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## OGC GeoPackage Extension for Tiled Gridded Coverage Data

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## **i. 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`<sup>1</sup>. 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.

## **ii. Keywords**

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

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

## **iii. 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<sup>2</sup>. 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

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<sup>1</sup> 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.

<sup>2</sup> [https://portal.opengeospatial.org/files/?artifact\\_id=70051&version=1](https://portal.opengeospatial.org/files/?artifact_id=70051&version=1)

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](#)<sup>3</sup> 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](#) (Clause 2.2.8 of the GeoPackage core) that can be used to hold tiled, gridded coverage data.
- Scope: read-write.

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*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.*

#### iv. 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>

#### v. Submitters

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

Name	Affiliation
Chris Clarke	Compusult
Carl Reed	Carl Reed and Associates
Jeff Yutzler	Image Matters

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<sup>3</sup> The GeoPackage (Clause 2.2) Tiles option specifies a mechanism for storing raster data in tile pyramids in a GeoPackage data store.

## 1. 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<sup>4</sup>.

## 2. 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

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<sup>4</sup> 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).

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<sup>5</sup>.

### 3. 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: ISO 12639:2004, 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](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](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<sup>®</sup> SWE Common Data Model Encoding Standard, version 2.0, 2011

UCUM: [The Unified Code for Units of Measure](#). 2014.

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

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<sup>5</sup> [www.opengeospatial.org/cite](http://www.opengeospatial.org/cite)



## 4. Terms and Definitions<sup>6</sup>

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.

### 4.1

#### **Continuous coverage**

**coverage** that returns different values for the same feature attribute at different **direct positions** within a single spatial object, temporal object or spatiotemporal object in its domain. [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.

### 4.2

#### **Coordinate Reference System (CRS)**

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

### 4.3

#### **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].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]

### 4.4

#### **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]

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<sup>6</sup> 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.

## **4.5**

### **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.

## **4.6**

### **Direct Position**

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

## **4.7**

### **Elevation**

Synonym for “height”

## **4.8**

### **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]

## **4.9**

### **Grid point**

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

## **4.10**

### **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.

## **4.11**

### **Regular grid**

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

## **5. 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.

### **5.1 Identifiers**

The normative provisions in this standard are denoted by the URI

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

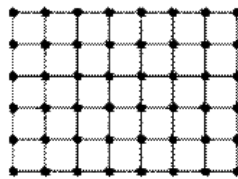
All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base. The three letter acronym “Req” is equivalent to the above URI. NOTE: The abbreviation “gr” stands for grid-regular.

## 6. Short introduction to coverages and CIS<sup>7</sup>

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<sup>8</sup>.



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<sup>7</sup> 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.

<sup>8</sup> 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.

## 6.1 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.

## 6.2 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.

## 6.3 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.

### 6.3.1 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 ( $\geq 1$ ) for this zoom level  
tile\_height: Tile height in pixels ( $\geq 1$ ) for this zoom level

### 6.3.2 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.

### 6.3.3 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](#) of this document.

### 6.3.4 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.

## 7. 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.

## 7.1 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	
<a href="http://www.opengis.net/spec/geopackage-gr/1.0/table-defs">http://www.opengis.net/spec/geopackage-gr/1.0/table-defs</a>	
Target type	Token
Dependency	<a href="http://www.geopackage.org/spec/#tiles">http://www.geopackage.org/spec/#tiles</a>
Requirement 1	Req/coverage-ancillary
Requirement 2	Req/tile-ancillary

### 7.1.1 Coverage Ancillary

Requirement 1
<a href="#">Req/table-defs/coverage-ancillary</a>
A GeoPackage that contains tiled gridded data <i>SHALL</i> contain a <code>gpkg_2d_gridded_coverage_ancillary</code> table or view as per the Coverage Ancillary Table Definition below. Subsequent extensions or custom implementations <i>MAY</i> add additional columns to this table. Clients <i>SHALL</i> 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 <a href="#">gpkg_tile_matrix_set</a>	no		FK	UNIQUE
datatype	TEXT	<i>integer or float</i>	no	<i>integer</i>		
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]	The smallest value that has meaning for this dataset	yes	1		
data_null	REAL[42]	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			

Table 1: Coverage Ancillary Table Definition						
Column Name	Column Type	Column Description	Null	Default	Key	Constraint
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		

### 7.1.1.1 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*.

### 7.1.1.2 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.

### 7.1.1.3 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<sup>9</sup> and the NASA QUDT semantic definitions<sup>10</sup>.

