GeoERA RESOURCE GROUNDWATER

Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

Deliverable 6.6

Justification of the choices to compile the Pan-EU Groundwater Resources maps by all participating countries

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INTRODUCTION

Although EU member states generally have a comprehensive overview of the groundwater resources in their homeland, a coherent overview of all fresh groundwater over Europe is not available for policy development and evaluation. The aim of the RESOURCE project and Work Package 6 (Pan-EU Groundwater Resources Map) is to produce a first information product at pan-European scale where available data is compiled and integrated to produce a map of the fresh groundwater resources of Europe. These maps are now available on EGDI, showing the volumes and depths of the fresh groundwater reserves in Europe.

This document describes the justifications of the choices that each participating survey has made in filling in the required data. It provides background information on how the templates have been filled in, what kind of data was used, and what choices were made to determine the different parameters. For an overview of the template and a more detailed explanation of the parameters that were used in gathering the data we refer to RESOURCE deliverable 6.2[1].

[1] Kivits, T., Broers, H.P., Janza, M., 2020. Deliverable 6.2. Database with information on volumes and depths at 10x10
and/or 25x25 km grids. GeoERA RESOURCE.

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RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata
The Netherlands

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Dutch template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for the Netherlands was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Generally, the Dutch template is filled by using hydrogeological models which describe the subsurface in vertically stratified units in great detail. Therefore, upscaling was necessary to simplify the model by limiting the maximum amount of layers included in the template. The upscaling was performed based on thresholds for transmissivities for aquifers and vertical resistances for aquitards. The number of layers was thereby reduced from over 100 units in the original hydrogeological model to a maximum of 10 layers in the final dataset. Other parameters were filled using a combination of model results, references to background information and expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the AHN2 dataset	https://data.overheid.nl/en/dataset/069b30cb-47f2-4c94-9cf2-99b8f5eb63c9
Total_depth_active_layers	Combination between fresh-salt interface at 1000 mg/l chloride and the hydrogeological base, as determined in REGIS II	https://www.grondwatertools.nl/thema-grondwater-projecten/zoet-en-zout-grondwater Vernes & van Doorn, 2005
Unsaturated zone thickness and extent	Determined from the average between the GHG and GLG datasets from 1998-2006, available from the NHI	https://data.nhi.nu/
Saturated zone thickness and extent	Determined from provincial models based on the national hydrogeological model of the Netherlands REGIS II. Aquifers are combined if their *kD* < 250 m^2/d, and aquitards are combined if their c < 1000 days	Vernes & van Doorn, 2005 Hummelman et al., 2019 https://www.dinoloket.nl/en/regis-ii-hydrogeological-model
Hydrogeofacies	Hydrogeofacies are based on layer types. Generally: aquifers = medium sand, aquitards = clay, except for the southern part of the country.	Vernes, 2009 https://www.dinoloket.nl/en/stratigraphic-nomenclature
Geological age	Based on known ages of formations which form the layers, when combining layers the youngest age is taken.	https://www.dinoloket.nl/en/stratigraphic-nomenclature/via-diagram/formation-by-age.
Layer type	Layers as described in the provincial models are labelled as aquifers/aquitards based on *kD* and *c* *v*alues.	Vernes & van Doorn, 2005
Aquifer type	Based on expert knowledge: Aquifers above first aquitard = unconfined, all aquifers below first aquitard = semi-confined	
Hydrological parameters	Based on model values and expert knowledge. kh and k_v values calculated from model *kD* and *c v*alues, porosity and anisotropy based on expert knowledge.	
Artesian/Paleo/Thermal	Paleo water occurrence based on age-dating study , only layers where it is known that paleo water exists are characterized. No artesian and thermal waters are included in the Netherlands.	Broers & de Weert, 2015

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in the Netherlands is available as a DEM (Digital Elevation Model) through the AHN (Algemeen Hoogtebestand Nederland). The version that was used for this project is the AHN2, which has a resolution of 0.5 m and is available as open data to the public (see https://data.overheid.nl/en/dataset/069b30cb-47f2-4c94-9cf2-99b8f5eb63c9). For the use in the Pan-EU groundwater resources map, the average value of the altitude of the surface level was calculated for each 10x10 km grid cell from an upscaled version of the AHN2 dataset (with a resolution of 100 m).

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active zone is defined by two boundaries in the Netherlands, the first being the fresh-salt groundwater interface (at 1000 mg/l of chloride) and the second being the top of the hydrogeological base. A map of the fresh-salt groundwater interface is available from https://www.grondwatertools.nl/thema-grondwater-projecten/zoet-en-zout-grondwater. For each of the 10x10 km cells an average value was calculated to get the depth of the fresh-salt interface. The hydrogeological base is defined as a layer with very high vertical resistances, where downward flow is basically absent. The top of this layer is defined in the provincial geohydrological models which are based on the national hydrogeological model of the Netherlands REGIS II (Regionaal Geohydrologisch Informatiesysteem), for more info see section 2.2 and Vernes & van Doorn (2005). The top of the hydrogeological base is defined by different hydrogeological units in each province, see Vernes & van Doorn (2005) for the precise definition in each province. The average value of the top of this layer was calculated for each 10x10 km grid cell. Where the fresh-salt interface is above the hydrogeological base, the fresh-salt boundary is used to define the total depth of the active zone, and if the fresh-salt interface is below the hydrogeological base the latter is used.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

For the calculation of the average thickness of the unsaturated zone, two dataset from the Netherlands Hydrological Instument (NHI, for more info see de Lange et al. (2014)) were used: the LHM 3.4 GHG 1998-2006 and the LHM 3.4 GLG 1998-2006, both available from https://data.nhi.nu/. These datasets cover the entire country and represent the average highest groundwater level (GHG, or Gemiddelde Hoogste Grondwaterstand) and the average lowest groundwater level (GLG, or Gemiddelde Laagste Grondwaterstand). Both these datasets were averaged for each 10x10 km grid cell, and subsequently the mean of these 2 values was calculated to get to the average groundwater level and thus the thickness of the unsaturated zone. All the information on the unsaturated zone is included in the first layer of the Dutch dataset. The unsaturated zone dynamics was set at N (or Naturally seasonal variability) for all cells in the Netherlands: although the unsaturated zone is impacted by groundwater depletion by pumping, and locally there is still recovery after mining, it is not significant enough on a 10x10 km scale.

3.2.2 *Saturated zone thickness & extent*

Most of the work into filling the Dutch template for RESOURCE WP6 went into determining the thicknesses of the saturated layers. In general, the information on the saturated layers is based on the national hydrogeological model of the Netherland, called REGIS II (Regionaal Geohydrologisch Informatiesysteem, see Vernes and van Doorn (2005)). REGIS II uses the Digital Geological Model of the Netherlands (DGM) as basis for a further subdivision of the geological layers into hydrogeological units, aquifers and aquitards. Also included in the model is hydrological parameters such as hydraulic conductivity, transmissivity and vertical resistivity. The model covers the entire country at a 100x100 m resolution. More information can be found on https://www.dinoloket.nl/en/regis-ii-hydrogeological-model and in Hummelman et al. (2019).

