, temporal object, or spatiotemporal object in its domain [ISO 19123/OGC Topic 6]

Depth

Distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface. [ISO 19111] Note 1 to entry: A height below the reference surface will have a negative value, which would embrace both gravity-related heights and ellipsoidal heights.

Direct Position

position described by a single set of **coordinates** within a **coordinate reference system** [ISO 19123]

Elevation

Synonym for “height”

Grid

Grid network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in an algorithmic way. NOTE The curves partition a space into grid cells.. [ISO 19123:2007]

Grid point

Point located at the intersection of two or more curves in a grid. ISO 19123:2005

Height

Distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface. [ISO 19111] Note 1 to entry: A height below the reference surface will have a negative value, which would embrace both gravity-related heights and ellipsoidal heights.

Regular grid

Grid whose grid lines have a constant distance along each grid axis

# Conventions

This section provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

## Identifiers

The normative provisions in this standard are denoted by the URI

http://www.opengis.net/spec/geopackage-gr/1.0

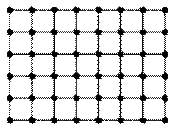
All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base. The three letter acronym “Req” is equivalent to the above URI. NOTE: The abbreviation “gr” stands for grid-regular.

# Short introduction to coverages and CIS[[7]](#footnote-7)

The GeoPackage tile grid extension is conceptually grounded in the OGC Coverage Implementation Schema (CIS). CIS specifies the OGC coverage model by establishing a concrete, interoperable, conformance-testable coverage structure. CIS is based on the abstract concepts of OGC Abstract Topic 6 (which is identical to ISO 19123:2005). ISO 19123 specifies an abstract model for coverages which is not per se interoperable. In other words, many different and incompatible implementations of the abstract model are possible. CIS, on the other hand, is interoperable in the sense that coverages can be conformance tested, regardless of their data format encoding, down to the level of single grid cell.

Coverages can be encoded in any suitable format (such as GML, JSON, GeoTIFF, TIFF, PNG or Net­CDF) and can be partitioned, e.g., for a time-interleaved representation. Coverages are independent from service definitions and, therefore, can be accessed through a variety of OGC services types, such as the Web Coverage Service (WCS) Standard. The coverage structure can serve a wide range of coverage application domains, thereby contributing to harmonization and interoperability between and across these domains.

Within the GeoPackage, a grid of elevations is a type of a regular gridded coverage (CIS:: GeneralGridCoverage, class grid-regular) that has a grid as their domain set describing the direct positions in multi-dimensional coordinate space, depending on the type of grid. In the class *grid-regular*, simple equidistant grids are established[[8]](#footnote-8).



## A note on “elevation”

Work on this extension originally focused on requirements for encoding a regular grid of elevations in a GeoPackage. The original (draft) version of this extension did not provide a definition of “elevation”. This version does include a very general definition of the term “elevation” as specified in ISO 19111 Spatial Referencing by Coordinates. This definition is almost identical to those found in a number of other documents, such as definitions for elevation (height) found in the Journal of Photogrammetry, standards documents from the International Civil Aviation Organization, American Society for Photogrammetry and Remote Sensing (ASPRS), the World Meteorological Organization, and the Federal Geographic Data Committee (FGDC). However, many of the definitions provided by those organizations take an earth centric view. OGC standards are being used for other planetary bodies. As such, this document uses a more general definition.

Variations of the definition used in this document are often provided to meet domain specific requirements. As an example, ICAO uses, “The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level. Official ICAO publications sometimes use the term "gravity-related height" as a synonym of elevation.” This is the same as the definition used in this standard with the caveat that “elevation” is measured from mean sea level.

The definition used in this standard accommodates any reference surface, including “elevation” as used in the building industry. Therefore, provision of proper coordinate reference system metadata is critical to determining the reference surface used for a specific elevation data set stored in a GeoPackage.

## Storage formats and grid cell values

This extension to the OGC GeoPackage Encoding Standard leverages the existing structure for raster tiles as defined in GeoPackage Clause 2.2 using PNG (16-bit, signed integer) and TIFF (32-bit, float) files as the container for the grid values, such as elevation. The data producer has the responsibility to ensure that the intended recipient is able to read GeoPackages that contain a grid-regular coverage encoding (PNG or TIFF). Please note that using multiple zoom levels for a grid-regular coverage is purely optional. There is no requirement that grid-regular tiles have to be in a full pyramid. Clause 2.2 specifies how each zoom level is encoded. There may be only one zoom level.

Clause 7.1.1.2 and Table 1 Ancillary Coverage Data Definition define how the application to specify how the value of a grid cell is assigned. Obviously, if we are dealing with a *continuous* gridded coverage, values between grid cell center points can be interpolated, such as for contouring.

## Cross Walk of GeoPackage Column Names and OGC/ISO Baseline

The following is a basic “crosswalk” between column names used in GeoPackage Clause 2.2 Tiles and semantics (tags) used in the OGC/ISO standards baseline, including Geography Markup Language (GML) and ISO 19123 Coverages. Please reference Annex B for an example of a GML encoding using domainSet, rangeType and rangeSet.

### GML GridEnvelope

This GML element (Clause 19.2.2) defines the “limits” in pixel space of the grid matrix. The equivalent in the core GeoPackage standard is defined in Clause 2.2.7 Table 9. Tile Matrix Metadata Table Definition:

tile\_width: Tile width in pixels (>= 1) for this zoom level

tile\_height: Tile height in pixels (>= 1) for this zoom level

### CIS/SWE rangeType

In the baseline, rangeType provides the ability to specify the characteristics of the coverage values contained in the rangeSet. As defined in ISO 19123, “The attribute *rangeType: RecordType* shall describe the range of the coverage”. More specifically, the rangeType component adds a structure description and technical metadata required for an appropriate (however, application independent) understanding of a coverage. Units of measure (UoM), allowed values (such as for radiance), and precision are rangeType metadata elements. Table 1 Coverage Ancillary Table Definitions provides columns for several key rangeType metadata elements.

