International Association of Oil & Gas Producers

Surveying and Positioning
Guidance Note Number 7, part 1

Using the EPSG Geodetic Parameter Dataset

Revision history:

Version	Date	Amendments
1.0	October 2004	First release of this document, GN7 part 1. Former GN7 now released as part 2.
1.1	November 2004	Minor editorial corrections to text. Annex E SQL scripts updated.
2.0	April 2006	Amendment to deprecation rules. Updated references to EPSG.
2.1	February 2007	Deprecation rules updated. Policy on code uniqueness clarified. Additional information on user update utility added. Minor editorial corrections to text.
3	July 2007	Use of data conditions amended. Annex F added.
4	May 2009	Major revision to include web registry as GN7 part 3. Access- and SQL-specific discussion moved to new GN7 part 4. This document covers issues common to both registry and relational implementations.
5	November 2009	Minor amendments to clarify sections 4.4, 5.11 and 5.12.

CONTENTS

PREFACE

The EPSG Geodetic Parameter Dataset, abbreviated to the **EPSG Dataset**, is a repository of parameters required to:

- define a *coordinate reference system* (CRS), which ensures that coordinates describe position unambiguously.
- define transformations and conversions that allow coordinates to be changed from one CRS to another CRS. Transformations and conversions are collectively called *coordinate operations*.

The EPSG Dataset is maintained by the OGP Surveying and Positioning Committee's Geodetic Subcommittee. It conforms to ISO 19111 – *Spatial referencing by coordinates*. It is distributed in three ways:

- the **EPSG Registry**, in full the *EPSG Geodetic Parameter Registry*, a web-based delivery platform in which the data is held in GML using the CRS entities described in ISO 19136.
- the **EPSG Database**, in full *the EPSG Geodetic Parameter Database*, a relational database structure where the entities which form the components of CRSs and coordinate operations are in separate tables, distributed as an MS Access database;
- in a relational data model as **SQL scripts** which enable a user to create an Oracle, MySQL, PostgreSQL or other relational database and populate that database with the EPSG Dataset;

OGP Surveying and Positioning Guidance Note 7 is a multi-part document for users of the EPSG Dataset.

- *Part 0, Quick Start Guide*, gives a basic overview of the Dataset and its use.
- *Part 1, Using the Dataset*, (this document), sets out detailed information about the Dataset and its content, maintenance and terms of use.
- *Part 2, Formulas*, provides a detailed explanation of formulas necessary for executing coordinate conversions and transformations using the coordinate operation methods supported in the EPSG dataset. Geodetic parameters in the Dataset are consistent with these formulas.
- *Part 3, Registry Developer Guide*, is primarily intended to assist computer application developers who wish to use the API of the Registry to query and retrieve entities and attributes from the dataset.
- *Part 4, Database Developer Guide*, is primarily intended to assist computer application developers who wish to use the Database or its relational data model to query and retrieve entities and attributes from the dataset.

The complete text may be found at http://www.epsg.org/guides/index.html. The terms of use of the dataset are also available at http://www.epsg.org/CurrentDB.html.

In addition to these documents, the Registry user interface contains online help and the Database user interface includes context-sensitive help accessed by left-clicking on any label.

This Part 1 of the multipart Guidance Note is primarily intended to assist computer application developers in using the EPSG geodetic parameter database. It may also be useful to other users of the data. Readers are recommended to have read Part 1 of the guidance note before tackling parts 3 or 4.

1 INTRODUCTION

Coordinates describing a position on or near the earth's surface are referenced to a model of the earth rather than to the earth itself. There are many models, and each model may be located with respect to the real earth in several different ways. The consequence is that one position on the real earth may be represented by multiple sets of coordinates, each referenced to different models. Furthermore, the direction, order and units of the coordinate system axes are subject to variation. Hence without a set of geodetic parameters which identify the model and its relationship to the earth, together with the coordinate system axes, coordinates are ambiguous.

The European Petroleum Survey Group created a dataset of geodetic parameters in 1985 for internal use of its members. In 1993 the dataset was made public as reference data to the then Petrotechnical Open Software Corporation data model (POSC has since rebranded as Energistics). In 2005 the European Petroleum Survey Group was reformed as the Surveying and Positioning Committee of the International Association of Oil and Gas Producers (OGP). Maintenance of the geodetic parameter database now resides with OGP Surveying and Positioning Committee's Geodetic Subcommittee. For continuity reasons the dataset name remains as the EPSG Geodetic Parameter Dataset, or in short the EPSG Dataset.

The terminology used in this Guidance Note follows that defined in ISO 19111 – *Geographic information – Spatial referencing by coordinates*. This was introduced to the world in the late 1990s. It regularises terms that were in use in different communities and different countries. Some terms used colloquially in the oil industry are used differently in ISO 19111 and this Guidance Note. In particular, the colloquial term "coordinate system" is *coordinate reference system* in this Guidance Note, whilst *coordinate system* as used in this Guidance Note has a narrower meaning (discussed below) than that used colloquially. The colloquial term "datum shift" is *transformation* in ISO 19111 and this Guidance Note. Further ISO terms and their colloquial equivalents are given in (Iliffe and Lott).

2 METADATA

2.1 Metadata for the EPSG Dataset

The metadata in this section follows the provisions of ISO 19115, Geographic information – Metadata.

Register	
Title	EPSG Geodetic Parameter Dataset
Alternate title	EPSG Dataset
Date	2009-05-21
Edition	See latest entry in Version History
Abstract	This dataset holds codes and parameter values for coordinate reference system (CRS) definitions. The CRSs held in the dataset are typically those defined by national mapping organisations to be used for national mapping and spatial data infrastructures as well as additional items of especial interest to the petroleum exploration and production industry. The CRSs described are local, national, regional or global in extent; local, national and regional systems may be from any part of the Earth. Several thousand systems are currently described. The dataset includes all components of these CRSs, for example datum, ellipsoid, prime meridian, map projection and coordinate system, as specified in ISO 19111. The dataset also includes definitions for over 1500 coordinate transformations between CRSs.
Purpose	Coordinates are ambiguous unless their reference system is defined. If coordinates are associated with a registry CRS entry, they then may be interpreted unambiguously. The inclusion of map projections and transformations facilitates the merging of spatially-referenced datasets by allowing all to be referenced to a common CRS.
Distribution	The EPSG Dataset is made available through three delivery mechanisms: • The EPSG Registry, a web-based delivery platform. • an MS Access database; • SQL scripts which enable a user to create an Oracle, MySQL, PostgreSQL or other database and populate that database with the EPSG Dataset; The Registry and the Access database include a user interface for querying and browsing the dataset as well as reporting capabilities. The Registry also supports a service-level interface. Up to and including version 6.18, the canonical version of the EPSG Dataset was the Access database. From version 7.1 (May 2009) the Registry becomes the canonical version of the EPSG Dataset. The Dataset is supported by OGP Surveying and Positioning Guidance Note 7, a multiple part document describing how to get the most from the Dataset and giving mathematical formulae for coordinate conversion and transformation methods supported in the Dataset. All are distributed at no charge through the internet, http://www.epsg.org

Registry content	coordinate reference systems, coordinate transformations
technical standard defining items	ISO/TS 19127:2004 EPSG Guidance Note 7 part 1, "Using the EPSG Dataset", December 2007, http://www.epsg.org
URI	www.epsg-registry.org
Extent	Global systems and local, national and regional systems from any part of the world.
Keywords	EPSG, coordinate, reference system, code, datum, ellipsoid, map projection, geodetic, parameter, registry, spatial referencing, spheroid, transformation
Constraints	See Terms of Use, given in GN7-1 section 3 and www.epsg-registry.org/help/xml/Terms_Of_Use.html
Update frequency	Approximately twice per year. The Registry (but not other delivery mechanisms) may include more frequent interim updates.
Language	English
Contact information:	
Organisation name	International Association of Oil and Gas Producers (OGP)
Contact position	Chairman, Geodesy Subcommittee
Role code	007
Contact address delivery point	209-215 Blackfriars Road
Contact address city	London
Contact address postal code	SE1 8NL
Contact address country	United Kingdom
Contact URI	http://www.ogp.org.uk

2.2 Metadata for the EPSG Registry

The metadata in this section follows the provisions of ISO 19135, Geographic information – Procedures for item registration.

Register

Name	EPSG Geodetic Parameter Registry
Content summary	Codes and parameter values for coordinate reference system (CRS) definitions. The CRSs held in the dataset are typically those defined by national mapping organisations to be used for national mapping and spatial data infrastructures as well as additional items of especial interest to the petroleum exploration and production industry. The CRSs described are local, national, regional or global in extent; local, national and regional systems may be from any part of the world. Several thousand systems are currently described. The Registry includes all components of these CRSs, for example datum, ellipsoid, prime meridian, map projection and coordinate system. The dataset also includes definitions for over 1500 coordinate transformations between CRSs.
Item class name	coordinate reference system
Item class technical standard	ISO 19111:2007
Item class name	coordinate transformation
Item class technical standard	ISO 19111:2007
URI	http://www.epsg-registry.org
Operating language name	English
Operating language code	eng
Operating language country code	GBR
Version name	(Given with each published version of the Registry)
Version date	(Given with each published version of the Registry)

Register Owner

Name	International Association of Oil and Gas Producers (OGP)
Contact position	Chairman, Geodesy Subcommittee
Role name	Owner

Role code	003
Contact address delivery point	209-215 Blackfriars Road
Contact address city	London
Contact address postal code	SE1 8NL
Contact address country	United Kingdom
Contact URI	http://www.ogp.org.uk

Registry Manager

Name	OGP Geodesy Subcommittee
Contact position	Chairman
email address	geodesy@ogp.org.uk
URI	http://www.epsg.org

3 USE OF THE DATA

1. The following definitions of terms apply:
   - "Registry" means the EPSG Geodetic Parameter Registry;
   - "EPSG Dataset" means EPSG Geodetic Parameter Dataset;
   - "OGP" means the International Association of Oil and Gas Producers, incorporated in England as a company limited by guarantee (number 1832064);
   - "EPSG Facilities" means the Registry, the EPSG Dataset (published through the Registry or through a downloadable MS-Access file or through a set of SQL scripts that enable a user to create an Oracle, MySQL, PostgreSQL or other database and populate that database with the EPSG Dataset) and associated documentation consisting of the Release Notes and the multiple parts of Guidance Note 7.
   - "the data" means the geodetic parameter data and associated metadata, contained in the EPSG Dataset; it also refers to any subset of data from the EPSG Dataset.
2. The EPSG Facilities are published by OGP at no charge. Distribution for profit is forbidden.
3. The EPSG Facilities are owned by OGP. They are compiled by the Geodetic Subcommittee of the OGP from publicly available and member-supplied information.
4. In order to use the EPSG Facilities, you must agree to these Terms of Use. You may not use the EPSG Facilities or any of them in whole or in part unless you agree to these Terms of Use.
5. You can accept these Terms of Use by clicking the command button 'Accept Terms' upon registering as a new user. You will also be required to accept any revised Terms of Use prior to using or downloading any EPSG Facilities. You understand and agree that any use of the EPSG Facilities or any of them, even if obtained without clicking acceptance, will be acceptance of these Terms of Use.
6. The data may be used, copied and distributed subject to the following conditions:

   6.1 Whilst every effort has been made to ensure the accuracy of the information contained in the EPSG Facilities, neither the OGP nor any of its members past present or future warrants their accuracy or will, regardless of its or their negligence, assume liability for any foreseeable or unforeseeable use made thereof, which liability is hereby excluded. Consequently, such use is at your own risk. You are obliged to inform anyone to whom you provide the EPSG Facilities of these Terms of Use.

   6.2 DATA AND INFORMATION PROVIDED IN THE EPSG FACILITIES ARE PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR A PARTICULAR PURPOSE.

   6.3 The data may be included in any commercial package provided that any commerciality is based on value added by the provider and not on a value ascribed to the EPSG Dataset which is made available at no charge.

6.4 Ownership of the EPSG Dataset by OGP must be acknowledged in any publication or transmission (by whatever means) thereof (including permitted modifications).

6.5 Subsets of information may be extracted from the dataset. Users are advised that coordinate reference system and coordinate transformation descriptions are incomplete unless all elements detailed as essential in OGP Surveying and Positioning Guidance Note 7-1 annex A are included.

6.6 Essential elements should preferably be reproduced as described in the dataset. Modification of parameter values is permitted as described in the table below to allow change to the content of the information provided that numeric equivalence is achieved. Numeric equivalence refers to the results of geodetic calculations in which the parameters are used, for example (i) conversion of ellipsoid defining parameters, or (ii) conversion of parameters between one and two standard parallel projection methods, or (iii) conversion of parameters between 7-parameter geocentric transformation methods.

6.7 No data that has been modified other than as permitted in these Terms of Use shall be attributed to the EPSG Dataset.