The REGIS II model has over 100 hydrogeological units, which is too detailed for the purpose of the RESOURCE WP6 Pan-EU groundwater map, where we aimed to limit the maximum number of units to preferably 10 layers. During the creation of the first version of REGIS II, an effort was made to reduce the complexity of the model by schematizing the many hydrogeological units into aquifers and aquifers. This was done separately for each of the 12 provinces of the Netherlands, to better align with the needs of each of them. Although the resulting geohydrological models are based on an old version of the REGIS II model and a newer REGIS II version is now available, the provincial models were still used since a large part of the schematization that is needed to reduce the amount of layers is already performed, and also because the upscaling to a 10x10 km grid would negate many of the updates from the more recent REGIS II version.

Even though the provincial geohydrological models are already a schematized version of the original REGIS II model, the amount of geohydrological units is often still too large for the purpose of RESOURCE WP6. Since each province had their own approach to schematizing the REGIS II model, the amount of units vary from a minimum of 8 layers in the province of Noord-Holland to a maximum of over 40 in the province of Gelderland. To reduce the amount of layers and also to make a harmonized grid for the entire country, further upscaling was performed on the provincial geohydrological models.

The upscaling involved combining aquifers together based on their transmissivity (*kD* in m^2/d) values and combining aquitards based on their vertical hydraulic resistance (c in d). Based on expert judgement, an aquifer was deemed important on an 10x10 km scale with a *kD* of at least 250 m^2/d and for aquitards a threshold of a resistance of 1000 days was used. Aquifers with transmissivities of under 250 m^2/d were added together until that threshold was reached, forming a combined layer (for more explanation see appendix 2 of Deliverable 6.2 (Kivits et al., 2020)). The same applies to the aquitards, where layers with a vertical resistance of less than 1000 days were added together. When combining aquifers together they are placed below an aquitard if it has a *c v*alue of >1000 days. The extent of the combined layers are determined by calculating the volume of each separate layer, and then dividing the total volume of the combined layers by the summed thickness, resulting in an extent that is true to the volume of the combined layers. Layers were only added together if they had similar hydrogeofacies, see the next section for more info. The upscaling as described above resulted in a further reduction of described units to a maximum of 10 layers.

3.2.3 Hydrogeofacies

The hydrogeofacies was mostly determined based on expert knowledge. Generally, most of the aquifers in the Netherlands are sandy (except for aquifers in the southern part of Limburg) and aquitards are clayey. In the hydrogeofacies list provided with this project, 3 types of sands are classified: fine, medium and coarse sands. In reality, the aquifers have a wide variety from fine/medium/coarse sands, with occasionally gravel deposits. However, for the purpose of this project, it didn't make much sense to distinguish each different layer based on the sand median since that would take significant time, while not providing much extra detail since the conductivities of the aquifers are included in the geohydrological models, and don't depend on the choice of the hydrogeofacies. Therefore, all aquifers (except for southern Limburg) are classified as medium sand. All aquitards are classified as clay. Although this is a gross oversimplification of reality (there are much more types of sediment besides sand and clay), on a 10x10 scale this made the most sense.

One region of the Netherlands which is geologically very different from the rest of the country is the southern part of the province of Limburg, in the very south of the country. The hydrogeological modelling based on REGIS for this province is described in Vernes (2009). There are other hydrogeofacies present here besides sand and clay. WVP2a (WaterVoerendPakket, of aquifer) is a combination between the Formations of Houthem, Maastricht and Gulpen which belong to the Chalk group, this layer was defined as an aquifer of fissured limestone and dolomite. The layer MDL2a is complex, existing of the Formation of Vaals and the Formation of Aken, which are classified as an aquitard consisting of an alteration of compact sedimentary hydrogeofacies. The layers SDL1a and 1b belong the Ville Formation consisting of Lignite. These layers with deviating hydrogeofacies were kept apart in the template, so the combination of layers based on *kD* and *c* as described in section 2.2 does not apply to these layers. More information on the different formations can be found in the stratigraphical nomenclature, see https://www.dinoloket.nl/en/stratigraphic-nomenclature.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations which make up these layers. Generally, most of the layers are Quaternary, with some deeper layers belonging to Tertiary Neogene. Only in the southern part of the Netherlands are older formations included in the template, with ages up to the Cretaceous era. When combining layers with different ages, the youngest age was taken for the entire layer. The geological ages for the different formations can be found on https://www.dinoloket.nl/en/stratigraphic-nomenclature/via-diagram/formation-by-age.

3.2.5 Layer type

In the provincial hydrogeological models based on REGIS II, 6 different layers are characterized (Vernes & van Doorn, 2005). Each of them are included as an aquifer or aquitard as follows:

- WVP: aquifer (Watervoerend pakket)
- SDL: aquitard (Slecht doorlatende laag)
- DKL: top layer (Deklaag).The DKL layers consist of the Holocene and anthropogenic deposits and are generally very shallow. These are classified as aquifers, but all of them are grouped together with the fist aquifer since their *kD* values do not exceed 250 m^2/d.

- MDL: layer with medium conductivity (Matig doorlatende laag). These are grouped with the aquifers or aquitards based on the transmissivity or resistance values. If the *kD* is high, these are classified as aquifers, and if c is high they are classified as aquitards.
- DTC: ice-pushed deposits (Gestuwde afzettingen). The ice-pushed deposits are complex structures with varying lithologies, but generally the *kD* values are high, so these are classified as aquifers.
- GHB: geohydrological base (Geohydrologische basis). The top of this layer is used, along with the fresh-salt interface (see section 1.1.2) as the lower boundary of the system, so these are not included as layers in the template.

3.2.6 Aquifer type

For the aquifer types, a simple classification was used: if the first combined aquifer is above an aquitard, it was included as an unconfined aquifer. All aquifers below the first aquitard are included as semi-confined aquifers.

3.2.7 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, and the anisotropy value) were determined based on a combination of model values and expert judgement. The porosity is based on expert judgement, with a value of 0.35 for sandy aquifers, 0.45 for clayey aquitards, 0.2 for limestone and dolomite, 0.1 for lignite, and 0.25 for the alteration of compact sedimentary hydrogeofacies. Horizontal and vertical conductivities were determined from the model values. The hydrogeological models included *kD* values for aquifers and *c v*alues for aquitards. When combining aquifers, the *kD* values were added and then divided by the total thickness of that layer to get the horizontal conductivity k_h in m/d. For the aquitards the total thickness of the layer was divided by the summed value of *c* to get to the vertical conductivity in m/d. The anisotropy value was determined by expert judgement and set at 10 for all aquifers.

3.2.8 Artesian/Paleo/Thermal

For the Netherlands, no artesian and thermal aquifers were characterized. Although there are artesian aquifers present in the Netherlands, these are not significantly large enough at a 10x10 km scale. Thermal waters are not present in the Netherland at the depth range of the active groundwater zone. For paleo waters, an age-dating study showed the presence of old water (>10.000 years) in an area known as the Roerdalslenk (Broers & de Weert, 2015). Here, all aquifers below the Waalre klei layer are indicated as paleo.