### CIS/SWE rangeSet

The rangeSet is comprised of the coverage range values, each one being associated with a direct position. In the case of the GeoPackage Grid Coverage extension, the rangeSet are the data values contained in the TIFF file. The requirements for using TIFF are defined in [Clause 8](#_TIFF_Encoding) of this document.

### GML/CIS/SWE domainSet

The gml:domainSet property describes the domain of the coverage. The metadata defining the domain is provided in both the core GeoPackage tables and coverage ancillary tables and associated requirements for the grid coverage GeoPackage extension. Key elements of the domain metadata are defined in the core GeoPackage standard:

* Clause 1.1.2 Table 2 Spatial Ref Sys Table Definition;
* Clause 2.2.7 Table 9 Tile Matrix Metadata Table Definition in the core GeoPackage standard; and
* Clause 1.1.3 Table 4 Contents Table Definition.

Additional metadata elements describing the domain of a continuous regular grid coverage are provided in the coverage ancillary table (Table 1) and include units of measure (UoM), precision, and pixel sample encoding method.

# Grid-Regular Coverage Extension Requirement Clauses

Clause 7 defines the requirements for encoding and storing regular, grid coverages in a GeoPackage. These requirements are in addition or complement the requirements for raster tiles as defined in the core GeoPackage standard Clause 2.2.

## Table Definitions

Clauses 7.1.1 and 7.1.2 define the requirements and elements of Tiled Grid Extension ancillary (additional) tables required for storing a regular grid of values such as elevation in a GeoPackage.

|  |  |
| --- | --- |
| **Requirements Class Table Definitions** | |
| **http://www.opengis.net/spec/geopackage-gr/1.0/table-defs** | |
| Target type | Token |
| Dependency | **http://www.geopackage.org/spec/#tiles** |
| **Requirement 1** | **Req/coverage-ancillary** |
| **Requirement 2** | **Req/tile-ancillary** |

### Coverage Ancillary

|  |
| --- |
| **Requirement 1** |
| Req/table-defs/coverage-ancillary |
| A GeoPackage that contains tiled gridded data *SHALL* contain a gpkg\_2d\_gridded\_coverage\_ancillary table or view as per the Coverage Ancillary Table Definition below. Subsequent extensions or custom implementations *MAY* add additional columns to this table. Clients *SHALL* ignore additional columns that are unrecognized. |

The following table provides definitions for columns in the Coverage Ancillary Table.

| Table 1: Coverage Ancillary Table Definition | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Column Name** | **Column Type** | **Column Description** | **Null** | **Default** | **Key** | **Constraint** |
| id | INTEGER | Autoincrement primary key | no |  | PK |  |
| tile\_matrix\_set\_name | TEXT | Foreign key to table\_name in [gpkg\_tile\_matrix\_set](http://www.geopackage.org/spec/#tile_matrix_set_data_table_definition) | no |  | FK | UNIQUE |
| datatype | TEXT | *integer* or *float* | no | *integer* |  |  |
| scale | REAL | Scale as a multiple relative to the unit of measure | no | 1 |  |  |
| offset | REAL | The offset to the 0 value | no | 0 |  |  |
| precision | REAL[[41](http://www.geopackage.org/spec/" \l "_footnote_41" \o "View footnote.)] | The smallest value that has meaning for this dataset | yes | 1 |  |  |
| data\_null | REAL[[42](http://www.geopackage.org/spec/" \l "_footnote_42" \o "View footnote.)] | The value that indicates NULL | yes |  |  |  |
| grid\_cell\_encoding | TEXT | Specifies how a value is assigned to a grid cell (pixel) | yes | grid-value-is-center |  |  |
| uom | TEXT | Units of Measure for values in the grid coverage | yes |  |  |  |
| field\_name | TEXT | Type of Gridded Coverage Data (default is Height). | yes | Height |  |  |
| quantity\_definition | TEXT | Description of the values contained in the Gridded Coverage. | yes | Height |  |  |

#### Using the Scale and Offset Values

Integer values MAY be scaled and offset in order to make more efficient use of 16-bit integer space available in PNG files. The scale and offset MAY be applied to the entire coverage and/or the individual tile. The scale and offset do not apply to the data\_null value as defined in the Coverage Ancillary Table Definitions (above).

Actual cell values are be calculated by:

* first multiplying the stored value by the gpkg\_2d\_gridded\_tile\_ancillary\_table.scale value and then adding the gpkg\_2d\_gridded\_tile\_ancillary\_table.offset,
* followed by multiplying that value by the gpkg\_2d\_gridded\_coverage\_ancillary.scale value and then adding the gpkg\_2d\_gridded\_coverage\_ancillary.offset.

In pseudo-code, this conversion would look like:

elevationInUnitOfMeasure = (SomeGrid\_RegularCoverage.tile\_data-pngpixels[i] \* gpkg\_2d\_gridded\_tile\_ancillary.scale + gpkg\_2d\_gridded\_tile\_ancillary.offset) \* gpkg\_2d\_gridded\_coverage\_ancillary.scale + gpkg\_2d\_gridded\_coverage\_ancillary.offset;

Note: *integer* and *float* refer to the values stored in the tiles. If *integer* values have a real scale or offset applied to them, then the resulting values will be real. The scale and offset do not apply to tiles of datatype *float*.

#### grid cell encoding

There is a small set of possible ways in how a value is actually assigned to a given grid cell. For example, a value could be assigned to the center of a cell, a corner of a cell, and so forth. Additionally, a value can be assigned to the entire cell. The OGC standards baseline currently states the use of pixel-is-point: GMLJP2 follows the definition of grids in GML 3.2.1 [OGC 07-036] clause 19.2.2: “When a grid point is used to represent a sample space (e.g. image pixel), the grid point represents the center of the sample space (see ISO 19123:2005, 8.2.2)”. In this extension, we use “grid-value-is-area” rather than “pixel-is-area” for discrete coverages such as classified satellite imagery and specifies that the value for an entire grid cell is the same value.