Table 1: permitted modifications of data

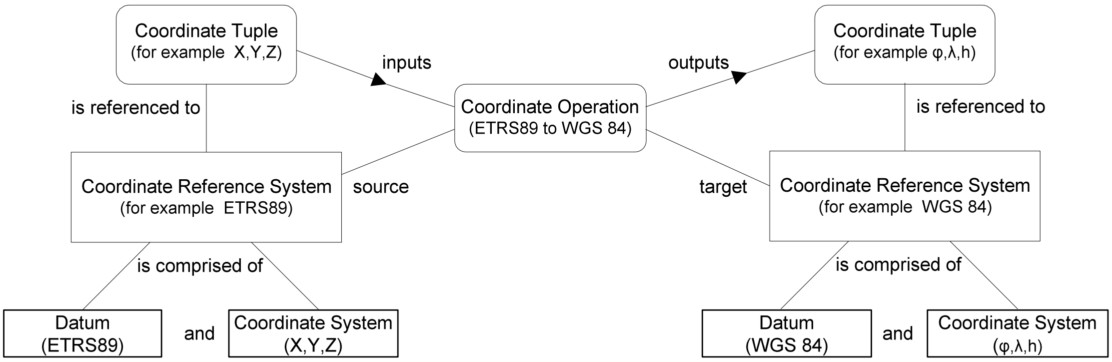
	As given in EPSG Dataset	Permitted change for vendors / users to adopt
Change of ellipsoid defining parameters.		
1a	Ellipsoid parameters a and b.	a and 1/f ; a and f; a and e; a and e^2.
1b	Ellipsoid parameters a and 1/f.	a and b; a and f; a and e; a and e^2.
Change of projection method		
2a	Lambert Conic Conformal (1 SP) method with projection parameters φ_O and k_O.	Lambert Conic Conformal (2 SP) method with projection parameters φ_1 and φ_2.
2b	Lambert Conic Conformal (2 SP) method with projection parameters φ_1 and φ_2.	Lambert Conic Conformal (1 SP) method with projection parameters φ_O and k_O.
3a	Mercator (1 SP) method with projection parameters φ_O and k_O.	Mercator (2 SP) method with projection parameter φ_1.
3b	Mercator (2 SP) method with projection parameter φ_1.	Mercator (1 SP) method with projection parameters φ_O and k_O.
4a	Hotine Oblique Mercator method with projection parameters FE and FN.	Oblique Mercator method with projection parameters E_C and N_C.
4b	Oblique Mercator method with projection parameters E_C and N_C.	Hotine Oblique Mercator method with projection parameters FE and FN.
5a	Polar Stereographic (Variant A) method with with projection parameters φ_O and k_O.	Polar Stereographic (Variant A) method with projection parameters φ_O and k_O.
5b	Polar Stereographic (Variant B) method with projection parameter φ_F.	Polar Stereographic (Variant A) method with projection parameters φ_O and k_O.
5c	Polar Stereographic (Variant A) method with projection parameters φ_O, k_O, FE and FN.	Polar Stereographic (Variant C) method with projection parameters φ_F, E_F and N_F.
5d	Polar Stereographic (Variant C) method with projection parameters φ_F, E_F and N_F.	Polar Stereographic (Variant A) method with projection parameters φ_O, k_O, FE and FN.
5e	Polar Stereographic (Variant B) method with projection parameter FE and FN.	Polar Stereographic (Variant C) method with projection parameters E_F and N_F.
5f	Polar Stereographic (Variant C) method with with projection parameters E_F and N_F.	Polar Stereographic (Variant B) method with projection parameter FE and FN.
Note: *Permitted projection method changes 2 to 5 inclusive during the parameter conversion must use the ellipsoid for the relevant projected coordinate reference system.*		
Change of transformation method		
6a	Position Vector 7-parameter transformation method parameters R_x R_Y and R_Z.	Coordinate Frame transformation method with signs of parameters R_X R_Y and R_Z reversed.

6b	Coordinate Frame transformation method parameters R_x R_Y and R_Z.	Position Vector 7-parameter transformation method with signs of parameters R_X R_Y and R_Z reversed.
7	Concatenated transformation using geocentric methods (Geocentric translations, Position Vector 7-parameter transformation, Coordinate Frame rotation).	Equivalent single geocentric transformation in which for each parameter the parameter values of the component steps have been summed.
Change of units		
8	NTv2 method grid file filename.	NTv2 method grid file relative storage path with file name including removal (if necessary) of "special characters" [spaces, parentheses, etc] which are replaced by underscore characters.
9	Parameter value.	Convert unit to another, for example from microradian to arc-second, *using conversion factors obtained from the EPSG dataset Unit table*.

4 THEORETICAL CONCEPTS

4.1 Coordinates

The high level abstract model for spatial referencing by coordinates is shown in the diagram below:



A coordinate is one of a sequence of values describing a position. The sequence is sometimes called a coordinate tuple. Coordinates are referenced to a *coordinate reference system* (CRS). A coordinate reference system is a *coordinate system* (CS) – an abstract mathematical concept without any relationship to a physical object – that is referenced through a *datum* to the Earth or some other object such as a vessel. A *coordinate operation* may be used to change coordinate values which are referenced to one CRS to being referenced to a second CRS.

4.2 Coordinate Reference Systems

Most *coordinate reference systems* (CRSs) consist of one *coordinate system* that is related to an object through one *datum*. For the CRSs of interest to the EPSG Dataset, that object is the Earth.

A *coordinate system* (CS) is a sequence of coordinate axes with specified units of measure. A coordinate system is an abstract mathematical concept without any defined relationship to the Earth. Coordinate systems generally have not been explicitly described in geodetic literature, and they rarely have well-known names by which they are identified. The historic colloquial use of 'coordinate system' usually meant coordinate reference system.

A *datum* specifies the relationship of a coordinate system to the Earth, thus ensuring that the abstract mathematical concept can be applied to the practical problem of describing positions of features on or near the earth's surface by means of coordinates.

Coordinate reference systems, coordinate systems and datums are each classified into several subtypes. Each coordinate system type can be associated with only specific types of coordinate reference system. Similarly each datum type can be associated with only specific types of coordinate reference system. Thus, indirectly through their association with CRS types, each coordinate system type can only be associated with specific types of datum.

4.2.1 Coordinate Reference System subtypes

Geodetic survey practice usually divides coordinate reference systems into a number of sub-types. The common classification criterion for sub-typing of coordinate reference systems can be described as the way in which they deal with earth curvature. This has a direct effect on the portion of the Earth's surface that can be covered by that type of CRS with an acceptable degree of error.

The following types of coordinate reference system are distinguished:

a) **Geographic**. A coordinate reference system based on a geodetic datum and using an ellipsoidal (including spherical) model of the Earth. This provides an accurate representation of the geometry of geographic features for a large portion of the Earth's surface. Geographic coordinate reference systems can be two- or three-dimensional. A **Geographic 2D** CRS is used when positions of features are described on the surface of the ellipsoid through latitude and longitude coordinates; a **Geographic 3D** CRS is used when positions are described on, above or below the ellipsoid and includes height above the ellipsoid. These ellipsoidal heights (*h*) cannot exist independently, but only as an inseparable part of a 3D coordinate tuple defined in a geographic 3D coordinate reference system. Thus ellipsoidal heights cannot be referenced to a *vertica*l coordinate reference system.

b) **Geocentric**. A coordinate reference system based on a geodetic datum that deals with the Earth's curvature by taking the 3D spatial view, which obviates the need to model the curvature. The origin of a geocentric CRS is at the centre of mass of the Earth.

ISO 19111 classfies both geographic and geocentric coordinate reference systems as **geodetic** CRSs.

c) **Projected**. A coordinate reference system that is based on a geographic CRS and then uses a map projection to convert the coordinates to a plane. The distortion that is inherent to the process is carefully controlled and known. Distortion correction is commonly applied to calculated bearings and distances to produce values that are a close match to observed field values. One geographic CRS may serve as the base for many projected CRSs. One map projection may be applied independently to many geographic CRSs.

d) **Engineering**. A coordinate reference system that is used only in a contextually local sense. This sub-type is used to model two broad categories of local coordinate reference systems:

- earth-fixed systems, applied to engineering activities on or near the surface of the earth;
- coordinates on moving platforms such as road vehicles, vessels or aircraft.

Earth-fixed Engineering CRSs are commonly based on a simple flat-earth approximation of the Earth's surface, and the effect of earth curvature on feature geometry is ignored: calculations on coordinates use simple plane arithmetic without any corrections for earth curvature. The application of such Engineering CRSs to relatively small areas and "contextually local" is in this case equivalent to "spatially local".

e) **Image**. An engineering coordinate reference system that is applied to images. Image CRSs are outside the scope of the EPSG Dataset.

f) **Parametric**. A coordinate reference system that uses parameters or parametric functions for a coordinate system axis. Parametric CRSs are outside the scope of the EPSG Dataset.

g) **Compound**. In historic geodetic practice, horizontal and vertical positions were determined independently. It is established practice to combine the horizontal coordinates of a point with a height or depth from a different coordinate reference system. This has resulted in coordinate reference systems that are horizontal (2D) and vertical (1D) in nature, as opposed to truly 3-dimensional. The coordinate reference system to which these 2D+1D coordinates are referenced combines the separate horizontal and vertical coordinate reference systems of the horizontal and vertical coordinates. Such a system is called a compound coordinate reference system (CCRS). It consists of a non-repeating sequence of two or more single coordinate reference systems.

For spatial coordinates, a number of constraints exist for the construction of compound CRSs. Coordinate reference systems that are combined shall not contain any duplicate or redundant axes. Valid combinations include:

1) Geographic 2D + Vertical
2) Geographic 2D + Engineering 1D (near vertical)
3) Projected + Vertical
4) Projected + Engineering 1D (near vertical)
5) Engineering (horizontal 2D) + Vertical
6) Engineering (1D linear) + Vertical

4.2.2 Coordinate System

The coordinates of points are recorded in a coordinate system (CS). A CS is an abstract mathematical concept that is not tied to any physical or virtual object. A coordinate system is the set of coordinate system axes that spans the coordinate space. Implicit are the mathematical rules that define how coordinate values are calculated from distances, angles and other geometric elements, and vice versa. EPSG recognises several types of coordinate system, differentiated by the geometric properties of the coordinate space spanned and the geometric properties of the axes themselves (straight or curved; perpendicular or not). Each CS type may be associated with only specific types of CRS. The following types of coordinate system are distinguished:

(a) **ellipsoidal**. A 2- or 3-dimensional coordinate system in which position is specified by geodetic latitude, geodetic longitude and (in the three-dimensional case) ellipsoidal height. The ellipsoidal height direction is exactly perpendicular to the surface of the ellipsoid. An ellipsoidal CS may be associated with one or more geographic CRSs.

(b) **gravity-related**. A 1-dimensional coordinate system dependent on the Earth's gravity field used to record the heights (or depths) of points. In general the gravity field is not exactly perpendicular to the surface of the ellipsoid used to model the Earth. A gravity-related CS may be associated with one or more vertical CRSs.

(c) **Cartesian**. A 1-, 2-, or 3-dimensional coordinate system. In the 1-dimensional case it contains a single straight axis. In the 2- and 3-dimensional cases it gives the position of points relative to orthogonal straight axes. In the multi-dimensional cases, all axes shall have the same unit of measure. A Cartesian CS may be associated with one or more geocentric, projected or engineering CRSs.

(d) **affine**. A 2- or 3-dimensional coordinate system with straight axes that are not necessarily orthogonal. An affine CS may be associated with one or more engineering CRSs.

(e) **linear**. A 1-dimensional coordinate system that consists of the points that lie on the axis of a linear feature, for example a pipeline. A linear CS may be associated with one or more engineering CRSs.

(f) **spherical**. A 3-dimensional coordinate system with one distance, measured from the origin, and two angular coordinates. Not to be confused with an ellipsoidal coordinate system based on an ellipsoid 'degenerated' into a sphere. A spherical CS may be associated with one or more geocentric or engineering CRSs.

(g) **polar**. A 2-dimensional coordinate system in which position is specified by distance from the origin and the angle between the line from origin to point and a reference direction. A polar CS may be associated with one or more engineering CRSs.

(h) **cylindrical**. A 3-dimensional coordinate system consisting of a polar coordinate system extended by a straight coordinate axis perpendicular to the plane spanned by the polar coordinate system. A Cartesian CS may be associated with one or more engineering CRSs.

The vast majority of CRSs documented in the EPSG Dataset use one of the first three types of CS.

4.2.3 Coordinate System axes

A coordinate system is composed of a non-repeating sequence of coordinate system axes. Each axis is completely characterised by a unique combination of axis name, axis abbreviation, axis direction and axis unit of measure.

The concept of coordinate axis requires some clarification. Consider an arbitrary *x, y, z* coordinate system. The *x*-axis may be defined as the locus of points with $y = z = 0$. This is easily enough understood if the *x, y, z* coordinate system is a Cartesian system and the space it describes is Euclidean. It becomes a bit more difficult to understand in the case of a strongly curved space, such as the surface of an ellipsoid, its geometry described by an ellipsoidal coordinate system (2D or 3D). Applying the same definition by analogy to the curvilinear *latitude* and *longitude* coordinates the latitude axis would be the equator and the longitude axis would be the prime meridian, which is not a satisfactory definition. Bearing in mind that the order of the coordinates in a coordinate tuple shall be the same as the defined order of the coordinate axes, the '*i*-th' coordinate axis of a coordinate system is defined as the locus of points for which all coordinates with sequence number not equal to '*i*', have a constant value locally (whereby $i = 1 \ldots n$, and n is the dimension of the coordinate space).