4 LITERATURE

Broers, H.P., de Weert, J. *Datering voor waterwinning: ede/gassen en isotopen in het ruwwater van Brabant Water. Vaststellen van de leeftijdsopbouw van het onttrokken water en de herkomst van methaan.* Deltares rapport BGS-14225-0001

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Vernes, R.W. (2009). *REGIS Limburg. Uitbreiding van de dataset REGIS II voor de provincie Limburg.* TNO-rapport 2008-U-R34140/A, Utrecht, Geological Survey of the Netherlands.

Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata Albania

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1 INTRODUCTION AND GENERAL BACKGROUND

The task for the completion of the Albanian template requires great knowledge of geological formations, tectonics, lithological composition of the rocks and many other factors which effect directly to the hydrogeological conditions.

This document describes the metadata information for the Albanian template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). In here you will find the background information on how the template for Albania was filled in, what data was used and what choices were made to determine the different hydrogeological parameters. First of all we have included an overview table, which explains quickly the process of filling in the template and the type of data that has been used. In chapter 3 each parameter has been described in details haw it was filled in and also describing the background data.

The geological and hydrogeological conditions of Albania are very complex. Template has been completed by using extensive information on hydrogeological data.

For the porous aquifers we have used the bore hole information. These well are distributed mainly in the Western part of Albania, South-eastern part of Albania, along the river basins where the quaternary strata has been deposited.

For karst and fissured aquifers, we have used mostly the expert judgment, hydrogeological maps and data on springs. Almost all of the grid cells of Albania are of a combination of different lithology and stratification, where layers are placed horizontally and vertically.

2 TABLE

Parameter	Short description	Link/reference
Altitude surface level	Average from the mean sea level.	Albanian Geological Survey
Total depth active layers	Hydrogeological base.	
Unsaturated zone thickness and extent	Combination of BH and expert judgement	
Saturated zone thickness and extent	Combination of BH and expert judgement	
Hydrogeofacies	Hydrogeofacies are based on geological layer types. Generally: aquifers = Gravel, coarse sand, medium sand, karstified limestone, limestone, conglomerate, fissured sandstone, compact igneous and metamorphic rock aquitards = clay, flysch	Hydrogeological map of Albania, scale 1: 200000.
Geological age	Based on the chronological stratigraphy	Geological Map of Albania
Layer type	Based on porosity and lithology of the geological formations	
Aquifer type	Based on BH/expert judgement: Aquifers above first aquitard = unconfined, all aquifers below first aquitard = confined	
Hydrological parameters	Based on BH and expert knowledge. kh values calculated from pumping tests, kv - from: Sruckmeijer & Margat: Hydrogeological Maps a Guide and Standard Legend, International Contributions to Hydrogeology, IAH, Vol 17, 1995.	
Artesian/Paleo/Thermal	Artesian waters based on piezometric levels.	

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

For the use in the Pan-EU groundwater resources map, the average value of the altitude of the surface level was secured from the department of geoinformatics within Albanian Geological Survey.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active zone in Albania is defined by top of the hydrogeological base H = hydrogeological boundary depth of aquitard or extent of fractured zone in karst systems.

3.2 Layer information

3.2.1 Saturated zone thickness & extent

Filling this section of the grid was based on the Bore Hole information for the quaternary deposits and on the hydrogeological map of Albania. For this project the thickness of the quaternary deposits of gravel have been taken into account as one layer, as in between the gravel deposits there are found deposits of clay layers. For the gravel, coarse sand and medium sand aquifers we have used the data from the hydrogeological wells.
There is no hydrogeological model for Albania. In this case the mean elevation of the springs and the mean sea level was used for determination of thickness for the karst and fissured aquifers.

3.2.2 Hydrogeofacies

Hydrogeofacies was determined from the information of the geological and hydrogeological maps of Albania.
The hydrogeofacies names have been chosen from the RESOURCE WP6 Hydrogeofacies list, which was received with the excel template.
Generally, the aquifers represent the layers of: gravel, coarse sand, medium sand, karstified limestone, limestone, conglomerate, fissured sandstone, compact igneous and metamorphic rock. Aquitards are: clay and flysch deposits.
The porous aquifers which are made of Gravel and sand, take part mainly in the Western part of Albania represented by the alluvium deposits in the lover part of the river flows, just before their discharge in the Adriatic. These aquifers are mainly made of gravel where in some cases are divided by discontinues clay deposits which vary from 1 m to tens of meters. They take up 8.4% of the total surface of the country. These aquifers are characterized by god hydraulic connections with the surface waters of the rivers. Mainly these aquifers are confined and unconfined aquifers and a small percentage of them is artesian.
Karstifiet limestone and lime stone aquifers are distributed mainly in the Southern part Northern part of the country and some spots and stains with approximately meridional direction. Their lithology is mainly composed of calcite and dolomite. These aquifers occupy a surface of 23.8 % of the total surface. They lay in great depths and are covered by flysch and molasses and from the porous aquifers in considerable part of them.

Conglomerate and fissured sandstone covers around 15 % of the country surface. They cover mainly the inner synclines. They are characterized by low parameters of water capacity.
Fissured aquifers are made of intrusive rock deposits. They immerse in the form of two belts stretching from North-West to South – East, in central Albania. They come to surface with 12.7% of the total area. They are characterized by a big number of springs but with very variable flow to the surface.
Aquitards are represented mainly by the clay and flysch deposits. On these formations are included all the deposits and formations that have inadequate porosity and water conductivity to withhold and transmit significant amount of water which can be exploited for supply. They are made of clay and sandy silt and cover up 33 % of the total surface. More information can be found in the hydrogeological map with scale 1: 200000.

3.2.3 Geological age

The geological age of the layers was determined from the chronostratigraphic formations that have been explained in the geological map of Albania.
The porous aquifers which are made of Gravel and sand, belong to the quaternary age.
Karstifiet limestone and lime stone aquifers are of ages from Triassic to Eocene.
Conglomerate and fissured sandstone are of geological age of upper Eocene – Mid Oligocene.
Fissured aquifers are made of intrusive rock deposits are formed from intrusive Paleozoic, ophiolites and continental granite rocks of Jurassic age.
Aquitards are represented mainly by the clay and flysch deposits. Flysch has e great span of geological age formation. It starts from ages of Ordovician-Silurian-Devonian, Permian -Triassic to the Pleistocene – Holocene Clays.
More information can be found in the Geology book and geology map of Albania to the scale 1: 200 000.

3.2.4 Layer type

Layer type was determined based on the hydrogeological map of Albania to the scale 1:200000. The layers are classified in two units: aquifers (AQF) and aquitards (AQT). This classification is based on the porosity and lithology of the geological formations. More information can be found in the hydrogeological map of Albania.

3.2.5 Aquifer type

Classification used for the aquifer types in this template, for Albania, are: C for confined aquifers and U for the unconfined aquifers.