For the purposes of grid coverage GeoPackage extension, the following values are allowed.

* grid-value-is-center: This is the default. Assume the value is center of grid cell.
* grid-value-is-area – Assume the entire grid cell has the same value.
* grid-value-is-corner – A typical use case is for a mesh of elevation values as specified in the OGC CDB standard Clause 5.6.1.

As other sampling methods are identified, the list of enumeration types can be expanded.

#### uom

The default is the units of measure as defined in the vertical CRS metadata, such as for heights (elevations). However, for many types of grid coverage data there will not be a vertical CRS defined in EPSG or other registries. Examples of such phenomenon are temperature, pressure, and wind speed. The formal (normative) definition for these phenomenon should be specified based on some well know accepted registry, ontology, or other community accepted units of measurement definitions. Currently, UCUM is used as the normative UoM reference in the OGC standards baseline. Some examples from UCUM are:

* Cel - Celsius, degree – temperature
* [degF] – degree Fahrenheit – temperature
* mbar - millibar
* B[uV] - microvolt, bel – electric potential level

There are other normative sources for UoM definitions, such as the World Meteorological codes registry[[9]](#footnote-9) and the NASA QUDT semantic definitions[[10]](#footnote-10).

An additional consideration is that a GeoPackage may be used in a disconnected environment. Therefore, the UoM specification should not be a URN or URI to some external resource. Consequently, the UoM code used should also have a specific field name and quantity definition.

This field is mandatory.

#### field\_name

field\_name is an element of rangeType. Specifically, each “field” attribute in a given GeoPackage gridded coverage instance is identified by a name that is unique to the coverage instance. For example, if the field\_name is “temperature”, then the entire coverage instance is “temperature”. Therefore, for this GeoPackage extension, there is only one field attribute and one instance. In the example below, consider a grid coverage comprised of temperatures and using SWE Data Common (08-094r1) to specify the field name.

<swe:field name="temperature">

<swe:Quantity definition="http://mmisw.org/ont/cf/parameter/air\_temperature">

<swe:label>Air Temperature</swe:label>

<swe:uom code="Cel"/>

</swe:Quantity>

</swe:field>

For a disconnected environment, the field\_name should not be a URN or a URI. Instead use the label from the normative resource being referenced. In the above example, the field\_name would be “air\_temperature.” The quantity definition would also need to be specified.

#### quantity definition

Associated with the field name is a definition of that field/attribute. In SWE Common this is defined in the Quantity class. In the above example, navigating to <http://mmisw.org/ont/cf/parameter/air_temperature> provides a very specific definition of what is meant by “temperature.”

Please note that in a disconnected environment, the use of URNs and URIs is discouraged. Instead, use the text field to provide the quantity definition for the UoM being used. For example, for the above example the Marine Metadata registry provides the following: “Air temperature is the bulk temperature of the air, not the surface (skin) temperature.”

This metadata element/column is required if the values contained in a grid coverage are anything other than height (elevation). This is a text string that describes the field (type). This could be an http uri to an ontology or enumeration, such as “http://sweet.jpl.nasa.gov/2.0/spaceExtent.owl#Height."

### Tile Ancillary

|  |
| --- |
| **Requirement 2** |
| Req/table-defs/tile-ancillary |
| A GeoPackage that contains tiled gridded data SHALL contain a gpkg\_2d\_gridded\_tile\_ancillary table or view as per [Tile Ancillary Table Definition](http://www.geopackage.org/spec/#gpkg_2d_gridded_tile_ancillary_table). Subsequent extensions or custom implementations MAY add additional columns to this table. Clients SHALL ignore additional columns that are unrecognized. |

| Table 2: Tile Ancillary Table Definition | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Column Name** | **Column Type** | **Column Description** | **Null** | **Default** | **Key** |
| id | INTEGER | Autoincrement primary key | no |  | PK |
| tpudt\_name | TEXT | Name of [tile pyramid user data table](http://www.geopackage.org/spec/#tiles_user_tables) | no |  | UNIQUE[[11]](#footnote-11) |
| tpudt\_id | INTEGER | Foreign key to id in [tile pyramid user data table](http://www.geopackage.org/spec/#tiles_user_tables) | no |  | UNIQUE[[12]](#footnote-12) |
| scale | REAL | Scale as a multiple relative to the unit of measure | no | 1 |  |
| offset | REAL | The offset to the 0 value | no | 0 |  |
| min | REAL[[45](http://www.geopackage.org/spec/" \l "_footnote_45" \o "View footnote.)] | Minimum value of this tile | yes |  |  |
| max | REAL[[46](http://www.geopackage.org/spec/" \l "_footnote_46" \o "View footnote.)] | Maximum value of this tile | yes |  |  |
| mean | REAL | The arithmetic mean of values in this tile | yes |  |  |
| std\_dev | REAL | The standard deviation of values in this tile | yes |  |  |

The min, max, and mean values are natural, i.e., not scaled or offset. Similarly, the std\_dev is calculated based on the natural values. The scale and offset do not apply to tiles of datatype *float*.