It will be evident that the addition of the word 'locally' in this definition apparently adds an element of ambiguity and this is intentional. The specified direction of the coordinate axes is often only approximate. For example, geodetic latitude is defined as the "Angle from the equatorial plane to the perpendicular to the ellipsoid through a given point, northwards treated as positive". However, when used in an ellipsoidal coordinate system the geodetic latitude axis will be described as pointing 'north'. At two different points on the ellipsoid the direction 'north' will be a spatially different direction, but the concept of latitude is the same.

In a number of cases usage of coordinate system axis names is constrained by geodetic custom, depending on the coordinate reference system type. These constraints are shown in the table below. This constraint works in two directions; for example the names 'geodetic latitude' and 'geodetic longitude' shall be used to designate the coordinate axis names associated with a geographic coordinate reference system. Conversely, these names shall not be used in any other context.

Some naming constraints for coordinate system axis

CS	CRS	Permitted coordinate system axis names
Cartesian	geocentric	geocentric X, geocentric Y, geocentric Z
spherical	geocentric	spherical latitude, spherical longitude, geocentric radius
ellipsoidal	geographic	geodetic latitude, geodetic longitude, ellipsoidal height (if 3D)
Cartesian	geographic	topocentric U, topocentric V, topocentric W
vertical	vertical	depth or gravity-related height
Cartesian	projected	northing or southing, easting or westing

Engineering coordinate reference systems may make use of names specific to the local context or custom and are therefore not included as constraints in the above list.

4.2.4 Datum

A datum implies a choice regarding the origin and orientation of the coordinate system. It is the datum that makes the coordinate system and its coordinates unambiguous. EPSG recognises three types of datum – geodetic, vertical and engineering.

A **vertical** datum defines the relationship of a gravity-related coordinate system to the Earth. An **engineering** datum defines the relationship of a coordinate system used for engineering purposes to the Earth or some other object. For both vertical and engineering types the most important attribute is the datum name, which implies the relationship. A **geodetic** datum defines the relationship of a geographic or geocentric coordinate system to the earth. In addition to the datum name (which again implies the relationship), essential attributes of a geodetic datum are the chosen model of the Earth – the **ellipsoid** – including details of name and defining parameter values, together with the details of the zero or **prime meridian** from which longitudes are reckoned.

4.2.5 Ellipsoid

The Earth's surface is highly irregular and therefore difficult to compute across. Spatial computations are simplified by modelling the Earth as an oblate ellipsoid (historically colloquially called a spheroid). Two parameters are required to describe the size and shape of an oblate ellipsoid. Historically the dimensions of the semi-major and semi-minor axes were defined. More recently the semi-major axis and inverse flattening, a ratio derived from the semi-major and semi-minor axes, have been used. Other ellipsoid parameters, such as its eccentricity, e, may be needed for coordinate conversion. These may be derived from the two describing parameters.

4.2.6 Prime Meridian

A graticule of latitude and longitude values is applied to the ellipsoid. Latitude has a natural starting point in the equator. There is no natural starting point for longitude, which is known as the prime meridian. It is arbitrarily defined. Historically, national systems usually adopted the meridian through their national astronomical observatory as the starting point for longitude. The meridian through Greenwich, England, has been accepted as the international norm for over a century, but its adoption for geodetic purposes has lagged somewhat. Longitudes based on other prime meridians, for example Paris, remain in use today. Longitude is unambiguous only when the prime meridian is defined.

4.3 Coordinate Operations

4.3.1 General

A coordinate operation changes coordinate values which are referenced to a source coordinate reference system to coordinate values which are referenced to a second (target) coordinate reference system. A coordinate operation is often popularly said to "*transform coordinate reference system A into coordinate reference system B*". Although this wording may be good enough for conversation, it should be realised that coordinate operations do not operate on coordinate reference systems, but on coordinates.

The EPSG dataset recognises the following types of coordinate operation:

- Conversion – a coordinate operation where both source and target coordinate reference systems are based on the same datum. The most frequently encountered conversion is a map projection. This changes coordinates between geographic and projected (i.e. grid) values, or vice-versa.
- Transformation – a coordinate operation where source and target coordinate reference systems are based on different datums.
- Concatenated operation – a series of transformations and/or conversions executed in sequence.

The fact that coordinate operations operate on coordinates rather than coordinate reference systems implies that a coordinate reference system cannot be created from another coordinate reference system by a coordinate operation. Neither can a coordinate operation be used to modify the definition of a coordinate reference system. In all such cases, the source and target coordinate reference systems involved have to exist before the coordinate operation can exist. There is an exception to the rule of explicit specification of source and target coordinate reference systems. This exception is for so-called *derived CRS*s. Then a *conversion* applied to a source or base CRS defines the target CRS. The best-known example of this base-derived relationship is a projected coordinate reference system, which is always related to a base geographic coordinate reference system. The associated map projection effectively defines the projected coordinate reference system from the geographic coordinate reference system. The derived projected CRS inherits attributes of the base geographic CRS, for example datum and ellipsoid. However, unlike projections, *transformations* always operate on coordinates referenced to two already-defined CRSs. The corollary is that transformations have no place in the definition of a CRS.

4.3.2 Coordinate Operation Methods

Every conversion and transformation has a method – a mathematical formula applied to coordinates. The formulas are generally differentiated by name. Unfortunately, names do not always refer uniquely to a particular formula – some names can apply to different formulas which produce significantly different results. This is especially the case with map projections where the name does not differentiate between approximate formulas for a sphere and exact formulas for an ellipsoidal model of the Earth. And some map projection names, for example "Stereographic", refer to very different ellipsoidal formulas which are effectively different methods using the same name. The formulas themselves therefore are critical to the identification of conversions and transformations. For conversions and transformations included within the EPSG Dataset, their formulas are documented as attributes of their method, but these formulas are written more clearly in Part 2 of this Guidance Note.

4.3.3 Coordinate Operation Method Parameters

Each coordinate operation method requires a set of parameters, the parameter set being particular to the method. Some parameter sets or individual parameters are used by several methods.

In many coordinate operation method formulas the required parameters include ellipsoid parameters. These ellipsoid parameters are considered to be attributes of the ellipsoid and are not included in the set of parameters which are included in the definition of the coordinate operation method.

4.3.4 Coordinate Operation Parameter Values

Each individual conversion and transformation is defined through a specific set of values for each of the parameters used by the method. Parameter values are numbers in given units. The units may not be those required by the method formula; when this is the case they need to be converted to the required units.

4.3.5 Transformation multiplicity

From the perspective of mathematical application, conversions and transformations are identical. But they differ in the manner in which their parameter values are obtained. During application of the coordinate operation this impacts the accuracy of the output coordinates. In a conversion, the parameter values are defined. They are therefore exact. Application of the conversion introduces no loss of positional accuracy. In contrast, application of a transformation introduces some loss of accuracy in the output position. For a transformation the parameter values are deduced through comparison of coordinate sets in the source and target CRSs. Multiple transformations between any two specific CRSs may coexist, derived for example through coordinate comparison at different locations, through different weighting strategies or through using different coordinate operation methods. These different variants or versions of the transformations have no common terminology within the geodetic community. Sometimes a certain version may be mandated for a particular use.

4.3.6 Coordinate Operation Reversibility

There is usually a requirement to convert or transform coordinates in both forward and reverse directions, that is from being referenced to CRS 'A' to being referenced to CRS 'B' and also the reverse from being referenced to CRS 'B' to being referenced to CRS 'A'. For the reverse case, the roles of forward case source and target CRS are reversed.

When a coordinate operation is reversible, the formula applies to both forward and reverse cases. Some operation parameters may need to have their sign reversed when defined for the forward direction and being applied to the reverse. For example, the *Geocentric translations* method for transforming geocentric coordinates uses three parameters – X-, Y- and Z-axis translations. The transformation of coordinates from being referenced to the CRS 'AGD66' to being referenced to the CRS 'GDA94' has parameter values of –127.8m, –52.3m and +152.9m respectively. The formulae used for the forward transformation can be used unchanged for the reverse operation, but for the reverse transformation from GDA94 to AGD66 the parameter values used by the method need to have their signs reversed, i.e. are +127.8m, +52.3m and –152.9m respectively. In this example all of the parameters required their signs to be reversed. This is not always the case. For example, in the *Molodensky-Badekas 10-parameter transformation* seven of the parameters need to be reversed whilst three parameters should not have their signs reversed. The necessity to reverse the signs of each parameter is one of the attributes of a coordinate operation method.

However not all methods are considered to be reversible. For example the *Similarity transformation* method is not reversible. This is because the parameters take quite different values for the forward and reverse transformations, despite the formula remaining unchanged. Whether or not the method is reversible is another of the attributes of a coordinate operation method.

There is a third case. Some coordinate operation methods are in principle not reversible but in practice are considered to be. These methods describe two formula, one for the forward direction and a second for the reverse. Both forward and reverse formulae are considered to be part of the one method. This is typically the case with map projections. For example, the *Transverse Mercator* coordinate operation method (a map projection method) includes formulae for both forward and reverse conversions. In this particular method for both forward and reverse transformations the same parameters are used without sign reversal.

Note that whilst it is the method itself which is reversible, it is the treatment of the parameter values within the method's formulae that determines the reversibility and has to be considered in application implementation.

4.3.7 Concatenated operations

A concatenated operation is a series of transformations and/or conversions executed in sequence. For a concatenated operation with *n* steps:

- the source CRS for the concatenated operation is the source CRS for step 1;
- the target CRS for step *m* is the source CRS for step *m*+1; and
- the target CRS for the concatenated operation is the target CRS for step *n*.

A concatenated operation is reversible only if each of its component steps is reversible.

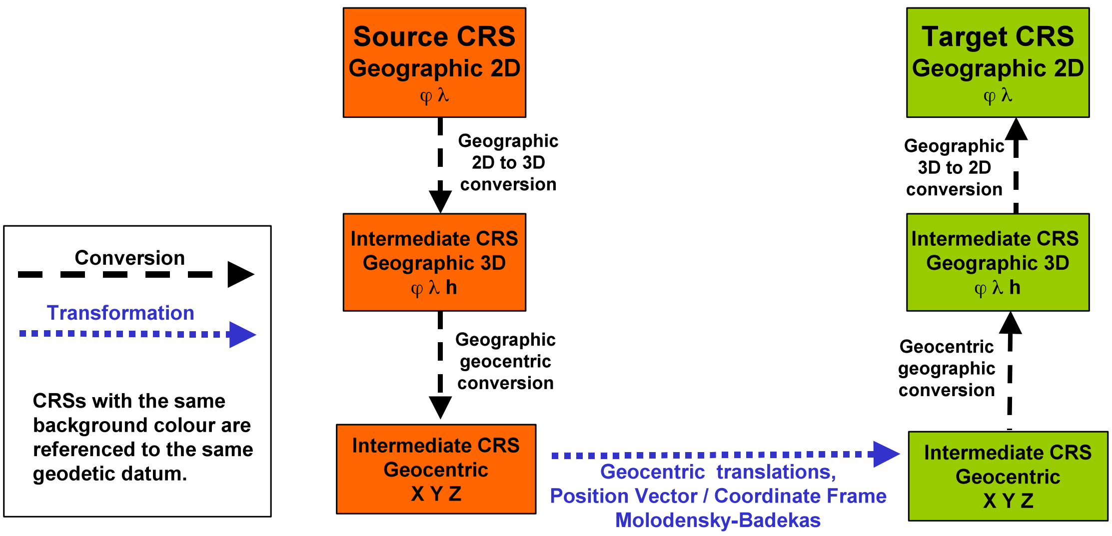
A concatenated operation is one of the potentially many transformation versions between the pair of initial source and final target CRSs.