3.2.6 Hydrological parameters

Hydrogeological parameters in this template are: porosity, horizontal and vertical conductivity, and the anisotropy value.
Horizontal conductivity was calculated from the hydrogeological wells and from the hydrogeological studies that have been caried out for building different scale hydrogeological maps. The porosity was determined based on expert judgement, based on the physical properties of rock deposits. For gravel from 0.25-0.32, 0.35 for sandy aquifers, 0.4 for clayey aquitards, 0.15-0.2 for karst, limestone and dolomite, and 0.25 for the alteration of compact sedimentary hydrogeofacies and 0.03 for igneous rocks. Vertical conductivities were determined from, Sruckmeijer & Margat: Hydrogeological Maps a Guide and Standard Legend, International Contributions to Hydrogeology, IAH, Vol 17, 1995e.

The anisotropy value was determined by expert judgement for all aquifers.

3.2.7 Artesian/Paleo/Thermal

Albania does have small % of artesian and thermal waters. The artesian waters have been explained as they fall within the range of fresh waters. For the paleo and thermal waters, we don't have enough information.

4 LITERATURE

Hydrogeological map of Albania, scale 1: 200000 (Albanian Geological Survey, year 2016).

Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata Austria

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1 INTRODUCTION AND GENERAL BACKGROUND

This document provides the metadata information about the Austrian contribution to RESOURCE WP6 – Pan-EU Groundwater Resources Map. It provides the background information how the Austrian template was filled in, what data were used, and what choices were made to determine the different parameters. Below, first a table is shown, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described, giving the process behind filling that particular parameter and describing the background of the data.

The Austrian template was calculated via GIS. Input data were withdrawn form selected digital maps, data bases and additional text documents. The digital maps include the Austrian groundwater bodies and their initial characterisations for Directive 2000/60/EC, Annex 1, point 2.1 (the originals are hosted at UBA, Austria's Environmental Agency). Furthermore there were used hydrogeological thematic maps of GBA and their explanatory notes as well as the actual preliminary version of the GIS dataset of the new hydrogeological map in the scale of 1 : 500 000. The new map will be published in two years, but its compilation is nearly finished (made by Rudolf Berka, GBA). The new hydrogeological map was mostly important for the interpretation of the karst aquifers and the Quaternary sediments.

The Austrian final RESOURCE WP6 template comprises 4 "layers". As the dataset is only a 2D map, this does not mean, that there exist 4 vertical layers, but this means that there are up to 4 different classes of lithology within one cell. Within a single cell all "layers" cover together 100 % of the cell (or less, if the cell do not cover only Austria).
The cells within "layer" shows the extend of the information and the weighted mean of the corresponding parameters. The background information refers to expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	This parameter was taken from the dataset „Digitales 10m - Geländemodell aus Airborne Laserscan Daten“ of www.data.gv.at by calculating the average value within a cell (link see on the right side).	https://gis.ktn.gv.at/OGD/Geographie_Planung/ogd-10m-at.zip
Total_depth_active_layers	This parameter is the sum of the thickness of the unsaturated and the saturated zone.	
Unsaturated zone thickness and extent	Where groundwater levels were available in eHYD, the data based on an interpolation of the data of eHYD (link see on the right side). When this was not possible, the information comes from the Austrian initial characterisations of groundwater bodies for Directive 2000/60/EC, Annex 1, point 2.1. The characterisations are hosted at UBA, Austria's Environmental Agency (link to groundwater bodies see on the right side).	https://ehyd.gv.at/ https://info.bmlrt.gv.at/themen/wasser/wasser-oesterreich/zahlen/grundwasser.html
Saturated zone thickness and extent	This information comes from the Austrian initial characterisations of groundwater bodies for Directive 2000/60/EC, Annex 1, point 2.1 (UBA, Austria's Environmental Agency) or from expert's estimations.	https://info.bmlrt.gv.at/themen/wasser/wasser-oesterreich/zahlen/grundwasser.html
Hydrogeofacies	The interpretation of the hydrogeofacies bases on the different hydrogeological maps of GBA. The link on the right side gives an overview of the maps (except the new one worked out by Rudolf Berka).	http://www.geologie.ac.at/onlineshop
Geological age	The age comes from the geological maps of GBA (the link on the right side gives an overview of the maps) and the stratigraphic table of Austria (link see right side)	http://www.geologie.ac.at/onlineshop http://austriafossilia.at/Geoinfos/Stratigraphische%20Tabelle.pdf
Layer type	The layer type is derived from the information if there exist artesian wells in deeper positions from Schubert 2015.	
Aquifer type	The interpretation concerning the aquifer type bases on the Hydrogeological map of Austria (Schubert 2003, link see on the right side) and on Schubert 2015.	http://opac.geologie.ac.at/ais312/dokumente/Hydrogeologische%20Karte_%C3%96sterreich_500.pdf
Hydrological parameters	This information comes from the Austrian initial characterisations of groundwater bodies for Directive 2000/60/EC, Annex 1, point 2.1 (UBA, Austria's Environmental Agency) and from expert's estimations.	https://info.bmlrt.gv.at/themen/wasser/wasser-oesterreich/zahlen/grundwasser.html
Artesian/Paleo/Thermal	This information comes from recently published thematic maps of GBA with explanatory notes.	Artesian/Paleo: Schubert (2015) https://www.bmnt.gv.at/wasser/wasserqualitaet/trinkbare_tiefen_gw.html Thermal: Elster et al (2016) https://www.bmnt.gv.at/wasser/wasserqualitaet/thermalwaesser.htm

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level was calculated for each 10x10 km grid cell separately. The input data was the free 100x100 m grid "DGM - Rasterweite 100 m, nur gesamt Österreich" of Federal Office of Metrology and Surveying (BEV) (https://www.bev.gv.at/portal/page?_dad=portal&_pageid=713,1572954&_schema=PORTAL).

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

In Austria there exist complicating tectonic structures. In mountain regions several tectonic napes can be stacked about each other. Furthermore also in the deep intramontane basins and the foreland basin of the Alps different groundwater storeys can be piled about each other. Due to this complicating situation, in Austria for the RESOURCE WP6 model it was decided to show only the most important groundwater storey which dominates the groundwater flow. In most cases this were the shallow groundwater bodies. In some basins (Molasse zone, Styrian basin etc.) this shallow groundwater bodies are connected with deeper, confined groundwaters, which are also of greater importance in this basins. In this case the uppermost, shallow groundwater bodies were calculated together with the deeper confined groundwater as one unit.

Within one cell the different "layers" are no vertical "layers", but they are located parallel to each other like groundwater bodies in a map. The area of all "layers" within one cell account for 100 % of the cell's area (except in cells which are situated at Austria's border).

Therefore it was possible to calculate the total depth by making a sum of the thickness of the unsaturated and the saturated zone. In the case the involvement of different "layers", the weighted mean was used.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

This is the weighted mean of the unsaturated zone's thickness of different "layers" within one cell (see 3.1.2).

3.2.2 Saturated zone thickness & extent

This is the weighted mean of the saturated zone's thickness of different "layers" within one cell (see 3.1.2).