## Table Values

The following requirements specify required and optional table values.

|  |  |
| --- | --- |
| **Requirements Class Table Values** | |
| **http://www.opengis.net/spec/geopackage-gr/1.0/table-values** | |
| Target type | Token |
| Dependency | **http://www.geopackage.org/spec/#tiles** |
| **Requirement 3** | **Req/gpkg-spatial-ref-sys-row** |
| **Requirement 4** | **Req/ gpkg-spatial-ref-sys-record** |
| **Requirement 5** | **Req/gpkg-contents** |
| **Requirement 6** | **Req/gpkg-extensions** |

### gpkg\_spatial\_ref\_sys

|  |
| --- |
| **Requirement 3** |
| Req/**gpkg-spatial-ref-sys-row** |
| GeoPackages complying with this extension *SHALL* have a row in the gpkg\_spatial\_ref\_sys table as described in [Spatial Ref Sys Table Record](http://www.geopackage.org/spec/#gpkg_spatial_ref_sys_record): |

Due to limitations in expressing 3d coordinate reference systems in the original OGC (circa 2001) [Well-known Text](#Old_WKT_Reference), it is recommended that GeoPackages complying with the grid-regular extension also comply with [ISO 19162](#New_WKT_Reference) WKT for Coordinate Reference Systems as described in the GeoPackage CRS extension <http://www.geopackage.org/spec/#extension_crs_wkt>. Please refer to clause F.10 WKT for Coordinate Reference Systems in the core [GeoPackage standard version 1.1](http://www.geopackage.org/spec110/) and later.

| Table 3. Spatial Ref Sys Table Record | | | | | |
| --- | --- | --- | --- | --- | --- |
| **srs\_name** | **srs\_id** | **organization** | **organization\_coordsys\_id** | **definition** | **description** |
| any | 4979 | EPSG or epsg | 4979 | any | any |

|  |
| --- |
| **Requirement 4** |
| Req/**gpkg-spatial-ref-sys-record** |
| The gpkg\_spatial\_ref\_sys table in a GeoPackage *SHALL* contain records to define all spatial reference systems used by tiled gridded data in a GeoPackage. The spatial reference system *SHALL* be used to define the vertical datum, reference geoid, and units of measure for the tiled gridded elevation data. |

### gpkg\_contents

|  |
| --- |
| **Requirement 5** |
| Req/**gpkg-contents** |
| The [gpkg\_contents](http://www.geopackage.org/spec/#_contents) table *SHALL* contain a row with a data\_type column value of *2d-gridded-coverage* for each tile pyramid containing tiled gridded data. When relevant, such as for elevation, the srs\_id column value for that row SHOULD reference an SRS that has a vertical datum. This requirement extends core requirement [GPKG-34](http://www.geopackage.org/spec/#r34)). NOTE: Ideally for elevation data the vertical datum for each pyramid of elevation will be specified. However, it is impractical to mandate this for a number of reasons, including the difficulty in testing whether a specific SRS has a valid vertical datum. |

### gpkg\_extensions

|  |
| --- |
| **Requirement 6** |
| Req/**gpkg-extensions** |
| GeoPackages complying with this extension SHALL have rows in the gpkg\_extensions table as described in Table 3 Extension Table Record (below). |

| Table 3: Extension Table Record | | | | |
| --- | --- | --- | --- | --- |
| **table\_name** | **column\_name** | **extension\_name** | **definition** | **scope** |
| gpkg\_2d\_gridded\_coverage\_ancillary | null | 2d\_gridded\_coverage | <http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data> | read-write |
| gpkg\_2d\_gridded\_tile\_ancillary | null | 2d\_gridded\_coverage | <http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data> | read-write |
| name of actual [tile pyramid user data table](http://www.geopackage.org/spec/#tiles_user_tables) containing grid-regular data | tile\_data | 2d\_gridded\_coverage | <http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data>[[13]](#footnote-13) | read-write |

## gpkg\_2d\_gridded\_coverage\_ancillary

The following requirements class defined mandatory and optional elements for the coverage ancillary table definition.

|  |  |
| --- | --- |
| **Requirements Class 2d Gridded Coverage Ancillary** | |
| **http://www.opengis.net/spec/geopackage-gr/1.0/grid-coverage-ancillary** | |
| Target type | Token |
| Dependency | **http://www.geopackage.org/spec/#tiles** |
| **Requirement 7** | **Req/gpkg-2d-gridded-coverage-ancillary** |
| **Requirement 8** | **Req/gpkg-2d-gridded-coverage-ancillary-set-name** |
| **Requirement 9** | **Req/gpkg-2d-gridded-coverage-ancillary-datatype** |

The following requirements refer to the gpkg\_2d\_gridded\_coverage\_ancillary table as per [Coverage Ancillary Table Definition](http://www.geopackage.org/spec/#gpkg_2d_gridded_coverage_ancillary_table).

|  |
| --- |
| **Requirement 7** |
| Req/**gpkg-2d-gridded** |
| For each row in gpkg\_contents with a data\_type column value of *2d-gridded-coverage*, there SHALL be a row in gpkg\_2d\_gridded\_coverage\_ancillary. Values of the tile\_matrix\_set\_name column SHALL reference values in the gpkg\_contents table\_name column. |

|  |
| --- |
| **Requirement 8** |
| Req/**gpkg-2d-gridded-coverage-ancillary-set-name** |
| Values of the gpkg\_2d\_gridded\_coverage\_ancillary tile\_matrix\_set\_name column SHALL reference values in the gpkg\_tile\_matrix\_set table\_name column. |

|  |
| --- |
| **Requirement 9** |
| Req/**gpkg-2d-gridded-coverage-ancillary-datatype** |
| Values of the gpkg\_2d\_gridded\_coverage\_ancillary datatype column MAY be *integer* or *float*. When the datatype is *float*, the scale and offset values SHALL be set to the defaults. |

## gpkg\_2d\_gridded\_tile\_ancillary

The following requirements class defined mandatory and optional elements for the tile ancillary table definition.

|  |  |
| --- | --- |
| **Requirements Class 2d Gridded Tile Ancillary** | |
| **http://www.opengis.net/spec/geopackage-gr/1.0/grid-tile-ancillary** | |
| Target type | Token |
| Dependency | **http://www.geopackage.org/spec/#tiles** |
| **Requirement 10** | **Req/gpkg-2d-gridded-tile-ancillary** |
| **Requirement 11** | **Req/gpkg-2d-gridded-tile-ancillary-values** |
| **Requirement 12** | **Req/gpkg-2d-gridded-tile-ancillary-dvalues-id** |

The following requirements refer to the gpkg\_2d\_gridded\_tile\_ancillary table as per [Tile Ancillary Table Definition](http://www.geopackage.org/spec/#gpkg_2d_gridded_tile_ancillary_table).