4.4 Implicit concatenated operations created by application software

Transformation applications may need to be able to create concatenated operations that provide a route to match source CRS and target CRS with the type of coordinates upon which the method operates. For example, if the requirement is to change latitude and longitude values (geographic 2D) referenced to a CRS using datum A into a geographic 2D CRS using datum B, and a search on the EPSG dataset reveals a suitable transformation using a method which operates in the geocentric coordinate domain (such as EPSG dataset coordinate operation method codes 9603, 9606, 9607 or 9636), the transformation application needs to implement the geocentric transformation as the central part of an implicit 5-step concatenated operation using the following steps:

- Geographic 3D to 2D conversion (reverse case, i.e. 2D to 3D)
- Geographic/geocentric conversions (forward case, i.e. geographic 3D to geocentric)
- The geocentric transformation
- Geographic/geocentric conversions (reverse case, i.e. geocentric to geographic 3D)
- Geographic 3D to 2D conversion (forward case)

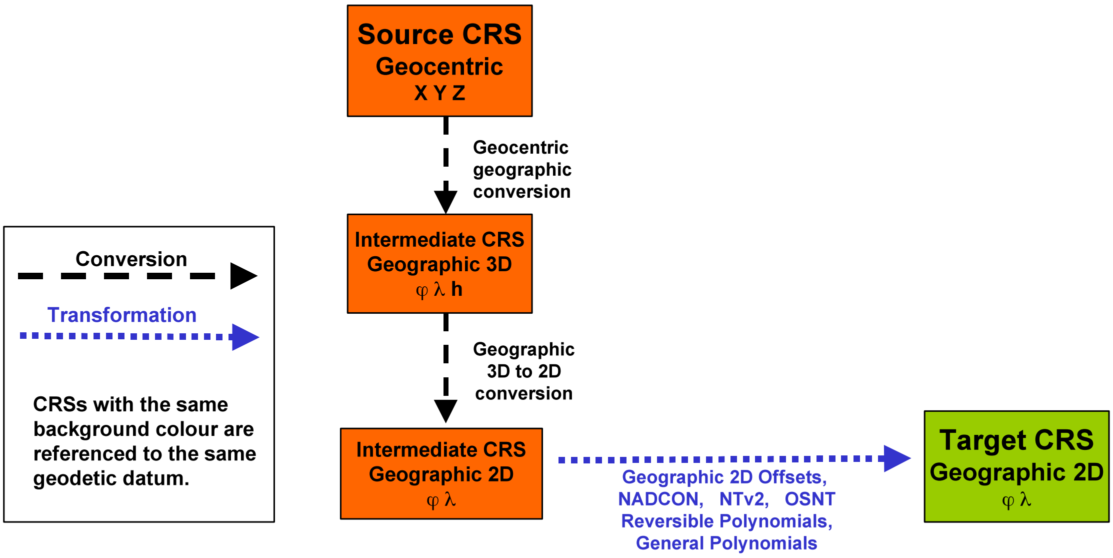
This implicit concatenated operation may be shown diagrammatically as:



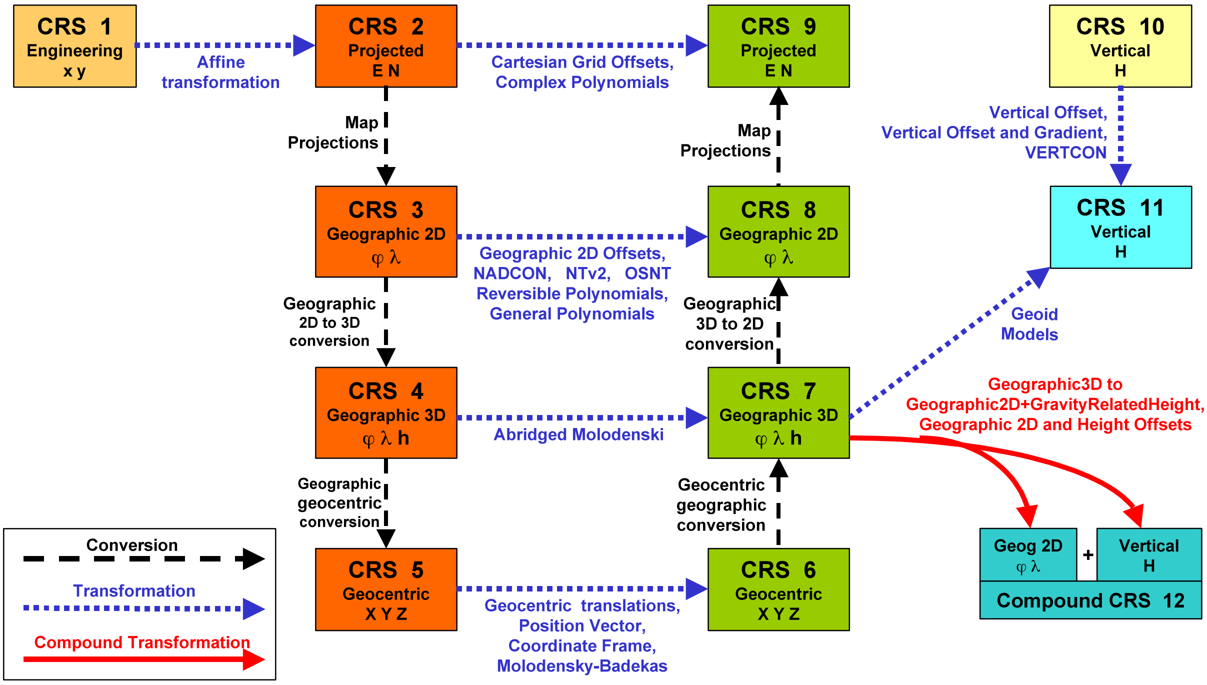
Alternatively if the transformation method operated in the geographic 2D domain (NADCON, NTv2, etc.) and the source CRS was geocentric, the flow would be:

1. Geographic/geocentric conversions (reverse case, i.e. geocentric to geographic 3D);
2. Geographic 3D to 2D conversion (forward case);
3. The geographic 2D to geographic 2D transformation.

which can be shown diagrammatically as:

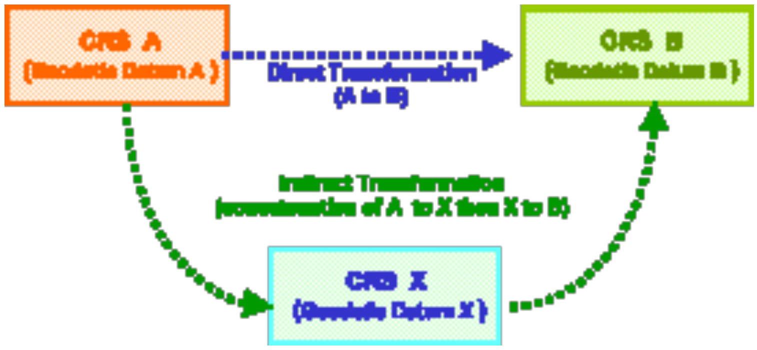


The exact flow of steps of an implicit concatenated operation is dependent upon (a) the CRS domain in which the transformation method operates and (b) the type of CRS for the source and target CRSs. The concept of implicit concatenated operations can be extended as shown in the following diagram:

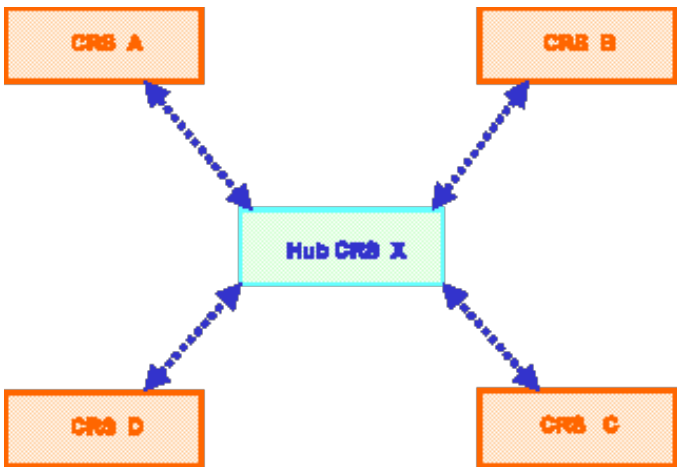


The implicit concatenated operation technique embedded within transformation application design should not be confused with concatenated operations within the EPSG dataset. The concatenated operation records capture practice that has evolved over time or is documented as a sequence of individual steps.

Implicit concatenated operation techniques can also be used to extend the transformations. For example, if a transformation is required from CRS A to CRS B and none is found in the dataset, it may be possible to transform indirectly via a third CRS. To be valid, the area of applicability for each of the steps forming the indirect concatenation transformation must embrace the area in which the coordinates fall.



It is possible to further extend this concept to a scheme in which a standard CRS is selected as a hub:-



The hub concept is an appealing way of implementing a generalised transformation application. However it should be remembered that there are several caveats:

- if a direct transformation is available, it must take precedence over any artificially created indirect concatenated operation.
- for an artificially created indirect concatenated operation through the hub to be valid, the area of applicability for both of the steps forming the indirect concatenated transformation must embrace the area in which the coordinates fall.
- a generalised solution that allows any CRS to be the hub, although mathematically possible, is unlikely to have any geodetic integrity.
- ***the implementation of a hub system must not be used to require CRS definitions to contain a transformation to the chosen hub CRS***. CRS's are self contained entities which can exist without any knowledge of a relationship to a second CRS referenced to another datum. The elements required for CRS definition are given in annex A.

5 EPSG DATASET MAINTENANCE AND DATA POPULATION POLICIES

5.1 Content

The data model is capable of describing coordinate reference systems and coordinate operations. The EPSG dataset contains several thousand records. However it does not describe every system or operation known to mankind. The emphasis is on systems used for national mapping and similar systems used for mapping or engineering for the petroleum industry. The content is not limited to systems of interest to the petroleum industry, and data of little interest to the petroleum industry is included in the dataset on request (see next section 5.2). But the primary focus of the maintenance group inevitably means that the content volume is biased towards that industry's requirements. There is minimal coverage of systems used for small-scale "atlas" mapping as these systems tend to be designed for one particular map. North American legal survey systems (which cannot be described in the data model) are excluded.

In general, supporting data for component parts of coordinate reference systems (such as ellipsoids, map projections or units) are only included within the dataset when they are utilised by a CRS or a coordinate operation.

Because the dataset does not describe every known CRS or coordinate operation, applications developers are cautioned that applications must be capable of using definitions from a full CRS description and not merely reliant on referencing a record from the dataset.

It is anticipated that some users may wish to complement the EPSG dataset with records of sole interest to themselves. To ensure that such users can take full advantage of the ongoing EPSG dataset releases, OGP provides an "update utility" to append user records to the latest Access database; see EPSG Guidance Note 7 part 4 annex B for a description of the update utility. Users with their own licence of the registry software have a facility to add EPSG updates.

5.2 How to make a request to add to or amend EPSG Dataset content

Suggestions for improvements or additions to dataset content are accepted from any interested party. They should be made by electronic submission of the change request form which can be found by following the links to the geodetic subcommittee at the foot of the OGP Surveying and Positioning Committee web page www.epsg.org or at the foot of the geodetic dataset page www.epsg.org/geodetic.html.

Change requests should clearly state what is being proposed. If the change is to existing dataset content then the entity type and code for the entity in question must be stated, preferably along with its name. If the request is to add new data then as a minimum the information tabulated in annex A of this document must be given. This minimum information may be included directly in the change request message or may be given indirectly by providing the URL for a publicly-available web site which contains the information.

Requests received will be acknowledged by the OGP Geodetic Subcommittee, normally with one working week of receipt. If they are within scope they will be allocated a change request number and then reviewed by the Subcommittee. The Subcommittee may require the proposer to provide supplementary information before reaching a decision. Changes that are accepted are first made in an unpublished copy of the dataset and are put through a quality control check. Correspondents may be asked to comment on draft entries. The Subcommittee aims to process all requests within one release cycle of the dataset. Correspondents will be advised the decision reached as soon as it has been made. Where new data is added, the code(s) for this are made public only at the time of the next dataset release.

5.3 Data maintenance responsibilities

The EPSG Geodetic Parameter Dataset is managed by the OGP Geodesy Subcommittee, members of which are appointed by OGP Surveying and Positioning Committee. Current membership of the Geodesy Subcommittee can be found on the EPSG Dataset web site at www.epsg.org.

5.4 Data release cycle

The dataset is updated on an as-needed basis. Publishing updated versions of the dataset is a compromise between making new information available as soon as possible and consolidating changes into batches issued on a regular but infrequent basis. Historically, new versions of the dataset have been released approximately twice per year.

With the introduction of the online registry the following process is followed:

- Full releases will continue to be published approximately twice per year.
- For the registry only, interim releases may be made as soon as data has been processed.
- Full releases will have a version number of the form x.y, for example 6.17. Interim release will have a version number of the form x.y.z, for example 6.17.2.
- At each full release the relational implementation (Access and SQL scripts) will consolidate all data released through registry interim releases since the previous full release.
- On publication of a new full release, the previous full release is moved to the dataset archive.

Up to and including version 6.18, the canonical version of the EPSG Dataset was the Access database. From version 7.1 (May 2009), the Registry became the canonical version of the EPSG Dataset.

5.5 Archiving

OGP undertakes to make available an archive of all full releases of the Dataset from v6.1 (February 2002) onwards. Interim releases are not archived. The archive consists of:

- All Access databases from v6.1, in the version of Access used for that dataset publication (Access 97 for dataset versions 6.x, Access 2000 for dataset versions 7.x. See Part 4 of this Guidance Note for further details of the Access implementation).
- All SQL script files from v6.5 (January 2004). (See Part 4 of this Guidance Note for further details of the SQL script implementation).
- GML Dictionaries for the Registry content from v7.1, using the GML schema used for that dataset publication (GML 3.2.0 for v7.x. See Part 3 of this Guidance Note for further details of the GML implementation).

The archive is accessible at http://www.epsg.org/archive.html.

5.6 Data validity and record life-cycle information

5.6.1 The Deprecated field

Effective from the release of database version 6.1 in July 2001, a strategy of never deleting records from the EPSG dataset has been adopted. Any records found to be in error are corrected. Minor corrections are made through amendment to the record. Significant errors are dealt with through "deprecation". All primary data records include a deprecation indicator. A record containing significantly erroneous data will have its deprecation indicator set to "yes" (or "true" or "1") and a corrected record added as a replacement. Valid records have a deprecation indicator set to "no" (or "false" or "0").

Records that have been deprecated in general should not be used – they contain significant error and are retained in the dataset only for purposes of replicating historical use of the records. See annex B of this document for a more detailed description of the deprecation policy applied to the Dataset.

Deprecated records have a "trail" which documents the date and reason for deprecation and if there are replacement records gives links to these records.

Note that ISO 19135 states "items that require modification that results in substantive semantic or technical change and are to replaced by one or more new items are to be given a status of 'superseded'). This is essentially what in the EPSG Dataset is termed deprecation. Note also that the EPSG Dataset also uses the term supersession, but in a different way to ISO 19135 - see below.