3.2.3 Hydrogeofacies

The hydrogeofacies was mostly determined based on expert knowledge. In Austria only few hydrogeofacies with the following corresponding ages were distinguished:

Hydrogeofacies	**Geological_age**	**Additional explanation**
Gravel	Quaternary	
Glacial till	Quaternary	
Conglomerate	Tertiary undistinguished	Conglomerate of Sattnitz in Carinthia

alternation of compact sedimentary hydrogeofacies	Tertiary undistinguished	
Karstified limestone	Cretaceous	
alternation of fissured sedimentary hydrogeofacies	Cretaceous	
Fissured marlstone, flysch	Cretaceous	Rhenodanubic flysch
Fissured limestone and dolomite	Mesozoic undistinguished	
alternation of fissured sedimentary hydrogeofacies	Mesozoic undistinguished	
Fissured limestone and dolomite	Paleozoic undistinguished	
alternation of fissured sedimentary hydrogeofacies	Paleozoic undistinguished	
Fissured igneous and metamorphic rock	Paleozoic undistinguished	

3.2.4 Geological age

The geological ages of the layers were derived from the ages of the formations which make up these "layers". The used ages are shown in the list above. The agees come from the geological maps of GBA and the stratigraphic table of Austria (see link in the list of chapter 2)

3.2.5 Layer type

In the "layers" only aquifers and mixed layers were distinguished. Areas with confined groundwater with artesian wells were attributed as mixed layers. The information is taken from Schubert 2003 and Schubert 2015.

3.2.6 Aquifer type

In Austria unconfined, semi confined and confined aquifers were distinguished. In the confined aquifers there are several artesian wells. The information is taken from Schubert 2003 and Schubert 2015.

3.2.7 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, and the anisotropy value) were estimated based on expert judgement. The same is due to porosity. Horizontal and vertical conductivities were not distinguished, as no reference data are available.

3.2.8 Artesian/Paleo/Thermal

In Austria there exist several regions with artesian wells, paleo waters, and thermal waters. The most important regions with such waters are the foreland basin in the north of the Alps (Molasse zone) and intramontane basins like the Styrian and the Vienna basin as well as the western margin of the Pannonian basin. Schubert 2015 gives an overview on the artesian wells and paleo waters, Elster et al 2016 on the thermal waters. By the way, some thermal waters are also connected with higher mountains and deep flow paths.

4 LITERATURE

Elster, D., Goldbrunner, J., Wessely, G., Niederbacher, P., Schubert, G., Berka, R., Philippitsch, R. & Hörhan, T., 2016, Erläuterungen zur geologischen Themenkarte Thermalwässer in Österreich 1:500.000, 296 p., Geological Survey of Austria, Vienna, ISBN: 978-3-85316-086-2

Schubert, G. (Ed.), 2003, Hydrogeologische Karte von Österreich 1 : 500.000. Hydrogeological Map of Austria 1 : 500.000, Geological Survey of Austria, Vienna, http://opac.geologie.ac.at/ais312/dokumente/Hydrogeologische%20Karte_%C3%96sterreich_500.pdf

Schubert, G. (Ed.), 2015, Trinkbare Tiefengrundwässer in Österreich, Abhandlungen der Geologischen Bundesanstalt, 64, 179 p., Geological Survey of Austria, Vienna, ISSN 0378-0864, ISBN 978-3-85316-085-5

Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Croatian template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for the Croatia was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Generally, the Croatian template is filled mostly by using 2D geological and hydrogeological maps and expert judgment. Subsurface hydrogeological models are scarce and mostly limited to the northern, intergranular aquifers. Layers were mostly combined as the data availability and the needed scale of 10x10 km directed such approach.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from DEM 20x20 m	
Total_depth_active_layers	Marker Q' for Pannonian (northern) part, hydrogeological base or saltwater contact for karst (southern) part	Urumović et al., 1976
Unsaturated zone thickness and extent	Determined from the differences of mean altitude surface level in the cell and mean groundwater level in the same cell	
Saturated zone thickness and extent	Determined from the differences of the mean aquifer system bottom in the cell and mean groundwater level in the same cell	
Hydrogeofacies	Hydrogeofacies are based on lithological composition. Generally: aquifers = sand, gravels, limestones and dolomites; aquitard = clay and silt	
Geological age	Based on known ages of formations which form the layers. Source data: geological maps, published papers	Croatian geological survey (2009)
Layer type	Layers are labelled as aquifers and aquitards based on *K* values	Brkić et al. (2010)
Aquifer type	Based on expert knowledge: Aquifer above the first important aquitard = unconfined and all aquifers below the first aquitard = semi confined	Biondić et al. (1996)
Hydrological parameters	Hydraulic conductivity and storage based on pumping tests and models values, as well as expert knowledge. Porosity and anisotropy based on expert knowledge.	
Artesian/Paleo/Thermal	No artesian/paleo/thermal water are included in shallow aquifer systems.	

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of Croatian cells is averaged from a DEM (Digital Elevation Model) acquired from GDi. DEM has a cell size of 20 x 20 meters and height accuracy is 5-10 meters.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The older Quaternary boundary (Lower Pleistocene-Middle Pleistocene) is defined by the conditional E-log marker Q' (URUMOVIĆ et al., 1976). According to URUMOVIĆ et al. (1976), Q' represents the most imposing lithostratigraphic boundary and can be tracked as a regional discontinuity during deposition. Above this marker, the coarse-grained sediments, gravel and sand, were deposited, while underlying sediments are silt and clay. The groundwater that accumulates in the sandy and gravelly aquifers above marker Q' is the main source of the water-supply for the whole region.
In karst areas, total depth is defined mostly by the depth of the hydrogeological base, where karstification is very low. Along the Adriatic coast, contact with saltwater is defining the total depth of aquifers. That depth is mostly deduced by expert knowledge, hence it is not precise. Fresh water must have less than 250 mg/l of chlorides.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

There is no global 3D geological model for the whole of Croatia. Small hydrogeological models, as well as borehole data, are available for some intergranular aquifers in the northern part of Croatia. Main source of information was geological and hydrogeological maps in a scale 1:100.000 and 1:300.000 (Croatian geological survey, 2009). Topographical maps in a scale 1:25.000 along with a DEM was also used (https://geoportal.dgu.hr/). Archive materials, along with hydrogeological databases of Croatian geological survey was also used. As the whole country is covered only with the surface data, expert judgment was extensively used in reconstructing subsurface. This is especially true for southern (karst) part which has generally less data then the northern (pannonnian) part of the country.

3.2.2 Saturated zone thickness & extent

There is no global 3D geological model for the whole of Croatia. Small hydrogeological models, as well as borehole data, are available for some intergranular aquifers in the northern part of Croatia. Main source of information was geological and hydrogeological maps in a scale 1:100.000 and 1:300.000 (Croatian geological survey, 2009). Topographical maps in a scale 1:25.000 along with a DEM was also used (https://geoportal.dgu.hr/). Archive materials, along with hydrogeological databases of Croatian geological survey was also used. As the whole country is covered only with the surface data, expert judgment was extensively used in reconstructing subsurface. This is especially true for southern (karst) part which has generally less data then the northern (pannonnian) part of the country.