|  |
| --- |
| **Requirement 10** |
| Req/**gpkg-2d-gridded-tile-ancillary-row** |
| For each row in a tile pyramid user data table corresponding to tiled, gridded elevation data, there SHALL be a row in gpkg\_2d\_gridded\_tile\_ancillary. |

|  |
| --- |
| **Requirement 11** |
| Req/**gpkg-2d-gridded-tile-ancillary-values** |
| Values of the gpkg\_2d\_gridded\_tile\_ancillary tpudt\_name column SHALL reference existing [tile pyramid user data tables](http://www.geopackage.org/spec/#tiles_user_tables) and rows in gpkg\_2d\_gridded\_coverage\_ancillary. When the datatype of the corresponding gpkg\_2d\_gridded\_coverage\_ancillary row is *float*, the scale and offset values SHALL be set to the defaults. |

|  |
| --- |
| **Requirement 12** |
| Req/**gpkg-2d-gridded-tile-ancillary-values-id** |
| Values of the gpkg\_2d\_gridded\_tile\_ancillary tpudt\_id column SHALL reference values in id column of the table referenced in tpudt\_name. |

## Tile Pyramid User Data Tables

The following is the requirements class for the CIS::GeneralGridCoverage, class grid-regular Tile Pyramid User Data Table extensions.

|  |  |
| --- | --- |
| **Requirements Class Tile Pyramid User Data Tables** | |
| **http://www.opengis.net/spec/geopackage-gr/1.0/tile-pyramid-user-data-tablaes** | |
| Target type | Token |
| Dependency | **http://www.geopackage.org/spec/#tiles** |
| **Requirement 13** | **Req/gpkg-pyramid-user-data-datatype-integer** |
| **Requirement 14** | **Req/gpkg-pyramid-user-data-datatype-integer** |

|  |
| --- |
| **Requirement 13** |
| Req/**gpkg- pyramid-user-data-datatype-integer** |
| For data where the datatype column of the corresponding row in the gpkg\_2d\_gridded\_coverage\_ancillary table is *integer*, the tile\_data BLOB in the [tile pyramid user data table](http://www.geopackage.org/spec/#tiles_user_tables) containing tiled, gridded data SHALL be of [MIME type](http://www.ietf.org/rfc/rfc2046.txt) image/png and the data SHALL be 16-bit unsigned integer (single channel - "greyscale"). |

|  |
| --- |
| **Requirement 14** |
| Req/**gpkg- pyramid-user-data-datatype-float** |
| (extends [GPKG-36](http://www.geopackage.org/spec/#r36) and [GPKG-37](http://www.geopackage.org/spec/#r37)) For data where the datatype column of the corresponding row in the gpkg\_2d\_gridded\_coverage\_ancillary table is *float*, the tile\_data BLOB in the [tile pyramid user data table](http://www.geopackage.org/spec/#tiles_user_tables) containing tiled, gridded data SHALL be of [MIME type](http://www.ietf.org/rfc/rfc2046.txt) image/tiff and the data SHALL be 32-bit floating point as described by the TIFF Encoding ([TIFF Encoding](http://www.geopackage.org/spec/#tiff_encoding)). |

# TIFF Encoding

Due to the wide range of possible TIFF encodings, the TIFF encoding for a GeneralGridCoverage, class grid-regular (such as for elevation data) tile has been constrained for the sake of interoperability and best practice. Further, these constraints are provided as a basis for enhanced interoperability with using GeoPackages in an OGC compliant CDB data store. CDB, used in the modelling and simulation industry, has a major requirement for using GeneralGridCoverage, class grid-regular such as terrain (a grid of elevations). CDB defines a strict set of requirements for encoding terrain as a tiled TIFF coverage in a CDB data store.

Each TIFF encoded tile is a baseline TIFF as defined in the Part 1 of the TIFF standard. The only allowed encoding extensions are:

* IEEE floating point (see Requirement 17 below); and
* LZW compression (see Requirement 18 below).

Tiles are encoded as a single-band image using one 32-bit floating point component per pixel. This implies a number of constraints which are listed below:

* There is only one band per TIFF tile, i.e., for any pixel in the TIFF tile, there SHALL be only one component (see Requirement 21 below).
* All pixels in the tile SHALL be set with a valid component value (see Requirement 21 below).
* Other TIFF tags are derived from the other constraints in this extension.
* No multi-image/tiling extensions defined in TIFF shall be used (see Requirement 19 and Requirement 20 below).

|  |  |
| --- | --- |
| **Requirements Class Tiff Encoding** | |
| **http://www.opengis.net/spec/geopackage-gr/1.0/tiff** | |
| Target type | Token |
| Dependency | **http://www.geopackage.org/spec/#tiles** |
| **Requirement 15** | **Req/gpkg-gr-tiff** |
| **Requirement 16** | **Req/gpkg-gr-tiff-samplesperpixel** |
| **Requirement 17** | **Req/gpkg-gr-tiff-float** |
| **Requirement 18** | **Req/gpkg-gr-tiff-lzw** |
| **Requirement 19** | **Req/gpkg-gr-tiff-single-image** |
| **Requirement 20** | **Req/gpkg-gr-tiff-internal-tiles** |
| **Requirement 21** | Req/**gpkg-tiff-valid-component-value** |

|  |
| --- |
| **Requirement 15** |
| Req/**gpkg-tiff** |
| A TIFF file used for storing tiled RectifiedGridCoverages, such as elevation data, *SHALL* conform to the TIFF specification[[14]](#footnote-14). |

|  |
| --- |
| **Requirement 16** |
| Req/**gpkg-tiff-samplesperpixel** |
| A TIFF file storing tiled GeneralGridCoverage, class grid-regular, such as elevation data, *SHALL* have one sample per grid cell[[15]](#footnote-15). This requirement constrains TIFF Section 2. |