5.6.2 Supersession and Retirement

The concept of supersession is very difficult to apply in the context of coordinate reference systems and transformations. This is because adoption of new systems or transformations is context dependent. The phasing-out of older systems and phasing-in of newer systems can be complex, varying by application, legal regime or user preference, and may take place over decades. However, replacement by 'better' data is one of the criteria that might influence the choice of transformation variant is selected when many are available in the dataset (see section 4.3.5). In v6.6 (October 2004), a "Supersession" entity (Access table) was added to the dataset. Although in principle applicable to any entity, it has only been populated for transformations, specifically to assist automated selection of transformation variant.

In v6.6 three forms of supersession were recognised:

- Replacement. The information as been withdrawn and replaced by its information source.
- Retirement. The information as been withdrawn by its information source and not replaced.
- Supersession. The old and new run in parallel. Adoption of the newer system is generally encouraged, but for backward compatibility reasons the older system remains in use.

In v6.13, these forms of supersession were redefined to bring them into closer alignment with the ISO 19135, Geographic information - Procedures for item registration. ISO 19135 uses the terms 'supersede' and 'retire' as status flags for life cycle management of data, making the data no longer valid for current usage. In the EPSG Dataset the supersession state does not impact record validity: superseded data remains valid, and validity is shown through the deprecation indicator.

From v6.13, two forms of supersession were recognised:

- Retirement: item deemed no longer suitable for use in production of new data. In the context of geodetic parameters, adoption of a newer system is generally encouraged, but for backward compatibility reasons the older system may remain in use in parallel with a new system;
- Supersession: deprecated by the information source (as opposed to OGP) because there is a significant problem with the data. Such records may then also be deprecated in the EPSG Dataset (see previous section).

Data that is replaced through improved science is considered to be retired, not superseded. Where the word 'superseded' was used extensively in its English language context in remarks it was changed to 'replaced'.

5.7 Data applicability

The applicability of the geodetic data is described through textual information in several fields:

- Area of use. This corresponds to the horizontal component of ISO 19115's Extent. Datum, CRS and coordinate operation records reference an area record. Historically in the EPSG Dataset the area of use of these entities has been a free text description. With effect from v6.6 (October 2004), bounding geographic maximum and minimum coordinates were added to the Area table. The values of these coordinates are approximate, intended for record selection purposes only, and are given in decimal degrees in terms of the WGS 84 geographic 2D coordinate reference system. The Area table also includes a field to reference an external file of coordinates describing the area through a boundary polygon. This is currently not populated.
- Scope. Text describing the usage and applicability.
- Remarks. Miscellaneous textual comment including supplementary information on applicability.

5.8 Record metadata

Metadata for the Dataset as a whole is given in chapter 2 of this document.

For each primary entity within the dataset, records include information on data and its source:

- Remarks. Text giving miscellaneous information about the data, including (if applicable) cross-reference to superseding records.
- Information source. This is a brief textual description of the source from which OGP Geodesy Subcommittee has obtained the information. It may include an internet URL current at the time of record population.
- Data source. This is the organisation, body or person who populated this record; for the EPSG dataset it is always either "EPSG" or "OGP".
- Change ID. This is a text field listing code or codes referencing a Change record in which any minor changes to the record are recorded. Not populated when records are first introduced to the dataset.
- Revision date. The date on which the record was created or, if minor changes to the record have been made, the date of the latest changes. The record revision date is not altered on deprecation.

The above metadata applies to all primary entity types. In addition, for the datum, coordinate reference system and coordinate operation entities only there is a text field describing the scope (applicability) of the data.

5.9 EPSG codes and names

5.9.1 Codes

In the EPSG Dataset codes are assigned to CRSs, coordinate transformations, and their component entities (datums, projections, etc.). Within each entity type, every record has a unique code.

Whilst EPSG codes are unique within any one entity type, a code value may be used for multiple entities of different types. For example, the code value 1234 is used to identify an area as well as a transformation. EPSG Dataset policy is to ensure no overlap of code values within the union of coordinate reference system and coordinate operation entity types. *The corollary is that for an EPSG code to be unique it is necessary to identify both the entity type and the code*.

Codes are assigned by OGP Geodesy Subcommittee. For most entity types, codes are integers but for change records codes are real numbers. Although historically some codes embodied a meaning, for example the EPSG codes of US State Plane projections were related to the FIPS code, this quickly broke down and was abandoned some years ago – it is unsustainable when entities may be deprecated and replaced. Now codes are assigned sequentially and no meaning should be interpreted. Codes are within the range 1024 to 32767 inclusive.

With effect from EPSG dataset version 6.3 (February 2003), the integer range from 6,000,000 to 6,999,999 was used for codes of geographic CRSs with coordinates in explicitly described degree representations. Although this mechanism is no longer supported by the EPSG dataset and the records have been deprecated, they remain in the dataset.

Users who wish to augment the EPSG data with their own information should utilise codes greater than 32767. This will prevent conflict with future additions to the EPSG Dataset. OGP does not monitor codes used by 3rd parties.

5.9.2 Re-use of Codes

Our deprecation policy came into effect in 2001 (see section 5.5.1 above). From this time - versions 5.3 and 6.1 of the dataset (February 2002) - any significantly erroneous data is not removed from the dataset but flagged as deprecated and left in the dataset. The codes for those deprecated records have not been and will not be reused.

5.9.3 Names

To assist users who wish to use names rather than codes as keys, with two exceptions described below the OGP Geodesy Subcommittee endeavours to retain uniqueness within each entity across the names of coordinate reference systems, coordinate operations and other primary entities. Although there is no global standard for naming geodetic entities, as far as is possible the OGP Geodesy Subcommittee adopts the official or popular name or its English language equivalent, if necessary modified to remain unique within the EPSG Dataset. The conventions adopted for naming in the EPSG Dataset are detailed in annex C of this document.

The first exception occurs if a record has been deprecated and replaced. Replacement records may, indeed often will, carry the same name as that of the record that has been deprecated. However, within any one entity type names should be unique across ***valid*** records (that is, records that have not been deprecated - see section 5.5.1).

The second exception concerns geodetic coordinate reference systems. Where geographic CRSs are derived from a geocentric CRS and based on the same geodetic datum, they will generally have the same name as each other. But the combination of name and geodetic CRS subtype will be unique across *valid* records.

5.10 Units

Unit of measure (UoM) information is referenced through the UOM_CODE field from records holding ellipsoid, prime meridian or coordinate operation parameter values or describing coordinate axis units. Three types of UoM – angle, length and scale – are included in the EPSG dataset, identified in the UNIT_OF_MEAS_TYPE field. The table includes an ISO standard unit for each UoM type – radian, metre and "unity" respectively. Each unit record includes two factors which relate the unit to the ISO standard unit. A unit equals (factor B / factor C) of the relevant ISO standard unit. For example a US survey foot (UoM code 9003) has values for FACTOR_B and FACTOR_C of 12 and 39.37 respectively. Then 1 US survey foot is 12/39.37 = 0.3048006096… metres. Units may be converted to other units of the same type through the ISO standard unit.

When parameter values are given by their information source in compound units, that is a 'unit' comprised of multiple units, for example "degrees and minutes", or "feet and inches", the unit of measure FACTOR_B and FACTOR_C fields are not populated. These compound units may be converted into a single unit by means of an appropriate formula.

To allow coordinate operation parameter values given by their information source in the compound unit sexagesimal degrees to be stored in the Dataset in a single numeric field but retaining the given values, an EPSG artificial unit "sexagesimal DMS" (UoM code 9110) has been created. The general format is: signed degrees - period - minutes (two digits) - integer seconds (two digits) - fraction of seconds (any precision). The value must include a leading zero for minutes or seconds less than 10 and exclude the decimal point for seconds. For example, 35°24'06.42" = 35.240642 sexagesimal DMS. This ‘unit’ allows storage of sexagesimal values to any precision, including integer minute or integer second, for example 35°24' = 35.24 sexagesimal DMS and 35°24'06" = 35.2406 sexagesimal DMS. When minute or second unit is a multiple of ten, the trailing zero will not be included if there is no further resolution, for example 35°20' = 35.2 sexagesimal DMS and 35°24'10" = 35.241 sexagesimal DMS. Conversely, 35.3 sexagesimal DMS = 35°30' = 35.5°. Parameters which are angles may be stored in the Dataset as real numbers or sexagesimal DMS. The Dataset includes identification of the unit.

5.11 Population of coordinate reference systems

5.11.1 Geodetic coordinate reference systems

Historically, the only geodetic CRSs defined were geographic 2D systems. These have no related geographic 3D or geocentric system in the EPSG Dataset. However transformation methods which operate in the geocentric domain may need applications to apply an implicit concatenated transformation to these geographic 2D CRSs. See section 4.4 of this document and section 2.4.4.1 of Guidance Note 7 part 2.

Modern geodetic CRSs are three-dimensional. When a geodetic system is 3-dimensional, in geodetic practice it is the geocentric CRS which is defined. The geographic 3D CRS is then derived from the geocentric CRS by conversion. Similarly, the geographic 2D CRS is derived from the geographic 3D CRS. From v6.6 of the dataset, this chain of conversions has been included in the EPSG Dataset. Related geographic 2D, geographic 3D and geocentric CRS records referenced to the same geodetic datum have different codes. For example, the codes for the CRSs based on the World Geodetic System 1984 (WGS 84) datum are 4326 (geographic 2D), 4979 (geographic 3D) and 4978 (geocentric). However, although the data model does not expect it, records for all three CRS subtypes geocentric, geographic 3D and geographic 2D are individually related to the (same) geodetic datum record. This allows for datum attributes of these derived systems to be obtained without navigating the complexities of the derived CRS mechanism.

In early versions of the EPSG dataset (prior to v6.0, November 2001), there was no distinction between geographic 2D, geographic 3D and geocentric CRS subtypes. All were implicitly included within the CRS type 'geographic', which is no longer used. That CRS type has been replaced by the CRS type geodetic which is subdivided into separate CRS types *geographic 2D*, *geographic 3D* and *geocentric*. When these separate geodetic CRS subtypes of geographic 2D, geographic 3D and geocentric were introduced, to minimise disruption to users all CRSs of type ‘geographic’ were changed to be of subtype ‘geographic 2D’ and their codes (and other attributes) were retained.

5.11.2 Geographic CRS axis units

When latitude and longitude coordinate values are given in *degrees*, several representations are in use, for example decimal degrees or degrees, minutes and seconds (sexagesimal degrees). Hemisphere quadrant may be indicated by sign or by abbreviation, as suffix or prefix. OGP recommends that real numbers are used for internal data processing but that for interfacing with human beings the preferred representation be sexagesimal degrees (degree, minute, second, hemisphere (DMSH)). For geographic coordinate reference systems supporting coordinates in degrees (as opposed to other units such as grads), early versions of the

EPSG dataset gave the degree representation explicitly as DMSH. In v6.4 (January 2003) CRSs using other explicitly described degree representations were introduced. These CRSs were given codes that were created by concatenation of datum code and CS code in the range from 60,000,000 to 69,999,999. Effective dataset v6.5 (January 2004) the strategy was changed. Support for CRSs with explicit degree representation given for the CS axes was withdrawn. CRSs with codes in the range from 60,000,000 to 69,999,999 were deprecated whilst geographic CRSs with codes in the range from 0 to 32767 had their explicit DMSH degree representation changed to "degree (supplier to define representation)". Coordinates are unambiguous only when the unit and unit representation used are identified. For geographic CRSs with units of degrees, the degree representation information is no longer explicitly provided as part of the CRS description in the EPSG Dataset. EPSG dataset geographic CRSs such as codes 4326 and 4267 allow (and require) the degree representation to be defined for the user by the coordinate data supplier.

5.11.3 Coordinate Systems

There is no global standard applied to CS attributes. For each CRS in the EPSG Dataset the local legal or conventional usage is implied through the CS associated with the CRS record. Many other combinations of axis order and unit are theoretically possible, some of which may be more straightforward to manipulate within computer systems, but because these other combinations have no geodetic, conventional or legal usage CRSs using them are not described in the EPSG Dataset.

5.11.4 Ellipsoids

The EPSG Dataset includes the following ellipsoid parameters:

- semi-major axis (a)
- semi-minor axis (b)
- inverse flattening
- ellipsoid shape indicator

The semi-major axis is always given. The second ellipsoid parameter is semi-minor axis for some old ellipsoids or inverse flattening for more modern ellipsoids, as given by the information source. For some very modern ellipsoids the inverse flattening value is derived from gravity and earth rotation parameters which are given in the record REMARKS field. Occasionally an old information source may give both semi-minor axis and inverse flattening. In these cases, values of both parameters will be given but the least preferred value as a remark.

5.12 Population of transformations

5.12.1 Transformations between geodetic coordinate reference systems

In the EPSG Dataset most transformations that operate between geodetic CRSs have source and target CRSs of type *geographic 2D*, regardless of whether the method operates in the geographic or geocentric coordinate domain or in 2 or 3 dimensions. The reason is historic and briefly described in the last paragraph of section 5.11.1 above. Existing transformations retained the codes for the source and target CRS – now geographic 2D CRSs. For consistency with this older practice, most transformations in the EPSG Dataset that operate in the geographic or geocentric coordinate domain continue to be associated with the CRS subtype geographic 2D even when they operate between geocentric or geographic 3D CRSs. Applications using this data may need to make appropriate adjustments and use the implicit concatenated operation technique as discussed in chapter 4.4 above. An exception is for transformations between geodetic CRSs which only have a geocentric form, in which case the transformation will of necessity be between geocentric CRSs. Although the same transformation mathematics is used in the geocentric domain, the transformation method is given a different method code from the equivalent implicit concatenated transformation method.