3.2.3 Hydrogeofacies

For the needed scale of 10x10 km grid, hydrogeofacies was simplified based on expert judgment. Aquifers in the pannonian part are mostly composed from variety of layers. Simplification was necessary to accommodate the 10x10 scale. In the karst part of the country, limestone and dolomite aquifers are dominant. Given the scale and available data, they are mostly treated as a mix.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations which make up these layers. Pannonian part is mostly composed of younger, Quaternary and Tertiary deposits. Karst part is composed of Mesozoic limestones and dolomites. They are often undistinguished, as separating them would be very hard with available data, and wouldn`t bring much benefit.

3.2.5 Layer type

Layer types are classified based on their hydrogeological properties in aquifers and aquitards. For very heterogenic layers, mix nomenclature was used.

3.2.6 Aquifer type

For the aquifer types, a simple classification was used: if the first combined aquifer is above an aquitard, it was included as an unconfined aquifer. All aquifers below the first aquitard are included as confined or semi-confined aquifers.

3.2.7 Hydrological parameters

Hydrogeological parameters were determined by hydrogeological models and pumping tests in some instances, but mostly by expert judgement. Expert judgment is dominant method in the karst part were the values are agreed upon beforehand to reflect our understanding of karst aquifer properties.

3.2.8 Artesian/Paleo/Thermal

We have no data for potential paleo water. Thermal waters are all with temperature above mean annual air temperature in the area. Artesian aquifer has to have pressure above the ground surface.

4 LITERATURE

Biondić, B.; Brkić, Ž.; Biondić, R. (1996): Water management basis of the Republic of Croatia. In Hydrogeology; 1st phase (technical report in Croatian); Croatian Geological Survey: Zagreb, Croatia, 1–55.

Brkić, Ž., Larva, O. & Urumović, K. (2010): Quantity status of groundwater in alluvial aquifers in northern Croatia.- Geol. Croat., 63/3, 283-298

Croatian Geological Survey (2009): Geological Map of the Republic of Croatia at a scale 1:300.000 (in Croatian). Croatian Geological Survey.

Croatian Geological Survey (2009): Guidebook of the Geological Map of the Republic of Croatia at a scale 1:300.000 (in Croatian).Velić, I. & Vlahović, I. (ed): Croatian Geological Survey, 141 p.

Urumović, K., Hernitz, Z., Šimon, J., Velić, J. (1976): About permeable medium of the Quaternary, Upper and Middle Pliocen's deposits in the northern Croatian (in Croatian). Zbornik radova 4. jug. simp. o hidrogeol. i inž. geol., knjiga 2, 395-410.

Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document provides metadata information for the Cypriot template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template was filled-in, on the data used, and on the choices made in determining the various parameters. An overview table is initially presented which gives a quick overview on the process of filling-in the template and type of data used. A more detailed description is then given in chapter 3, where each parameter is described in detail by presenting the process in filling each particular parameter and by describing the data background.

Generally, the template was filled either by using the geological model created within the framework of the Resource project of by using background information and expert judgment. The abovementioned geological model was created by using tens of borehole log data and hydrogeological information held by Cyprus Geological Survey Department.

2 OVERVIEW TABLE

Parameter	Short description (2/3 sentences)	Link/reference
Altitude_surface_level	Averaged from local dataset (Dem25m50k)	
Total_depth_active_layers	Combination between fresh-salt interface at 2500μS/cm of EC and hydrogeological boundary.	
Unsaturated zone thickness and extent	Combination of boreholes log data and pumping test data.	
Saturated zone thickness and extent	Combination of boreholes log data and pumping test data.	
Hydrogeofacies	The closest matched from RESOURCE WP6 hydrogeofacies list.	
Geological age	The closest matched from table in page 14 of D6.2 Draft "Final template that will be used by all participating surveys to collect the required data"	
Layer type	Based on expert Judgement and in Individual cases on boreholes and pumping test data.	
Aquifer type	Based on expert Judgement.	
Hydrological parameters	Based on expert Judgement.	
Artesian/Paleo/Thermal	No paleo and thermal waters are included in the Cypriot template. Artesian water from pumping test data.	

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level is available as a DEM (Digital Elevation Model) through the Department of Lands and Surveys (DLS). The version that used for the RESOURCE project is DEM25m50k, whose cells dimension are 25 X 25 m. For each 10 X 10 km grid cell of RESOURCE project, average value from 160000 DEM grid cells (25 X 25 m) have been calculated.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth active zone was defined based on a combination of chemical and hydrogeological criteria. The chemical criteria based on the fresh-salt interface at 2500µS/cm of electric conductivity (Ec) and the hydrogeological criteria based on hydrogeological boundary. The hydrogeological boundary is defined as a layer with no downward flow (very high vertical resistance) and the fresh-salt interface defined as a depth where the electrical conductivity (Ec) reached 2500µS/cm. For each 10 X 10 Km cells, and an average value was calculated.

Furthermore, in cells where sea water intrusion is observed and/or in gypsum cells, the fresh-salt interface was mainly used while in the rest of the cells, the hydrogeological boundary criterion was adopted. In cases where the fresh-salt interface is observed above the hydrogeological base, the fresh-salt boundary is used to define the total depth of the active zone; otherwise, the hydrogeological base was used.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

For the calculation of the unsaturated zone, we used data from borehole logs and pumping tests. For each 10 X 10 Km grid cell, representative boreholes were selected and a 3D subsurface model was created using a computer software.

3.2.2 Saturated zone thickness & extent

For the calculation of the saturated zone, we used data from borehole logs and pumping tests. For each 10 X 10 Km grid cell, representative boreholes were selected and a 3D subsurface model was created using a computer software.

3.2.3 Hydrogeofacies

The hydrogeofacies were determined based on a combination of borehole data and expert judgement. The closest matched from RESOURCE WP6 hydrogeofacies list, was selected.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the corresponding formations. The closest matched from table in page 14 of D6.2 Draft "Final template that will be used by all participating surveys to collect the required data", was selected.

3.2.5 Layer type

In Cyprus there are three classes of aquifers. The first one is that of the clastic aquifers which are mainly developed in river and deltaic deposits as well as in marine terraces. In the second class belong the karstic and pseudo karstic aquifers that are developed in carbonated rocks, and the third class is the fractured aquifers in which water fills up the space created by the fracturing of the sound bedrock-mass (fractured zones). The aquitards are mainly marly, clayey or muddy layers. Layers consisting of gravels, medium sands and sandstones were characterized as aquifer (AQF) representative the first class of aquifer, layers consisting of karstified limestone and chalk characterized as aquifer (AQF) representative the second class of aquifer, and finally, layers consisting of fissured basalt, gabbro and lava characterized as aquifer (AQF) representative the third class of aquifer. Layers consisting of clay, marl and mudstone characterized as aquitard (AQT). No MIX type has been selected.