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.

### 7.1.1.4 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

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<sup>9</sup> <https://codes.wmo.int/def/common/Unit>

<sup>10</sup> <http://www.qudt.org/>



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.

#### 7.1.1.5 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](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.”

#### 7.1.2 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](#). 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 <a href="#">tile pyramid user data table</a>	no		UNIQUE <sup>11</sup>
tpudt_id	INTEGER	Foreign key to id in <a href="#">tile pyramid user data table</a>	no		UNIQUE <sup>12</sup>
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]	Minimum value of this tile	yes		
max	REAL[46]	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*.

## 7.2 Table Values

The following requirements specify required and optional table values.

Requirements Class Table Values	
<a href="http://www.opengis.net/spec/geopackage-gr/1.0/table-values">http://www.opengis.net/spec/geopackage-gr/1.0/table-values</a>	
Target type	Token
Dependency	<a href="http://www.geopackage.org/spec/#tiles">http://www.geopackage.org/spec/#tiles</a>
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

### 7.2.1 gpkg\_spatial\_ref\_sys

Requirement 3
<a href="#">Req/gpkg-spatial-ref-sys-row</a>
GeoPackages complying with this extension <i>SHALL</i> have a row in the

<sup>11</sup> These two values are designed to be jointly unique so that they refer to a single row in a single table.

<sup>12</sup> These two values are designed to be jointly unique so that they refer to a single row in a single table.

gpkg\_spatial\_ref\_sys table as described in [Spatial Ref Sys Table Record](#):

Due to limitations in expressing 3d coordinate reference systems in the original OGC (circa 2001) [Well-known Text](#), it is recommended that GeoPackages complying with the grid-regular extension also comply with [ISO 19162](#) WKT for Coordinate Reference Systems as described in the GeoPackage CRS extension [http://www.geopackage.org/spec/#extension\\_crs\\_wkt](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](#) and later.

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.

### 7.2.2 gpkg\_contents

#### Requirement 5

[Req/gpkg-contents](#)

The `gpkg_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](#). 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.

### 7.2.3 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_name	column_name	extension_name	definition	scope
gpkg_2d_gridded_coverage_ancillary	null	2d_gridded_coverage	<a href="http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data">http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data</a>	read-write
gpkg_2d_gridded_tile_ancillary	null	2d_gridded_coverage	<a href="http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data">http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data</a>	read-write
name of actual <a href="#">tile pyramid user data table</a> containing grid-regular data	tile_data	2d_gridded_coverage	<a href="http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data">http://www.geopackage.org/spec/#extension_tiled_gridded_elevation_data</a> <sup>13</sup>	read-write

### 7.3 gpkg\_2d\_gridded\_coverage\_ancillary

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

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

The following requirements refer to the `gpkg_2d_gridded_coverage_ancillary` table as per [Coverage Ancillary Table Definition](#).

#### Requirement 7

<sup>13</sup> Need to change this and the two above to this document.

### [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.

## 7.4 `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	
<a href="http://www.opengis.net/spec/geopackage-gr/1.0/grid-tile-ancillary">http://www.opengis.net/spec/geopackage-gr/1.0/grid-tile-ancillary</a>	
Target type	Token
Dependency	<a href="http://www.geopackage.org/spec/#tiles">http://www.geopackage.org/spec/#tiles</a>
Requirement 10	<a href="#">Req/gpkg-2d-gridded-tile-ancillary</a>
Requirement 11	<a href="#">Req/gpkg-2d-gridded-tile-ancillary-values</a>
Requirement 12	<a href="#">Req/gpkg-2d-gridded-tile-ancillary-dvalues-id</a>

The following requirements refer to the `gpkg_2d_gridded_tile_ancillary` table as per [Tile Ancillary Table Definition](#).