By setting TIFF TAG 277 (SamplesPerPixel) to be 1, the GeoPackage producer indicates that there is a single sample per grid cell.

|  |
| --- |
| **Requirement 17** |
| Req/**gpkg-tiff-float** |
| A TIFF file storing tiled GeneralGridCoverage, class grid-regular, such as elevation data, *SHALL* have the 32-bit floating (FLOAT – 11) data type. This requirement constrains TIFF Section 19. |

By setting TAG 339 (SampleFormat) to be 3, the producer indicates that the Sample Value is IEEE floating point as defined in Part 2 (TIFF Extensions) Section 19: Data Sample Format TIFF. By setting TAG 258 (BitsPerSample) to be 32, the producer indicates that there are 32 bits per sample.

|  |
| --- |
| **Requirement 18** |
| Req/**gpkg-tiff-lzw** |
| A TIFF file storing tiled GeneralGridCoverage, class grid-regular, such as elevation data, *MAY* use the LZW compression option as per TIFF Section 13. |

NOTE to developers: Client applications that support the TIFF encoding are expected to support this LZW compression. This is due to the fact that GeoPackages containing gridded coverages delivered to a client may or may not use LZW compression.

|  |
| --- |
| **Requirement 19** |
| Req/**gpkg-tiff-single-image** |
| A TIFF file storing tiled R GeneralGridCoverage, class grid-regular, such as elevation data, *SHALL* only contain single images per TIFF file. This requirement constrains TIFF Section 2. Multiple image files are not allowed. |

|  |
| --- |
| **Requirement 20** |
| Req/**gpkg-tiff-internal-tiles** |
| A TIFF file storing tiled GeneralGridCoverage, class grid-regular, such as elevation data, SHALL NOT contain internal tiles as per TIFF Section 15. This requirement constrains TIFF Section 15. |

|  |
| --- |
| **Requirement 21** |
| Req/**gpkg-tiff-valid-component-value** |
| All pixels in an elevation tile *SHALL* be set with a valid component value. The mechanisms defined in this extension *SHALL* be used to indicate a missing value for a pixel. Use the data\_null value defined in [Coverage Ancillary](#_Coverage_Ancillary). Special Note: Special floating point values such as NaN and Inf SHALL NOT be used. |

Annex A: Conformance Class Abstract Test Suite (Normative)

**A.1 Table Definitions**

Coverage Ancillary

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_def/gpkg\_2d\_gridded\_coverage\_ancillary |
| **Test Purpose:** | Verify that the "gpkg\_2d\_gridded\_coverage\_ancillary" table has the proper definition. |
| **Test Method:** | 1. PRAGMA table\_info(gpkg\_2d\_gridded\_coverage\_ancillary) 2. Fail if table does not have all of the columns specified in Table 27 3. Pass if logged pass and no fails |
| **Reference** | Req 1 |
| **Test Type** | Basic |

Tile Ancillary

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_def/gpkg\_2d\_gridded\_tile\_ancillary |
| **Test Purpose:** | Verify that the "gpkg\_2d\_gridded\_tile\_ancillary" table has the proper definition. |
| **Test Method:** | 1. PRAGMA table\_info(gpkg\_2d\_gridded\_tile\_ancillary) 2. Fail if table does not have all of the columns specified in Table 1 3. Pass if logged pass and no fails |
| **Reference** | Req 2 |
| **Test Type** | Basic |

**A.2 Table Values**

Spatial Reference

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_val/gpkg\_spatial\_ref\_sys/rows |
| **Test Purpose:** | Verify that the “gpkg\_spatial\_ref\_sys” table has the required rows. |
| **Test Method:** | 1. SELECT COUNT(\*) FROM gpkg\_spatial\_ref\_sys WHERE organization\_coordsys\_id = 4979 AND (organization = *EPSG* OR organization = *epsg*) 2. Fail if count is zero 3. Pass if logged pass and no fails |
| **Reference** | Annex F.11 Req 3 |
| **Test Type** | Basic |

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_val/gpkg\_spatial\_ref\_sys/refs |
| **Test Purpose:** | Verify that all elevation data uses an SRS that is defined in gpkg\_spatial\_ref\_sys |
| **Test Method:** | 1. SELECT table\_name FROM gpkg\_contents WHERE data\_type = *2d-gridded-coverage*; 2. For each table\_name    1. SELECT COUNT(\*) FROM gpkg\_tile\_matrix\_set WHERE table\_name = *{table\_name}*    2. Fail if count is not 1 3. Pass if no fails |
| **Reference:** | Annex F.11 Req 4 |
| **Test Type** | Capability |

**A.3 Contents**

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_val/gpkg\_spatial\_ref\_sys |
| **Test Purpose:** | Verify that all elevation data uses an SRS that is defined in gpkg\_spatial\_ref\_sys |
| **Test Method:** | 1. SELECT table\_name FROM gpkg\_contents WHERE data\_type = *2d-gridded-coverage*; 2. Not testable if result set is empty 3. Manually inspect that all elevation data is accounted for in the result set |
| **Reference:** | Annex F.11 Req 5 |
| **Test Type** | Capability |

**A.4 Extensions**

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_val/gpkg\_extensions |
| **Test Purpose:** | Verify that all required rows are present in gpkg\_extensions |
| **Test Method:** | 1. SELECT table\_name, column\_name, extension\_name, definition, scope from gpkg\_extensions"; 2. Verify that the required rows in Table 3 for table\_name gpkg\_2d\_gridded\_coverage\_ancillary and gpkg\_2d\_gridded\_tile\_ancillary are present. 3. SELECT table\_name FROM gpkg\_contents WHERE data\_type = *2d-gridded-coverage*; 4. For each table\_name    1. SELECT column\_name, definition, scope from gpkg\_extensions WHERE extension\_name = *gpkg\_elevation\_tiles* AND table\_name = *{table\_name}*    2. Fail if no rows found    3. Fail if the results do not match the entry in Table 30 for a user defined table 5. Pass if no fails |
| **Reference:** | Annex F.11 Req 6 |
| **Test Type** | Capability |