5.12.2 OGP transformations to WGS 84

Many transformations that are available are between a local or national system and a system which is defined relative to the global standard, the International Earth Rotation Service Terrestrial Reference System (ITRS). At a geodetic level of significance these realisations of the ITRS are discrete. But at a level of accuracy quite satisfactory for most GIS and oil industry applications – nominally submetre accuracy – the differences between these ITRS realisations are not significant. The EPSG dataset facilitates the use of these transformations in a hub implementation (described in section 4.4 above) by:

- choosing the GPS satellite navigation system's CRS WGS 84, which in recent years has been maintained within 0.1m of the ITRS, as a standard for use as a hub CRS.

- creating transformations from national or regional realisations of the ITRS to WGS 84 which result in no change in coordinate values, with a transformation accuracy of 1m.
- duplicating selected transformations to national or regional realisations of the ITRS as a transformation to WGS 84, with a transformation accuracy of the lesser of 1 metre or that of the original transformation.

These transformations created by OGP Geodesy Subcommittee will include EPSG or OGP within the coordinate operation version text and ascribe EPSG or OGP as the information source. It must be recognised that these transformations may not necessarily be approved by the originator of the original transformation. It should also be recognised that CRSs other than WGS 84 may be more appropriate as a hub. For example, in Europe when there is a need to retain positions with respect to the EuroAsian tectonic plate, because with time positions on this plate change with respect to a global best fit system such as WGS 84, the adoption of ETRS89 as a hub would be preferable.

5.12.3 Coordinate Operation accuracy

Because transformations are empirically determined, their application to input coordinates in general will degrade the quality of the coordinates. From dataset v6.6 the approximate accuracy of a transformation, as reported by the information source, is included in the coordinate operation's ACCURACY field. This is a value in metres, with smaller values indicating less loss of accuracy. A value of 999 is a flag to indicate that an accuracy estimate is not available.

Map projections, which in terms of coordinate conversion are considered to be errorless, are given an accuracy of zero.

5.12.4 Transformation and conversion methods and parameters

Within the EPSG dataset, each transformation and conversion is related to a coordinate operation method. It is the method formula, not just the name, that fully identifies the coordinate operation method. Both formula and example are given in a more readable format in EPSG Guidance Note number 7 part 2, *Coordinate Conversions and Transformations including Formulas*.

Each method utilises specific coordinate operation parameters. Each transformation and conversion has specific values for each of the parameters that its method utilises. For each method there is a preferred order in which parameters should be listed. In the Registry this is implied through the order in which parameters are associated with the method. In the Access and SQL relational implementations the sort order is explicitly given. Generally the values will run from 1 through *n* where *n* is the number of parameters used by the method. For polynomial methods, for which the coefficients are considered to be parameters, provision is made for all coefficients to be ordered. However, those coefficients which have non-zero values in all *transformations* in the dataset which use the method are not entered in the Dataset. As a consequence the sort order values for the polynomial methods of higher degree may be discontinuous. For example, at the time of writing the sort order values for method 9654 (Reversible polynomial of degree 13) are 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 14, 20, 34… It is possible that currently missing coefficients could be added to the dataset at a later date, as needs arise.

6 SEARCHING THE DATASET

This section describes information relevant for searching both the Registry and Access database implementations. Further information specific to these is given in GN7 part 3 for the Registry and GN7 part 4 for the Access and SQL implementations.

6.1 Valid data

As described in section 5.6 and annex B, the dataset includes records which are invalid. Record validity is indicated by the setting in the DEPRECATED field.

In general, searches for data should exclude the invalid records. This may be accomplished by searching for data including a filter for the value of the DEPRECATED field = "false" (or "No" or "0").

There may be occasions when there is a requirement to replicate data used previously, regardless of its current validity. On these rare occasions the search constraint criteria should omit the filter of DEPRECATED. If there is a need to exactly replicate a record, then the search should be made on the version of the dataset used for the earlier work.

6.2 Searching by Name

The strategy for the population of names is described in section 5.6 and annex C. Alternative names may be given as an alias field of the alias table. A user may not know whether the name of an object as he knows it is stored in the dataset as name or alias. A search on 'name' should therefore be made not only on the name of the relevant object, but also on its the aliases. A name may have many aliases and an alias may be associated with several names.

6.3 Searching by Area of Use

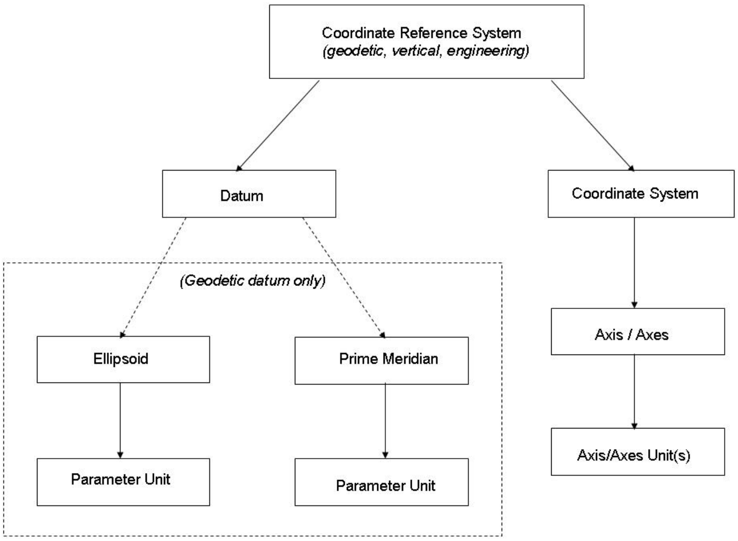
Datum, coordinate reference system and coordinate operation entities are associated with Area of Use. The area record includes the following:

- AREA_NAME. A short cryptic text field used only to list area of use records in a compact manner for selection purposes. Although this text often summarises the area of use it is not an abbreviation and may contain other, non-area, data. This field should not be used in searches.
- AREA_OF_USE. A text field briefly describing the area. It will always include country name (using the spelling in English from ISO 3166) and may also include administrative units within a country or other geographical constraints such as longitude limits of a projection zone. Searches on Area of Use need to take into account the uncertainties of text string content. A text string might contain sub-area or super-area text within the description. A search on the country name alone then will not return the record. For example, a search for "Sudan" would not find an area described as "Ethiopia and Sudan." or one described as "Sudan east of 30 deg East". To ensure success in these circumstances the argument should be included within wildcards (e.g. "*Sudan*"). The use of the wildcard may return extra, unwanted, records. For example a search using "*Oman*" will return data not only for Oman but also for R**oman**ia.
- GEOGRAPHIC BOUNDING BOX. Four fields giving the approximate (0.01 degree = 1 mile or 1.5 km precision) latitude and longitude limits for the area. The values are referenced to the WGS 84 geographical 2D CRS and are given in decimal degrees. For areas straddling the 180º meridian, the "west" longitude will have a higher absolute value than the "east" longitude. These bounding boxes can be used for searches but the nature of bounding boxes means that they surround much spurious territory as well as the area over which a geodetic entity is used.
- AREA POLYGON. This field is currently not populated. It is planned to add a description of the area of use boundary through GML. (A shape file may also be provided [to be confirmed]). When available the polygons will give a significantly more refined description than bounding box.
- COUNTRY CODES, taken from ISO 3166 part 1. These fields are not intended for searching by area. They are populated only for areas which are complete single countries. In ISO 3166, a "country" is a landmass. In the EPSG database a "country" includes the offshore limits of maritime states. For most area records – subdivisions of a country or regions including multiple countries – these fields are not populated.

6.4 Searching for Coordinate Reference System definitions

6.4.1 Data mining

The EPSG Dataset's focus is on the complete description of Coordinate Reference Systems (CRSs). The values of parameters of CRS components such as ellipsoids and map projections are given, along with the units for those values as described by the information source. In addition the Coordinate System (CS) elements necessary to make coordinates unique – the dimension, axes names, abbreviation, direction, order and units – are given. It is necessary to drill down through the data to mine this information and resolve the lower-level entities.



6.4.2 Geographic CRS axis units

The axis unit associated with EPSG Dataset geographic CRSs is discussed in 5.11.2. Geographic CRSs require the degree representation to be defined for the user by the coordinate data supplier.

6.4.3 Ellipsoids

When reporting ellipsoid information it is recommended that name, semi-major axis and inverse flattening are given. The name of the unit for the ellipsoid semi-major axis should be included (obtained from the unit of measure table). When reporting ellipsoid parameters as part of a geographic or geocentric CRS definition, use the ellipsoid table unit of measure. When reporting ellipsoid parameters as part of a projected CRS definition, the value of the semi-major axis should be given in the unit of measure used for the projected CRS CS axes, if necessary converting when the ellipsoid UOM_CODE differs from the coordinate axis UOM_CODE using:

[(ellipsoid UoM FACTOR_B * CS Axis UoM FACTOR_C) /
(ellipsoid UoM FACTOR_C * CS Axis UoM FACTOR_B)]

For example, for projected CRS code 2919 [NAD83(HARN) / Texas South Central (ftUS)] the CS axis unit of measure is "US survey foot" (UoM code 9003) but the ellipsoid used is GRS 1980 (code 7019) for which the ellipsoid axis UoM is "metre" (code 9001). The ellipsoid semi-major axis value of 6378137.0 m is converted to 20925604.474 ftUS.

If the ellipsoid record includes an entry in the semi-minor axis field, inverse flattening should be calculated from:

$$1/f = [a / (a – b)]$$

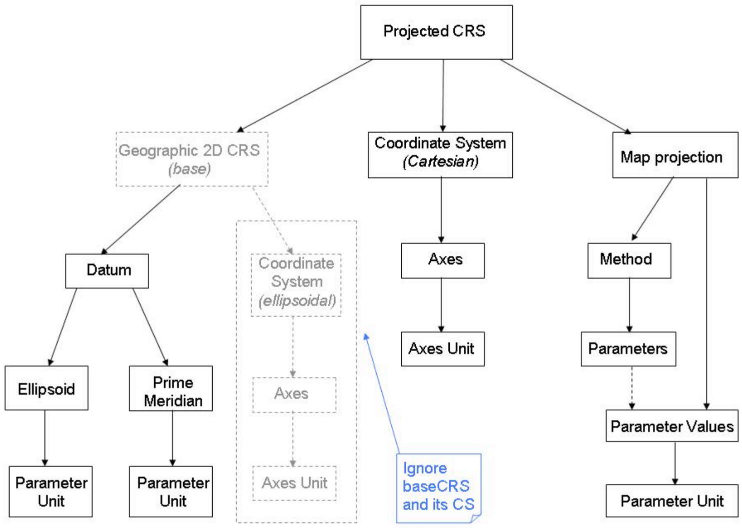
and quoted to seven decimal places.

6.4.4 Prime meridians

The majority of geographic (and hence projected) coordinate reference systems use the Greenwich meridian as their prime meridian. Following the recommendations of EPSG Guidance Note number 5, when this is the case the prime meridian name and longitude may be omitted from the CRS description.

6.4.5 Projected CRSs

Projected CRSs inherit geodetic datum (and its attributes including prime meridian) through their base geographic CRS. Projected CRSs are associated with their own coordinate system and the coordinate system for the base CRS should be ignored. Projected CRSs also have a reference to their map projection. These lower-level components need to be resolved.



The components may not all be in consistent linear or angle units. This needs to be checked for and if necessary the parameter values need to be converted into a consistent unit, normally the CRS unit.

Map projection methods include a parameter "Longitude of [natural/false] origin". This is incompletely specified within the projection because a longitude is meaningless without its reference prime meridian. Within the EPSG dataset the prime meridian for a projected CRS is inherited from its base geographic CRS. The value for "Longitude of [natural/false] origin" is implicitly referenced to the prime meridian forming part of this base geographic CRS definition.

6.5 Searching for Coordinate Operation definitions

6.5.1 Geocentric transformation methods

The EPSG dataset currently supports four transformation methods between geocentric coordinate reference systems with 3-, 7- or 10-parameters. Two 7-parameter methods are supported which use different conventions for the rotation parameters. Care is required to ensure that the method and its parameter values are consistent with the method supported in applications.

All transformations that operate between the CRS types geographic 2D, geographic 3D and geocentric are given in the EPSG dataset with geographic 2D CRSs as their source and target CRS. The reason is historic – see section 5.11 above. Consequently, if an application is presented with a CRS for which the type is geocentric or geographic 3D, a search of the EPSG dataset coordinate operation table on source- or target-CRS code will return no transformations. The application should first determine the CRS code for the related geographic 2D CRS, and then use the code for this CRS in the search for transformations.

6.5.2 Transformation and conversion parameters

If the parameter value is stored in the Dataset in sexagesimal DMS, for display at the human interface it should to be decoded into the implied degree, minute and second fields.

Some methods use a gridded data file or files. These gridded values are not included in the EPSG Dataset. The Dataset does, however, include a reference to the data file(s) in the field PARAM_VALUE_FILE_REF. This may be an FTP or web URL address given from which the file may be opened or downloaded (sometimes zipped). Alternatively it may be a file name, in which case information about where the file may be obtained from is given within the coordinate operation's INFORMATION_SOURCE field.