### 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](#) 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`.

**7.5 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	
<a href="http://www.opengis.net/spec/geopackage-gr/1.0/tile-pyramid-user-data-tables">http://www.opengis.net/spec/geopackage-gr/1.0/tile-pyramid-user-data-tables</a>	
Target type	Token
Dependency	<a href="http://www.geopackage.org/spec/#tiles">http://www.geopackage.org/spec/#tiles</a>
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](#) containing tiled, gridded data SHALL be of [MIME type](#) `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](#) and [GPKG-37](#)) 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](#) containing tiled, gridded data SHALL be of [MIME type](#) `image/tiff` and the data SHALL be 32-bit floating point as described by the TIFF Encoding ([TIFF Encoding](#)).

## 8. 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	
<a href="http://www.opengis.net/spec/geopackage-gr/1.0/tiff">http://www.opengis.net/spec/geopackage-gr/1.0/tiff</a>	
Target type	Token
Dependency	<a href="http://www.geopackage.org/spec/#tiles">http://www.geopackage.org/spec/#tiles</a>
Requirement 15	<a href="#">Req/gpkg-gr-tiff</a>
Requirement 16	<a href="#">Req/gpkg-gr-tiff-samplesperpixel</a>
Requirement 17	<a href="#">Req/gpkg-gr-tiff-float</a>
Requirement 18	<a href="#">Req/gpkg-gr-tiff-lzw</a>
Requirement 19	<a href="#">Req/gpkg-gr-tiff-single-image</a>
Requirement 20	<a href="#">Req/gpkg-gr-tiff-internal-tiles</a>
Requirement 21	<a href="#">Req/gpkg-tiff-valid-component-value</a>

Requirement 15
<a href="#">Req/gpkg-tiff</a>
A TIFF file used for storing tiled <code>RectifiedGridCoverages</code> , such as elevation data, <i>SHALL</i> conform to the TIFF specification <sup>14</sup> .

Requirement 16
<a href="#">Req/gpkg-tiff-samplesperpixel</a>
A TIFF file storing tiled <code>GeneralGridCoverage</code> , class <code>grid-regular</code> , such as elevation data, <i>SHALL</i> have one sample per grid cell <sup>15</sup> . 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.

<sup>14</sup> <https://www.loc.gov/preservation/digital/formats/fdd/fdd000022.shtml>

<sup>15</sup> Note: In this document, pixel and grid cell may be considered as equivalent terms.



### 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 `RGeneralGridCoverage`, 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](#). 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

<b>Test Case ID</b>	/extensions/elevation/table_def/gpkg_2d_gridded_coverage_ancillary
<b>Test Purpose:</b>	Verify that the "gpkg_2d_gridded_coverage_ancillary" table has the proper definition.
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. PRAGMA table_info(gpkg_2d_gridded_coverage_ancillary)</li> <li>2. Fail if table does not have all of the columns specified in Table 27</li> <li>3. Pass if logged pass and no fails</li> </ol>
<b>Reference</b>	Req 1
<b>Test Type</b>	Basic

#### Tile Ancillary

<b>Test Case ID</b>	/extensions/elevation/table_def/gpkg_2d_gridded_tile_ancillary
<b>Test Purpose:</b>	Verify that the "gpkg_2d_gridded_tile_ancillary" table has the proper definition.
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. PRAGMA table_info(gpkg_2d_gridded_tile_ancillary)</li> <li>2. Fail if table does not have all of the columns specified in Table 1</li> <li>3. Pass if logged pass and no fails</li> </ol>
<b>Reference</b>	Req 2
<b>Test Type</b>	Basic

### A.2 Table Values

#### Spatial Reference

<b>Test Case ID</b>	/extensions/elevation/table_val/gpkg_spatial_ref_sys/rows
<b>Test Purpose:</b>	Verify that the "gpkg_spatial_ref_sys" table has the required rows.
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. SELECT COUNT(*) FROM gpkg_spatial_ref_sys WHERE organization_coordsys_id = 4979 AND (organization = EPSG OR organization = epsg)</li> <li>2. Fail if count is zero</li> </ol>