**A.5 Coverage Ancillary**

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_ref/gpkg\_contents/gpkg\_2d\_gridded\_coverage\_ancillary |
| **Test Purpose:** | Verify that all required rows are present in gpkg\_2d\_gridded\_coverage\_ancillary |
| **Test Method:** | 1. SELECT table\_name FROM gpkg\_contents WHERE data\_type = *2d-gridded-coverage*; 2. For each table\_name    1. SELECT COUNT(\*) FROM gpkg\_2d\_gridded\_coverage\_ancillary WHERE tile\_matrix\_set\_name = *{table\_name}*    2. Fail if count is not 1 3. Pass if no fails |
| **Reference:** | Annex F.11 Req 7 |
| **Test Type** | Capability |

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_ref/gpkg\_2d\_gridded\_coverage\_ancillary/gpkg\_tile\_matrix\_set |
| **Test Purpose:** | Verify that gpkg\_2d\_gridded\_coverage\_ancillary references gpkg\_tile\_matrix\_set |
| **Test Method:** | 1. SELECT tile\_matrix\_set\_name FROM *gpkg\_2d\_gridded\_coverage\_ancillary*; 2. For each tile\_matrix\_set\_name    1. SELECT count(\*) FROM gpkg\_tile\_matrix\_set WHERE table\_name = *{tile\_matrix\_set\_name}*    2. Fail if count is not 1 3. Pass if no fails |
| **Reference:** | Annex F.11 Req 8 |
| **Test Type** | Capability |

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_val/gpkg\_2d\_gridded\_coverage\_ancillary |
| **Test Purpose:** | Verify that gpkg\_2d\_gridded\_coverage\_ancillary contains valid column values |
| **Test Method:** | 1. SELECT datatype, scale, offset FROM *gpkg\_2d\_gridded\_coverage\_ancillary* WHERE tile\_matrix\_set\_name IN (SELECT table\_name FROM gpkg\_contents WHERE data\_type = *2d-gridded-coverage*); 2. For each result in 1    1. Fail if datatype is not "integer" or "float"    2. Fail if datatype is "float" and scale is not 1.0    3. Fail if datatype is "float" and offset is not 0.0 3. Pass if no fails |
| **Reference:** | Annex F.11 Req 9 |
| **Test Type** | Capability |

**A.6 Tile Ancillary**

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_ref/tpudt/gpkg\_2d\_gridded\_tile\_ancillary |
| **Test Purpose:** | Verify that all required rows are present in gpkg\_2d\_gridded\_tile\_ancillary |
| **Test Method:** | 1. SELECT table\_name FROM gpkg\_contents WHERE data\_type = *2d-gridded-coverage*; 2. For each table\_name    1. SELECT {table\_name}.id as tid, gpkg\_2d\_gridded\_tile\_ancillary.tpudt\_id as taid from elev\_png LEFT OUTER JOIN gpkg\_2d\_gridded\_tile\_ancillary ON {table\_name}.id = gpkg\_2d\_gridded\_tile\_ancillary.tpudt\_id AND gpkg\_2d\_gridded\_tile\_ancillary.tpudt\_name = *{table\_name}*    2. For each row       1. Fail if taid is null 3. Pass if no fails |
| **Reference:** | Annex F.11 Req 10, 12 |
| **Test Type** | Capability |

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_val/gpkg\_2d\_gridded\_tile\_ancillary |
| **Test Purpose:** | Verify that all required rows in gpkg\_2d\_gridded\_tile\_ancillary have valid values |
| **Test Method:** | 1. SELECT tpudt\_name, scale, offset FROM gpkg\_2d\_gridded\_tile\_ancillary; 2. For each row    1. PRAGMA table\_info({tpudt\_name})    2. Fail if tpudt\_name is not a table or view    3. SELECT datatype from gpkg\_2d\_gridded\_coverage\_ancillary WHERE tile\_matrix\_set\_name = *{tpudt\_name}*    4. Fail if no rows found    5. Fail if datatype is "float" and scale is not 1.0    6. Fail if datatype is "float" and offset is not 0.0 3. Pass if no fails |
| **Reference:** | Annex F.11 Req 11 |
| **Test Type** | Capability |

**A.7 Tile Pyramid User Data Table**

|  |  |
| --- | --- |
| **Test Case ID** | /extensions/elevation/table\_val/tpudt |
| **Test Purpose:** | Verify that all rows in tile pyramid user data tables have valid values |
| **Test Method:** | 1. SELECT table\_name FROM gpkg\_contents WHERE data\_type = *2d-gridded-coverage*; 2. For each table\_name    1. SELECT t.datatype AS datatype, u.id AS id, u.tile\_data AS tile\_data FROM gpkg\_2d\_gridded\_coverage\_ancillary t, {table\_name} u WHERE t.tile\_matrix\_set\_name = *table\_name*;    2. For each row       1. If datatype is float, fail if tile\_data is not a valid TIFF image as per requirements 115-121       2. If datatype is integer, fail if tile\_data is not a valid PNG image 3. Pass if no fails |
| **Reference:** | Annex F.11 Req 13, 14, 115-121 |
| **Test Type** | Capability |

Annex B: Informative - GML example showing domainSet, rangeType, and rangetSet

<?xml version="1.0" encoding="UTF-8"?>

<gmlcov:RectifiedGridCoverage gml:id="DTM001" xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:gmlcov="http://www.opengis.net/gmlcov/1.0" xmlns:swe="http://www.opengis.net/swe/2.0" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://schemas.opengis.net/gmlcov/1.0/coverage.xsd">

<gml:domainSet>

<gml:RectifiedGrid gml:id="rg0001\_C0002" dimension="2" srsName="http://www.opengis.net/def/crs/EPSG/0/32633">