6.5.3 Coordinate Operation reversibility

See section 4.3.6 for general remarks on transformation and conversion reversibility.

Within the EPSG geodetic parameter dataset, each coordinate operation method has a flag to indicate whether the method itself is reversible, that is the parameters for the forward operation can be used for the reverse operation. If the method is reversible, the entry in the coordinate operation method table's REVERSE_OP field will be 'yes' (or 'true' or '1'). When a method is reversible, each parameter used by that method has a flag to indicate whether the parameter value needs to have its sign reversed for the reverse transformation. When the method itself is not reversible the reversibility of parameter values is not indicated.

These reversibility flags allow coordinate operation data for reversible operations to be stored only once in the dataset. For example, using the Australian example cited in section 2.2.5 above (EPSG dataset coordinate operation code 1278), the dataset stores the transformation giving the source CRS as AGD66, the target CRS as GDA94, the method as geocentric translations, and the values for the three parameters used by that method as –127.8m, –52.3m and +152.9m respectively. There is sufficient information here for applications to use this data to transform coordinates from AGD66 to GDA94 or from GDA94 to AGD66.

Applications seeking to transform data from CRS 'A' to CRS 'B' therefore should not be searching on coordinate operation name but should examine coordinate operation's SOURCE_CRS_CODE and TARGET_CRS_CODE fields for match using the code of each CRS as both source and target. If a match is found the coordinate operation method's REVERSE_OP field should be examined to determine whether the dataset contains the information needed to perform a reversible operation.

When a coordinate operation is not reversible, two coordinate operations may be in the dataset for reciprocal 'forward' and 'reverse' directions. For example, a transformation published by the national mapping agency of The Netherlands from the Amersfoort / RD New projected CRS to the ED50 / UTM zone 31N projected CRS uses the complex polynomial of degree 4 method (EPSG dataset coordinate operation code 1044), which is not reversible. This is complemented by a similar transformation using the same method but with different parameter values (EPSG dataset coordinate operation method 1045). In coordinate operation 1044, the source CRS is 'Amersfoort / RD New' (CRS code 28992) and the target CRS is 'ED50 / UTM zone 31N' (CRS code 23031). In coordinate operation 1045, the source CRS is code 23031 and the target CRS is code 28992. These reciprocal operations are cross-referenced in the remarks field of each coordinate operation. Reciprocal transformations have the following characteristics: they use the same method, the source and target CRSs are transposed, and they have identical transformation versions. The reciprocal transformation for a non-reversible transformation may be found using a SQL query: see Guidance Note 7 part 4 annex E example 1.09. Note that not all transformations using non-reversible methods will have a reciprocal.

6.5.3.1 Concatenated operation reversibility

A concatenated operation is a sequence of single operations (i.e. transformations and/or conversions). If any of the steps use a reversible transformation or conversion, that transformation or conversion will be stored only once in the EPSG dataset. Its source and target CRSs in the dataset may the opposite of that required in the concatenated operation step, in which case the reverse transformation or conversion needs to be applied.

A concatenated operation is only reversible when all of its component steps are themselves reversible.

6.5.4 Multiplicity of transformations between specific source and target CRSs.

In the EPSG dataset, the multiplicity of transformations and/or concatenated operations between two specific CRSs is represented in two ways:

- transformation *variants* of each pair of source and target CRSs are numbered sequentially as they are loaded to the dataset. These sequentially-allocated numbers are artefacts of the EPSG dataset

management and have no prior meaning to users. They are given as integers in the COORD_OP_VARIANT field.
- each variant is also allocated a textual *version* which cryptically indicates the transformation derivation or information source and its area of applicability. These are given in the COORD_TFM_VERSION field.

This multiplicity in transformations between given pairs of CRSs causes difficulties for transformation users. There is a need to select the appropriate variant. This is a non-trivial task. Several criteria may be used in the assessment, including:

- Area of use of the transformation – is it consistent with the area for the coordinate data to be transformed?
- Scope – is the purpose for which the transformation was derived consistent with the proposed usage?
- Supersession – has the data been replaced or superseded?
- Accuracy – is it sufficient for the purpose?
- Method – is it supported by the software application?

In general, appropriate selection will require matching the purpose, area of applicability and accuracy of the transformation against similar user criteria.

Take for example a hypothetical situation in the northern North Sea straddling the UK-Norway international boundary, in which data for oil exploration has been derived in ED50 geographic CRS terms in three general ways:
(a) positioned using GPS and transformed from WGS 84 to ED50 using the transformation officially recognised by Norwegian regulatory authorities.
(b) positioned using GPS and transformed from WGS 84 to ED50 using the de facto standard transformation for UK offshore oil industry purposes.©) older data predating satellite navigation systems and positioned directly in ED50 by radio-navigation.

Users or their organisations may adopt different strategies for addressing the problem of merging these datasets. User 1 may wish to work in ED50 coordinates honouring them as they have been produced. He or she will merge the three ED50 datasets without applying any further transformation. User 2 may wish to adopt the official Norwegian transformation. He would accept the coordinates for datasets a and c but take the view that the ED50 coordinates of dataset b could be "improved" by returning the coordinates to their original WGS 84 form by applying in reverse the WGS 84 to ED50 transformation variant initially applied to the data, and then applying to these WGS 84 coordinates the official Norwegian transformation. User 3 may have a strategy to do all of her work in the WGS 84 CRS. She will take ED50 datasets (a) and (b) and to each apply in reverse the transformation variant initially applied. For dataset (c) she may decide to arbitrarily prefer one ED50 to WGS 84 transformation variant, or alternatively apply the variant used for (a) and (b) depending upon whether the data falls on Norwegian or UK side of the international boundary. Meanwhile, user 4 has adopted a strategy of working in the ETRS89 CRS recommended for pan-European applications. For him, it is ETRS89, not WGS 84, which is the "standard" CRS. He will have to decide whether, for his particular purposes, the sub-metre difference between WGS 84 and ETRS89 is significant.

Application design should be capable of accommodating any of these example user strategies and not forcing one strategy on all.

6.5.4.1 Coordinate Operation accuracy

The coordinate operation accuracy information may be used for ranking transformations applicable to an area of interest. It needs to be treated with caution. Although described as accuracy, in reality the value may be a measure of the internal precision of the transformation derivation. Whilst accuracy for transformations from a single information source may be safely ranked, "accuracy" from different information sources may not be consistent.

7 BIBLIOGRAPHY

Iliffe, Jonathan and Lott, Roger (2008). *Datums and Map Projections*, Whittles Publishing

ANNEX A – ESSENTIAL ELEMENTS FOR DESCRIPTION OF CRS AND TRANSFORMATION

In the table below, elements that are essential for the unambiguous description of coordinate reference system or transformation are indicated by a 0.

Element: MS Access Table Name	Element: Entity Name	Geodetic CRS	Projected CRS	Engineering CRS	Vertical CRS	Transformation
Coordinate Reference System	COORD_REF_SYS_CODE	0	0	0	0	
Coordinate Reference System	COORD_REF_SYS_NAME	0	0	0	0	
Coordinate Axis Name	COORD_AXIS_NAME	0 Note 1	0 Note 1	0 Note 1	0	
Coordinate Axis	COORD_AXIS_ORIENTATION	0 Note 1	0 Note 1	0 Note 1	0	
Coordinate Axis	ORDER	0 Note 1	0 Note 1	0 Note 1		
Unit of Measure	Axis unit name	0 Note 1	0 Note 1	0 Note 1	0	
Datum	DATUM_NAME	0	0	0	0	
Ellipsoid	ELLIPSOID_NAME	0	0			
Ellipsoid	SEMI_MAJOR_AXIS	0	0			
Unit of Measure	Ellipsoid sma unit name	0	0			
Ellipsoid	INV_FLATTENING or (1/f calculated from a and b)	0 Note 2	0 Note 2			
Prime Meridian	PRIME_MERID_NAME	0	0			
Coordinate_Operation	COORD_OP_NAME		0			0
Coordinate_Operation Method	COORD_OP_METHOD_NAME		0			0
Coordinate_Operation Method	REVERSE_OP					0
Coordinate_Operation	UOM_CODE_SOURCE_COORD_DIFF					0
Coordinate_Operation	UOM_CODE_TARGET_COORD_DIFF					0
Coordinate_Operation Parameter	PARAMETER_NAME		0 Note 3			0 Note 4
Coordinate_Operation Parameter Usage	PARAM_SIGN_REVERSAL					0 Note 4
Coordinate_Operation Parameter Value	PARAMETER_VALUE		0 Note 3			0 Notes 4,5
Unit of Measure	Parameter unit name		0 Note 3			0 Notes 4,5
Coordinate_Operation Parameter Value	PARAM_VALUE_FILE_REF					0 Notes 4,5

Notes
1. These attributes are required for each axis.
2. When the dataset provides only ellipsoid parameters a and b, 1/f may be calculated from a/(a-b).
3. These attributes are required for each projection parameter.
4. These attributes are required for each transformation parameter.
5. Either Parameter Value with unit name or Parameter Value File Reference is required.

ANNEX B – RULES FOR DEPRECATION

Revision history:

Version	Date	Amendments
1	July 2002	First release as EPSG Guidance Note Number 12.
2	August 2004	Rules for deprecation of Transformation Name clarified. Incorporated into GN7 part 1; GN12 withdrawn.
3	April 2006	CRS name removed from critical data.
4	January 2007	Rules for EPSG duplicate to WGS 84 of ITRF transformations clarified.
5	July 2008	Minor text changes to allow for both registry and relational implementations.

1. If errors are found in data, these are corrected as soon as possible. OGP Geodesy Subcommittee has adopted two distinct strategies for error correction, the first used up to July 2001[1] (up to and including the release of version 5.21 of the data set) and the second brought into effect from July 2001 (effective from the release of version 6.1 of the data set).

2 In both strategies a distinction is made between critical and non-critical data. Critical data is anything that would significantly affect the result of a mathematical operation applied to coordinates through a coordinate transformation or coordinate conversion (map projection), in particular changes to parameter values. Critical data also includes the *codes* of Coordinate Reference System and Transformation records, as well as four Transformation fields *SourceCRS*, *TargetCRS*, *Transformation_Variant* and *Transformation_Version*, as these may be used as external references. All other information is non-critical. Non-critical data includes (but is not limited to) *area_of_use* and *remarks* as well as *names* of coordinate reference systems, datums, ellipsoids, map projections (conversions) and transformations.

3 From July 2001 (effective version 6.1 of the dataset) the following rules will be adhered to:
- (i) No record will be deleted from the database.
- (ii) If critical data is in error:
  - (a) the erroneous record will have its *deprecated* flag set to *true*. No other change will be made to the deprecated record.
  - (b) the error will be corrected through the introduction of a replacement record. This replacement record will have a new code allocated but will carry the same name as the original (except when the name in the deprecated record is in error). The *revision_date* of this new record will be set to the date of the deprecation and replacement.
  - (c) all records that are dependent upon the deprecated record (for example, projected coordinate reference systems using a deprecated projection) will themselves be deprecated and replaced as described in (a) and (b) above.
  - (d) a change record will be entered into the dataset.
  - (e) details describing the reason for deprecation and the deprecation and replacement path will also be recorded in the dataset.
- (iii) Spurious or bogus records that are deprecated will not be replaced.
- (iv) Records with the *deprecated* field set to “true” (or “yes” or "1") are no longer valid. Conversely, records with the *deprecated* field set to “false” (or “no” or "0") are valid.
- (v) In many cases of deprecation and replacement, the name will be retained. For any one name, in any one entity type there will be no more than one valid record, i.e. no more than one record with the *deprecated* field set to “false”. An exception to this

[1] Prior to July 2001, erroneous data was corrected either through amendment or deletion and replacement of the record. Changes to critical data were recorded in the change table, the change record identifier included in the amended data record and the date of the record changed to the date that the change was implemented. If non-critical data was amended the action *may* have been recorded in the change table, but regardless of this a change record identifier was not included in the amended data record.

rule is made within the CRS entity type where CRSs of type geocentric, geographic 3D and geographic 2D which are based on the same geodetic datum may carry identical names. Additionally, a name may be duplicated across different entity types.

(vi) Where non-critical data is amended, the *revision_date* in the affected data record will be updated. A change record will be added to the Change table and this reference added to the *change_id* field of the affected record. No change will be made to the record *code* or to any dependent records.

(vii) Where a transformation name has not been constructed according to the conventions of Annex D, it may be amended without deprecation to accord to those conventions. However a record will be added to the Deprecation table in which the transformation record is replaced by itself and appropriate remarks included. The name before amendment will not be re-used.

4. If data becomes obsolete or usage superseded, such historic data is not deleted from nor deprecated in the EPSG dataset.

5. Transformations to WGS 84**.** As described in section 4, Dataset Maintenance, where transformations are given by the information source to a realisation of the ITRS other than WGS 84 (for example, to ETRS89 or to GDA94) then the EPSG dataset will duplicate the transformation as a transformation to WGS 84. If the initial transformation (to the non-WGS84 ITRS realisation) becomes deprecated, action as appropriate will be made with regard to the EPSG dataset duplicate.