	3. Pass if logged pass and no fails
<b>Reference</b>	Annex F.11 Req 3
<b>Test Type</b>	Basic

<b>Test Case ID</b>	/extensions/elevation/table_val/gpkg_spatial_ref_sys/refs
<b>Test Purpose:</b>	Verify that all elevation data uses an SRS that is defined in gpkg_spatial_ref_sys
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. SELECT table_name FROM gpkg_contents WHERE data_type = 2d-gridded-coverage;</li> <li>2. For each table_name <ol style="list-style-type: none"> <li>a. SELECT COUNT(*) FROM gpkg_tile_matrix_set WHERE table_name = {table_name}</li> <li>b. Fail if count is not 1</li> </ol> </li> <li>3. Pass if no fails</li> </ol>
<b>Reference:</b>	Annex F.11 Req 4
<b>Test Type</b>	Capability

### A.3 Contents

<b>Test Case ID</b>	/extensions/elevation/table_val/gpkg_spatial_ref_sys
<b>Test Purpose:</b>	Verify that all elevation data uses an SRS that is defined in gpkg_spatial_ref_sys
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. SELECT table_name FROM gpkg_contents WHERE data_type = 2d-gridded-coverage;</li> <li>2. Not testable if result set is empty</li> <li>3. Manually inspect that all elevation data is accounted for in the result set</li> </ol>
<b>Reference:</b>	Annex F.11 Req 5
<b>Test Type</b>	Capability

### A.4 Extensions

<b>Test Case ID</b>	/extensions/elevation/table_val/gpkg_extensions
<b>Test Purpose:</b>	Verify that all required rows are present in gpkg_extensions

<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. <code>SELECT table_name, column_name, extension_name, definition, scope from gpkg_extensions";</code></li> <li>2. Verify that the required rows in Table 3 for table_name <code>gpkg_2d_gridded_coverage_ancillary</code> and <code>gpkg_2d_gridded_tile_ancillary</code> are present.</li> <li>3. <code>SELECT table_name FROM gpkg_contents WHERE data_type = 2d-gridded-coverage;</code></li> <li>4. For each table_name <ol style="list-style-type: none"> <li>a. <code>SELECT column_name, definition, scope from gpkg_extensions WHERE extension_name = gpkg_elevation_tiles AND table_name = {table_name}</code></li> <li>b. Fail if no rows found</li> <li>c. Fail if the results do not match the entry in Table 30 for a user defined table</li> </ol> </li> <li>5. Pass if no fails</li> </ol>
<b>Reference:</b>	Annex F.11 Req 6
<b>Test Type</b>	Capability

### A.5 Coverage Ancillary

<b>Test Case ID</b>	/extensions/elevation/table_ref/gpkg_contents/gpkg_2d_gridded_coverage_ancillary
<b>Test Purpose:</b>	Verify that all required rows are present in <code>gpkg_2d_gridded_coverage_ancillary</code>
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. <code>SELECT table_name FROM gpkg_contents WHERE data_type = 2d-gridded-coverage;</code></li> <li>2. For each table_name <ol style="list-style-type: none"> <li>a. <code>SELECT COUNT(*) FROM gpkg_2d_gridded_coverage_ancillary WHERE tile_matrix_set_name = {table_name}</code></li> <li>b. Fail if count is not 1</li> </ol> </li> <li>3. Pass if no fails</li> </ol>
<b>Reference:</b>	Annex F.11 Req 7
<b>Test Type</b>	Capability
<b>Test Case ID</b>	/extensions/elevation/table_ref/gpkg_2d_gridded_coverage_ancillary/gpkg_tile_matrix_set
<b>Test Purpos</b>	Verify that <code>gpkg_2d_gridded_coverage_ancillary</code> references <code>gpkg_tile_matrix_set</code>