3.2.6 Aquifer type

For aquifer type a simple classification schema was developed: the gravel and sand aquifers were classicised as unconfined (U), sandstones and karstified limestone as semi confined (SC) and chalk, lava, gabbro and basalt as confined (C).

3.2.7 Hydrological parameters

The hydrological parameters and more specifically for the porosity, vertical conductivity and anisotropy, they were determined based on expert judgement. The anisotropy value was set at 1 for all aquifers. For horizontal conductivity both expert judgement and pumping test data were used.

3.2.8 Artesian/Paleo/Thermal

No paleo and thermal aquifers were characterized. Despite that paleo water occurs in some cases in Cyprus, they are not observed in significantly large volumes, at a 10x10 km scale. Artisan conditions were reported for each layer, in cases where even a single artesian borehole exists.

4 LITERATURE

United Nations. Survey of Groundwater and Mineral Resources Cyprus (1970)

Food and Agriculture Organization of the United Nations. Re-Assessment of the Water Resources and Demand of the island of Cyprus (2002)

Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Czech template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for the Czech Republic was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given with a quick overview on the process of filling in the template and types of data used. A more detailed description is given in chapter 3.

The Czech template is filled using a combination of hydrogeological maps, borehole data, expert knowledge and in case of hydrogeological basins also by using results of hydrogeological models.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the ZABAGED dataset.	https://geoportal.cuzk.cz//
Total_depth_active_layers	Combination between fresh-salt interface at and hydrogeological base – general background values, provincial models, expert knowledge.	Krásný et al. 2012
Unsaturated zone thickness and extent	Averaged from provincial models in the hydrogeological basins. Combination of the hydrogeological borehole data and expert judgement in the hydrogeological massif.	https://mapy.geology.cz/vrtna_prozkoumanost/
Saturated zone thickness and extent	Averaged from provincial models in the hydrogeological basins. Combination of the hydrogeological borehole data and expert judgement in the hydrogeological massif.	https://mapy.geology.cz/vrtna_prozkoumanost/
Hydrogeofacies	Based on lithology from Geological map of Czech Republic 1 : 500 000 and Geological map of Czech Republic 1 : 50 000.	https://mapy.geology.cz/geological_map500/?locale=en https://mapy.geology.cz/geocr50/
Geological age	Based on stratigraphy from Geological map of Czech Republic 1 : 500 000 and Geological map of Czech Republic 1 : 50 000.	https://mapy.geology.cz/geological_map500/?locale=en https://mapy.geology.cz/geocr50/
Layer type	Layers are labelled aquifers/aquitards mostly based on lithology.	Krásný 2012; Hydrogeological map of Czech Republic at scale 1 : 50 000 (Czech Geological Survey Edition – different authors)
Aquifer type	Based on provincial models and expert knowledge.	Krásný 2012; Hydrogeological map of Czech Republic at scale 1 : 50 000 (Czech Geological Survey Edition – different authors)
Hydrological parameters	Based on provincial models, borehole and map data and expert knowledge.	Krásný 2012; Hydrogeological map of Czech Republic at scale 1 : 50 000 (Czech Geological Survey Edition – different authors)
Artesian/Paleo/Thermal	Thermal water occurrence based on local mineral water studies and general mineral waters monography.	Janoška 2011; Květ 2011

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Czech Republic was calculated from Fundamental Base of Geographic Data of the Czech Republic (ZABAGED®) – altimetry – 3D contours (see https://geoportal.cuzk.cz/(S(caox5pxfq2vctucosqe4tgqr))/Default.aspx?lng=EN&mode=TextMeta&side=vyskopis&metadataID=CZ-CUZK-ZABAGED-VV&mapid=8&menu=304).

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The depth of the active zone in Czech Republic is defined either by the base of active circulation in the aquifers or by the fresh/salt water interface (at 125 mS/m). The data for hydrogeological basins (Cretaceous, Neogene) is available in the provincial hydrogeological and hydraulic models produced during the Review of groundwater resources in the Czech Republic. The datasets are not for public use, the visualisations and results are given in final reports (http://www.geology.cz/extranet/vav/prirodni-zdroje/podzemni-vody/rebilance, in Czech only). The data for hydrogeological massifs (crystalline unites, Carboniferous or Permian fractured sediments) and flysch belt of Western Carpathians are given by combination of expert knowledge, general background values (Krásný et al. 2012)

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The unsaturated zone thickness in hydrogeological basins was determined from provincial models (see above) where the average groundwater table depth in top-most aquifer is represented by groundwater level contours (in meters below the surface). The datasets was averaged for each 10x10 km cell of the grid and the groundwater. In other hydrogeological units (the hydrogeological massif, flysch), the groundwater level is highly variable in the area of a grid cell. General background values were taken from maps (Hydrogeological map of Czech Republic at scale 1 : 50 000 (Czech Geological Survey Edition – different authors), regional studies (Krásný et al. 2012) in combination with hydrogeological borehole data (https://mapy.geology.cz/vrtna_prozkoumanost/).
The unsaturated zone dynamic was set in majority of the grid cells as N (naturally seasonal variability). Information on the groundwater depletion or impact of the mining is taken from local studies.

3.2.2 Saturated zone thickness & extent

The saturated zone thickness and extent in hydrogeological basins was determined from provincial models (see above) where the altitudes of the top and the bottom of individual aquifers are expressed by contours in meters above sea level. The saturated zone thickness was calculated as the difference between the top and bottom of individual aquifers. In topmost aquifer, the thickness of unsaturated zone was subtracted.

In other hydrogeological units (the hydrogeological massif, flysch, alteration of aquifers), the general saturated zone thickness values were taken from maps (Hydrogeological map of Czech Republic at scale 1 : 50 000 (Czech Geological Survey Edition – different authors), regional studies (Krásný et al. 2012) in combination with hydrogeological borehole data (https://mapy.geology.cz/vrtna_prozkoumanost/) and expert knowledge.

3.2.3 Hydrogeofacies

The hydrogeofacies were determined based on lithology from Geological map of Czech Republic 1 : 500 000 and Geological map of Czech Republic 1 : 50 000 (https://mapy.geology.cz/geological_map500/?locale=en, https://mapy.geology.cz/geocr50/). Simplification of the varied geology of Czech Republic was necessary while filling the grid cells. In Quaternary and Tertiary hydrogeological basins the aquifers were classified mostly as sand or coarse sand, the aquitards mostly as clay or silt. Some of the Tertiary basins with lithologicaly varied sediments are classified as alternation of unconsolidated sedimentary hydrogeofacies. In Cretaceous basins the aquifers are classified as sandstone, the aquitards as claystones and siltstones. The mixture of Cretaceous and Neogene sediments (sand, silt, clay, gravel) in the basins in Southern Bohemia is classified as alternation of unconsolidated sedimentary hydrogeofacies. The wide variety of Cretaceous to Paleogene sediments of Western Carpathians Flysch Belt is classified as flysch. The highly compacted Carboniferous sediments are generally classified as fissured sandstone, although other lithological types are present (siltstones, nonglomerates). The mixture of varied Carboniferous to Permian sediments is classified as alternation of fissured sedimentary hydrogeofacies. Not very vast, but unique areas of Moravian and Bohemian Karst are classified as limestones. Varied, highly compacted sediments of Precambrian to Lower Paleozoic age in the Central Bohemia (the Barrandien) are classified as Alternation of fissured sedimentary hydrogeofacies. The crystalline units of Precambrian to Paleozoic age classified as Fissured igneous and metamorphic rock.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the geological formations which make up these layers. The oldest rock formations of Czech Republic are of Precambrian age, the youngest are Quaternary. The geological ages of different formations can be found on geological maps of Czech Republic see https://mapy.geology.cz/geological_map500/?locale=en, https://mapy.geology.cz/geocr50/) and in stratigraphy schemes.