Note: Deprecated records are not shown in the EPSG database browse forms or reports. In the registry web interface deprecated records are not shown to guest users nor, by default, to registered users; registered users may elect to override this default and see both valid data and deprecated data.

ANNEX C – DATA NAMING CONVENTIONS

Revision history:

Version	Date	Amendments
0.1	August 2000	Geodesy working group internal draft
1	January 2002	First release as EPSG Guidance Note Number 9.
2	January 2003	Added provisions for degree representations.
3	January 2004	Withdraw provisions for degree representations and amend provisions for geographic 3D systems.
4	August 2004	Incorporated into GN7 part 1; GN9 withdrawn.
5	March 2008	Convention for Vertical CRS amended to include suffix.

This annex documents the strategy and style adopted for the systematic allocation of names of records included in the EPSG dataset.

Names are limited to 80 characters. Where names exceed 24 characters, or if an abbreviation is in common usage, an abbreviation is constructed (as an alias). **Abbreviations** are normally limited to 24 characters. Names and abbreviations will use characters from the standard ASCII code set.
Within any one entity type (corresponding to database table), names shall be unique except when:
(i) the entity is a direct replacement for a deprecated record, or
(ii) the entity is a 3-dimensional geographic CRS.

Datums are allocated a name, usually in English, which corresponds to the local naming of the reference frame. This may be the name of the fundamental point, network adjustment, etc. Long names may also be allocated an abbreviation. Examples: datum name = *European Datum 1950*, datum abbreviation = *ED50*.

Geographic coordinate reference systems (GeogCRS)
Geographic CRSs are allocated the name of the related geodetic datum abbreviation (if it exists) else the geodetic datum full name, followed by the prime meridian name in parentheses. However if the prime meridian is Greenwich it is omitted from the GeogCRS name. For example:

NGO 1948 (Oslo)	Prime meridian is Oslo, i.e. not Greenwich.
NGO 1948	Prime meridian is Greenwich by implication.
ED50	Prime meridian is Greenwich by implication.

In choosing the GeogCRS name, consideration should be given to its use as part of a projected coordinate reference system name.

Where geographic CRSs are 3-dimensional, three CRS entries will be included in the dataset:
(i) geographic 3D CRS.
(ii) geographic 2D CRS, where the 3D vertical axis is omitted.
(iii) geocentric.
All three will have unique CRS codes but will carry the same CRS name.

Where EPSG dataset data is mapped into a setting requiring unique names as the record key, the following strategy is recommended. The EPSG dataset name should be replaced by a name consisting of the EPSG dataset name followed by the CRS type in parentheses, for example:

EPSG dataset Code	EPSG dataset Name	CRS Kind	Recommended unique name
4937	ETRS89	geographic 3D	ETRS89 (3D)
4258	ETRS89	geographic 2D	ETRS89 (2D)
4936	ETRS89	geocentric	ETRS89 (geocentric)

Projections are allocated a name, usually in English, which corresponds to the local naming convention. A country prefix or suffix may be added when local naming might result in ambiguity in a global database.

For a Transverse Mercator projection which takes UTM parameter values other than central meridian and has no local name, the name assigned in the EPSG dataset comprises TM, space, longitude of natural origin value, space, two characters to indicate hemisphere quadrant. For example:

TM 56 SW	a projection with origin at 0ºN, 56ºW, scale factor of 0.9996, false easting of 500,000m and false northing of 10,000,000m.

Zoned Gauss-Kruger projections are found with and without a zone prefix to the false easting value. In the absence of a given naming convention, in the EPSG dataset these are named:

Gauss-Kruger zone 19	a projection with zone prefix to FE, for example FE = 19500000, with zone number 19.
Gauss-Kruger CM 111E	a projection without prefix to FE, for example FE = 500000, with the longitude of natural origin being 111ºE.

Projected coordinate reference systems (ProjCRS) are usually allocated a name comprising the Geog2D CRS abbreviation (if it exists) or name, space/space, projection abbreviation (if it exists) or name, for example:

PSAD56 / TM 56 SW
Pulkovo 1942 / Gauss-Kruger zone 19

For projected CRSs using a UTM projection there is no internationally-accepted convention for coordinate and axis order. In the EPSG dataset a UTM CRS with easting coordinate before northing coordinate is considered 'standard' and the projection part of the CRS name assigned in the EPSG dataset will be UTM, space, 'zone', space, zone number (1 through 60), one character to indicate northern or southern hemisphere, for example:

ED50 / UTM zone 33N

In abbreviations, 'zone' may be omitted, for example

ED50 / UTM 33N

UTM CRSs used locally with northing coordinate before easting coordinate may be added to the dataset on demand. These will be given a different name to that just described. This may be as known locally, or the projection part of the CRS name assigned in the dataset may use the EPSG conventional syntax TMznXN, for example

ED50 / TMzn33N

and an alias added using the conventional EPSG naming convention as described in the previous paragraph. . In the example case an alias for this projected CRS *ED50 / TMzn33N* will be:

ED50 / UTM zone 33N

Note that this syntax is distinct from but not dissimilar to that used for a Transverse Mercator projection which takes UTM parameter values other than central meridian and has no local name, as described in the projections section above.

Vertical coordinate reference systems (VertCRS) are allocated the name of the related vertical datum abbreviation (if it exists) or of the vertical datum name. From dataset version 6.15 (April 2008) the suffix "height" or "depth" as appropriate is added.

Compound coordinate reference systems are allocated a name comprising the GeogCRS or ProjCRS abbreviation (if one exists) or name, space+space, VertCRS abbreviation (if one exists) or name, for example:

NAD83 + NAVD88
NAD83 / UTM zone 15N + NAVD88

<u>CRS names including a relationship to a standard CRS</u>

Many applications (incorrectly) require that a coordinate reference system definition includes a transformation to a standard CRS (usually WGS 84). Where this practice exists it is recommended that the

GeogCRS name, and for projected CRSs the GeogCRS element of the projCRS name, be modified to the GeogCRS abbreviation or name, space*space, transformation version. For example:

Name for GeogCRS + transformation: *ED50 * IGN-Fra*
Name for ProjCRS + transformation: *ED50 * EPSG-Nor N62 2001 / UTM zone 32N*

Transformations are allocated a name comprising source GeogCRS abbreviation (if one exists) or name, space, "to", space, target GeogCRS abbreviation (if one exists) or name, space, (transformation variant). For example:

ED50 to ETRS89 (1)

Transformation variant is a sequential number for that source/target pair
Where transformations are reversible, and one of the source or target CRSs is a realisation of the ITRS (for example, WGS 84 or ETRS89), then the transformation should be entered in the direction from local to ITRF, i.e. ED50 to ETRS89 and not ETRS89 to ED50.

Transformations are also allocated a version. These are constrained to be unique within any particular pair of source and target CRSs. The version comprises a cryptic indication of the information source for the transformation (usually the organisations initials), - (hyphen), the ISO 3-character country code, and if the transformation is not applicable to a complete country a cryptic indication of its area or scope. For example:

IGN-Fra a transformation for all France from the Institut Géographique National (IGN).
IGN-Fra NW a transformation for northwest France from the IGN.

As described in section 4, Dataset Maintenance, where transformations are given by the information source to a realisation of the ITRS other than WGS 84 (for example, to ETRS89) then the EPSG dataset will duplicate the transformation as a transformation to WGS 84. In such duplicate transformations the cryptic indication of the information source will be EPSG or OGP.

ANNEX D – COMPLIANCE WITH ISO/TS 19127 - REGISTRY OF GEODETIC CODES AND PARAMETERS

Test Purpose	**Test Method**	**Reference**	**OGP Compliance Statement**
ISO 19127			
Verify that the register is managed according to the rules specified in this Technical Specification.	Check the procedures described in the information distributed by the registration manager.	ISO 19127 Clause 6 and ISO 19135, Clause 6.	Pass. Procedures for registry and register management are described in OGP Guidance Note 7 part 1.
Verify that the register contains the minimum specified content.	Inspect entries in the register to ensure that they include all elements of information required by ISO 19135 and this Technical Specification.	ISO 19127 Clause 7 and ISO 19135, Clause 8.	Exceptions: (i) entities with a status of submitted are not accessible except to the registry management. (ii) the EPSG Registry includes a status of 'deprecated' to indicate erroneous data that has been withdrawn from the valid dataset. (iii) Superseded and retired as defined in ISO 19135 are difficult to interpret in the context of geodetic entities and are implemented as sub-states within the
ISO 19135			
Verify that the register owner has identified a register manager and a control body for the register, specified criteria that determine which organizations may act as submitting organizations, and established a procedure to process appeals of decisions made by the control body.	Request information about the register from the register owner and/or register manager. Verify that required information is included.	ISO 19135, 5.2	Pass. Ownership, management and procedures for item registration are described in OGP Guidance Note 7 part 1.
Verify that the register manager distributes an information package containing a description of the register and how to submit proposals and that the register manager provides reports to the register owner at intervals specified by the register owner.	Request a copy of the information package and review for completeness. Request copies of register manager reports from the register owner.	ISO 19135, 5.3	Pass. Information about the register is described in multipart document OGP Guidance Note 7.

Test Purpose	**Test Method**	**Reference**	**OGP Compliance Statement**
Verify that all submitting organizations satisfy the criteria established by the register owner, and that register items have been submitted by approved submitting organizations.	Obtain a copy of the criteria for submitting organizations determined by the register owner and inspect the list of submitting organizations to verify that all satisfy these criteria. Check the submitting organization associated with each of a sample of register items to verify that each is listed as a submitting organization.	ISO 19135, 5.4.1, 8.9.10	Pass. Procedures for registry and register management are described in OGP Guidance Note 7 part 1.
Verify that the register is managed according to the rules specified in this International Standard.	Check the procedures described in the information package distributed by the register manager.	ISO 19135, Clause 6	Pass. Procedures for registry and register management are described in OGP Guidance Note 7 part 1.
Verify that the items in the register contain the minimum specified content.	Inspect each of a sample of entries in the register to ensure that they include all elements of information required by this International Standard and the technical standard that specifies the corresponding item class.	ISO 19135, Clause 8	Pass. The register data model is an extension to the data model in ISO 19111, the extension being supplementary metadata describing the geodetic entities.
Verify that the contents of the register are publicly available.	Check the information packet distributed by the register manager. Visit the web site or electronically processable form and inspect the information made available.	ISO 19135, 6.4	Pass. Available through http://www.epsg.org.
ISO 19111:2007			
CRS Completeness test To determine whether all of the relevant entities and elements which are specified to be mandatory or mandatory under the conditions specified have been provided in the description.	Check the coordinate reference system to ensure that the coordinate reference system description includes as a minimum all of the elements indicated as mandatory for that type of system in Tables 1 to 41 and, in the case of projected coordinate reference systems, additionally Tables 42 to 56.	ISO 19111, Clauses 6 to 10 and, in the case of projected coordinate reference systems, also Clause 11.	Pass. The register data model is fully compliant with the data model in ISO 19111. The scope of the data within the register is limited to a subset of geodetic data as described in OGP Guidance Note 7 part 1.

Test Purpose	**Test Method**	**Reference**	**OGP Compliance Statement**
CRS Maximum occurrence test To ensure each coordinate reference system element occurs not more than the number of times specified in the standard.	Examine the subject coordinate reference system for the number of occurrences of each entity and element provided to ensure that the number of occurrences for each shall be not more than the "Maximum Occurrences" attribute specified in Clauses 6 to 10 and, in the case of projected coordinate reference systems, additionally Clause 11.	ISO 19111, Clauses 6 to 10 and, in the case of projected coordinate reference systems, also Clause 11.	Pass. The register data model is fully compliant with the data model in ISO 19111
CRS Data type test To determine if each coordinate reference system in the dataset uses the specified data type.	Check the data type of each element of the description of a coordinate reference system to ensure that it is of the data type specified in Clauses 6 to 10 and, in the case of projected coordinate reference systems, additionally Clause 11.	ISO 19111, Clauses 6 to 10 and, in the case of projected coordinate reference systems, also Clause 11.	Pass. The register data model is fully compliant with the data model in ISO 19111.
Transformation Completeness test To determine whether all of the relevant entities and elements which are specified to be mandatory or mandatory under the conditions specified have been provided in the description.	Check the coordinate reference system to ensure that the coordinate reference system description includes as a minimum all of the elements indicated as mandatory for that type of system in Tables 1 to 41 and, in the case of projected coordinate reference systems, additionally Tables 42 to 56.	ISO 19111, Clause 11.	Pass. The register data model is fully compliant with the data model in ISO 19111
Transformation Maximum occurrence test To ensure each coordinate reference system element occurs not more than the number of times specified in the standard.	Examine the subject coordinate reference system for the number of occurrences of each entity and element provided to ensure that the number of occurrences for each shall be not more than the "Maximum Occurrences" attribute specified in Clauses 6 to 10 and, in the case of projected coordinate reference systems, additionally Clause 11.	Clause 11.	Pass. The register data model is fully compliant with the data model in ISO 19111

Test Purpose	**Test Method**	**Reference**	**OGP Compliance Statement**
Transformation Data type test To determine if each coordinate reference system in the dataset uses the specified data type.	Check the data type of each element of the description of a coordinate reference system to ensure that it is of the data type specified in Clauses 6 to 10 and, in the case of projected coordinate reference systems, additionally Clause 11.	ISO 19111, Clause 11.	Pass. The register data model is fully compliant with the data model in ISO 19111