<b>e:</b>	
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. SELECT tile_matrix_set_name FROM gpkg_2d_gridded_coverage_ancillary;</li> <li>2. For each tile_matrix_set_name <ol style="list-style-type: none"> <li>a. SELECT count(*) FROM gpkg_tile_matrix_set WHERE table_name = {tile_matrix_set_name}</li> <li>b. Fail if count is not 1</li> </ol> </li> <li>3. Pass if no fails</li> </ol>
<b>Reference:</b>	Annex F.11 Req 8
<b>Test Type</b>	Capability
<b>Test Case ID</b>	/extensions/elevation/table_val/gpkg_2d_gridded_coverage_ancillary
<b>Test Purpose:</b>	Verify that gpkg_2d_gridded_coverage_ancillary contains valid column values
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>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);</li> <li>2. For each result in 1 <ol style="list-style-type: none"> <li>a. Fail if datatype is not "integer" or "float"</li> <li>b. Fail if datatype is "float" and scale is not 1.0</li> <li>c. Fail if datatype is "float" and offset is not 0.0</li> </ol> </li> <li>3. Pass if no fails</li> </ol>
<b>Reference:</b>	Annex F.11 Req 9
<b>Test Type</b>	Capability

## A.6 Tile Ancillary

<b>Test Case ID</b>	/extensions/elevation/table_ref/tpudt/gpkg_2d_gridded_tile_ancillary
<b>Test Purpose:</b>	Verify that all required rows are present in gpkg_2d_gridded_tile_ancillary
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. SELECT table_name FROM gpkg_contents WHERE data_type = 2d-gridded-coverage;</li> <li>2. For each table_name <ol style="list-style-type: none"> <li>a. SELECT {table_name}.id as tid, gpkg_2d_gridded_tile_ancillary.tpudt_id as taid from elev_png LEFT OUTER JOIN</li> </ol> </li> </ol>

	<p>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}</p> <p>b. For each row  i. Fail if taid is null</p> <p>3. Pass if no fails</p>
<b>Reference:</b>	Annex F.11 Req 10, 12
<b>Test Type</b>	Capability
<b>Test Case ID</b>	/extensions/elevation/table_val/gpkg_2d_gridded_tile_ancillary
<b>Test Purpose:</b>	Verify that all required rows in gpkg_2d_gridded_tile_ancillary have valid values
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. SELECT tpudt_name, scale, offset FROM gpkg_2d_gridded_tile_ancillary;</li> <li>2. For each row <ol style="list-style-type: none"> <li>a. PRAGMA table_info({tpudt_name})</li> <li>b. Fail if tpudt_name is not a table or view</li> <li>c. SELECT datatype from gpkg_2d_gridded_coverage_ancillary WHERE tile_matrix_set_name = {tpudt_name}</li> <li>d. Fail if no rows found</li> <li>e. Fail if datatype is "float" and scale is not 1.0</li> <li>f. Fail if datatype is "float" and offset is not 0.0</li> </ol> </li> <li>3. Pass if no fails</li> </ol>
<b>Reference:</b>	Annex F.11 Req 11
<b>Test Type</b>	Capability

### A.7 Tile Pyramid User Data Table

<b>Test Case ID</b>	/extensions/elevation/table_val/tpudt
<b>Test Purpose:</b>	Verify that all rows in tile pyramid user data tables have valid values
<b>Test Method:</b>	<ol style="list-style-type: none"> <li>1. SELECT table_name FROM gpkg_contents WHERE data_type = 2d-gridded-coverage;</li> <li>2. For each table_name <ol style="list-style-type: none"> <li>a. 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;</li> <li>b. For each row <ol style="list-style-type: none"> <li>i. If datatype is float, fail if tile_data is not a valid TIFF</li> </ol> </li> </ol> </li> </ol>

	<p>image as per requirements 115-121</p> <p>ii. If datatype is integer, fail if tile_data is not a valid PNG image</p> <p>3. Pass if no fails</p>
<b>Reference:</b>	Annex F.11 Req 13, 14, 115-121
<b>Test Type</b>	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/EPSSG/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