<gml:limits>

<gml:GridEnvelope>

<gml:low>0 0</gml:low>

<gml:high>3327 2946</gml:high>

</gml:GridEnvelope>

</gml:limits>

<gml:axisName>x</gml:axisName>

<gml:axisName>y</gml:axisName>

<gml:origin>

<gml:Point gml:id="P0001" srsName="http://www.opengis.net/def/crs/EPSG/0/32633">

<gml:pos>291355.903287358 4640962.87782889</gml:pos>

</gml:Point>

</gml:origin>

<gml:offsetVector srsName="http://www.opengis.net/def/crs/EPSG/0/32633">0.298582141738734 0</gml:offsetVector>

<gml:offsetVector srsName="http://www.opengis.net/def/crs/EPSG/0/32633">0 -0.298582141738591</gml:offsetVector>

</gml:RectifiedGrid>

</gml:domainSet>

<gml:rangeSet>

<gml:File>

<gml:rangeParameters/>

<gml:fileName>D:\Documents\Data\DTM001.tiff</gml:fileName>

<gml:fileStructure>Not interleaved</gml:fileStructure>

</gml:File>

</gml:rangeSet>

<gmlcov:rangeType>

<swe:DataRecord>

<swe:field name="Height">

<swe:Quantity definition="http://sweet.jpl.nasa.gov/2.0/spaceExtent.owl#Height" referenceFrame="http://www.opengis.net/def/crs/EPSG/0/9001">

<swe:description>Height above mean sea level</swe:description>

<swe:uom code="m"/>

</swe:Quantity>

</swe:field>

</swe:DataRecord>

</gmlcov:rangeType>

</gmlcov:RectifiedGridCoverage>

Annex C: Table Definition SQL for Grid-Regular Extension (Normative)

**Coverage Ancillary Table Definition SQL**

CREATE TABLE 'gpkg\_2d\_gridded\_coverage\_ancillary' (

id INTEGER PRIMARY KEY AUTOINCREMENT NOT NULL,

tile\_matrix\_set\_name TEXT NOT NULL UNIQUE,

datatype TEXT NOT NULL DEFAULT 'integer',

scale REAL NOT NULL DEFAULT 1.0,

offset REAL NOT NULL DEFAULT 0.0,

precision REAL DEFAULT 1.0,

data\_null REAL,

grid\_cell\_encoding TEXT (DEFAULT grid-value-is-center),

uom TEXT,

field\_name TEXT DEFAULT 'Height',

quantity\_definition TEXT DEFAULT 'Height',

CONSTRAINT fk\_g2dgtct\_name FOREIGN KEY('tile\_matrix\_set\_name') REFERENCES

gpkg\_tile\_matrix\_set ( table\_name )

CHECK (datatype in ('integer','float')));

**Tile Ancillary Table Definition SQL**

CREATE TABLE gpkg\_2d\_gridded\_tile\_ancillary (

id INTEGER PRIMARY KEY AUTOINCREMENT NOT NULL,

tpudt\_name TEXT NOT NULL,

tpudt\_id INTEGER NOT NULL,

scale REAL NOT NULL DEFAULT 1.0,

offset REAL NOT NULL DEFAULT 0.0,

min REAL DEFAULT NULL,

max REAL DEFAULT NULL,

mean REAL DEFAULT NULL,

std\_dev REAL DEFAULT NULL,

CONSTRAINT fk\_g2dgtat\_name FOREIGN KEY (tpudt\_name) REFERENCES gpkg\_contents(table\_name),

UNIQUE (tpudt\_name, tpudt\_id));

Annex D: Revision history

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Date | Release | Author | Paragraph modified | Description |
| 2018-02-26 | R1 | Carl Reed | All | Address comments from TC vote |
|  |  |  |  |  |
|  |  |  |  |  |

1. Grid-regular in OGC Coverage Implementation Schema (CIS). More specifically, for a continuous grid-regular coverage, see CV\_ContinuousQuadrilateralGridCoverage in ISO 19123 and OGC Topic Volume 6. [↑](#footnote-ref-1)
2. https://portal.opengeospatial.org/files/?artifact\_id=70051&version=1 [↑](#footnote-ref-2)
3. The GeoPackage (Clause 2.2) Tiles option specifies a mechanism for storing raster data in tile pyramids in a GeoPackage data store. [↑](#footnote-ref-3)
4. We acknowledge that this approach will not support certain applications that require a high degree of precision and/or accuracy (e.g., targeting). This is due to the encoding mechanism (PNG or TIFF). [↑](#footnote-ref-4)
5. [www.opengeospatial.org/cite](http://www.opengeospatial.org/cite) [↑](#footnote-ref-5)
6. The definitions for “height” and “depth” are meant to be general and are derived from ISO 19111. However, the reader should note that there are domain specific variations or enhancements of the definitions used in this standard. [↑](#footnote-ref-6)
7. The text in this section is extracted/summarized from the OGC Coverage Implementation Schema 1.1 (CIS) standard [OGC 09-146r6]. Please note that This GeoPackage extension references CIS 1.1 and not CIS 1.0. [↑](#footnote-ref-7)
8. This GeoPackage extension uses the CIS 1.1. CIS 1.1 provides a definition for Rectified Grid Coverage for backwards compatibility with CIS 1.0. Please see CIS 1.1 sections 7.1 and 7.2 for discussion of compatibility. [↑](#footnote-ref-8)
9. https://codes.wmo.int/def/common/Unit [↑](#footnote-ref-9)
10. http://www.qudt.org/ [↑](#footnote-ref-10)
11. These two values are designed to be jointly unique so that they refer to a single row in a single table. [↑](#footnote-ref-11)
12. These two values are designed to be jointly unique so that they refer to a single row in a single table. [↑](#footnote-ref-12)
13. Need to change this and the two above to this document. [↑](#footnote-ref-13)
14. <https://www.loc.gov/preservation/digital/formats/fdd/fdd000022.shtml> [↑](#footnote-ref-14)
15. Note: In this document, pixel and grid cell may be considered as equivalent terms. [↑](#footnote-ref-15)