3.2.5 Layer type

Layer types in hydrogeological basins were determined based on provincial models. In the rest of the area, the expert knowledge of hydrogeological conditions in different lithological formations was used.

3.2.6 Aquifer type

The aquifer type was determined based on the expert knowledge in combination with hydrogeological boreholes data.

3.2.7 Hydrological parameters

The parameters included in the template (porosity, hydraulic conductivity, anisotropy) were determined based on model values (in hydrogeological basins) and the combination of the general background values from hydrogeological maps and the expert knowledge.

3.2.8 Artesian/Paleo/Thermal

Thermal water occurrence was determined based on mineral water studies and monography (Janoška 2011; Květ 2011)

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Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata Denmark

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Danish template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for Denmark was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. A more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

The Danish template is filled with data extracted from the Danish national water resource model – the DK-model. The model is based on tree individual hydrostratigraphic layer models and one voxel model for the Island of Bornholm. Together they represent aquifers and aquitards in the majority of Denmark. Only three minor islands in The Kattegat Sea (Samsø, Læsø and Anholt) are not covered by the DK model, here expert judgement was made from borehole data and groundwater mapping reports.

The DK-model describes the subsurface in up to 27 horizontally stratified units in 100 x 100 m grid. As the template generally only require 10 layers in a 10 x 10m grid cell, it was necessary to simplify the model by limiting the maximum number of layers included in the template. This was performed by setting a threshold for thickness (3 m) and extent (5%) of each hydrostratrigraphic unit in each cell, as this was considered the minimum volume of interest in a European scale.

After this reduction of layers, a huge number of cells still had more than 10 layers. It was therefore decided to allow up to 13 layers in a cell, thus bringing the number of cells to go through manually down to a minimum. Expert judgement was used for manually reducing layers within the cells to a maximum of 13 layers.

The model for the Island of Bornholm consists of a lithological voxel model (250m x 5m voxels) which is divided horizontally into 6 calculation layers in the DK-model. It is these 6 calculation layers which have been used to calculate extent and thickness in the template for Bornholm.

Other parameters required in the template were filled using a combination of model results, references to background information and expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Is calculated using a surface grid from the National Danish Elevation Model.	The Danish Elevation Model (DK-DEM). (sdfe.dk) DHM-2007/Terræn (10 m grid) | Kortforsyningen download
Total_depth_active_layers	Is defined as a hydrogeological base in the majority of DK, except for the Island of Læsø in The Kattegat Sea where chloride concentration above 250 mg/l is the limit.	Stisen S. et al, 2019. Naturstyrelsen Aarhus, 2012 Miljøcenter Aalborg, 2010 https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Unsaturated zone thickness and extent	Using ArcGIS and Python programming the thickness and extent of each layer in the DK model is calculated for each 10x10 km cell. The unsaturated part of each layer in each cell is calculated using a grid of the unsaturated zone from the DK-model. For the tree Islands in The Kattegat Sea groundwater level in well data is used.	Stisen S. et al, 2019. https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Saturated zone thickness and extent	Using ArcGIS and Python programming the thickness and extent of each layer in the DK model is calculated for each 10x10 km cell. The saturated part of each layer in each cell is calculated using a grid of the unsaturated zone from the DK-model. For the tree Islands in The Kattegat Sea groundwater level in well data is used.	Stisen S. et al, 2019. https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Hydrogeofacies	Hydrogeofacies are based on the lithology of the layers in the DK-model, local groundwater or geological mapping reports, well-data and expert judgement.	Stisen S. et al, 2019. Naturstyrelsen Aarhus, 2012. Miljøcenter Aalborg, 2010. Ditlefsen et al, 2008. https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Geological age	Geological age is based on the chrono stratigraphy of the layers in the DK-model, local groundwater or geological mapping reports well-data from the national well database (Jupiter) and expert judgement.	Stisen S. et al, 2019. Naturstyrelsen Aarhus, 2012. Miljøcenter Aalborg, 2010. Ditlefsen et al, 2008. https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Layer type	The layer type is derived from the DK-Model, well-data and expert judgement.	Stisen S. et al, 2019. https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Aquifer type	Based on expert knowledge are all aquifers set to semi-confined except for the aquifers in layer 1 or 2	Expert Judgement and well information.

	with an overlying aquifer. These aquifers are unconfined.	https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Hydrological parameters	Is calculated based on optimised parameters from the calibrated DK-model. For the Islands of The Kattegat Sea Kh/Kv has been calculated as a rough estimate based on pumping data from the Jupiter well database.	Stisen S. et al, 2019. Naturstyrelsen Aarhus, 2012. https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter
Artesian/Paleo/Thermal	Artesian is marked if the hydrostratigraphic unit is artesian in more than 50 % of the cell. Paleo water occurrence based on age-dating studies in previous EU and internal projects, only layers where it is known that paleo water exists are marked. No thermal waters are marked in DK.	Hinsby et al, 2001. Meyer et al, 2018. https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/national-boringsdatabase-jupiter

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The used altitude surface model is a national digital elevation model describing the elevation of the landscape above sea level DHM-2007/Terræn (10 m grid) | Kortforsyningen download. All objects as trees, houses, cars etc. is removed. The model is downloaded in a 10x10 m grid and re-gridded to 100x100 m for use in the DK-model. For the use in the Pan-EU groundwater resources map, the mean value of the altitude of the surface level was calculated for each 10x10 km grid cell from the grid used in the DK-model. The calculation was performed in ArcGIS using a Phyton script programmed for this purpose.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of active layers is primarily defined by the top of the hydrogeological base, which is a layer with very high vertical resistances, where downward flow is basically absent. The top of the hydrogeological base has been mapped in local models from geophysical data from the national GERDA database (Møller et al, 2009) and wells from the national JUPITER database or defined by expert judgement. The local models are compiled in the DK-model, see Stisen et al, 2020.

The lithology of the hydrogeological base differs from the different regions in the DK-model. In the main part of Denmark, the hydrological base consists of Paleogene fat clay. In Northern Jutland and parts of Zealand and parts of Funen, the hydrological base mainly consists of compact Cretaceous Limestone/chalk, defined as being below 50 m of the top of the Limestone, as the top 50 m of the Limestone is typically fissured due to glacial overpressure and glaciotectonics. On the Island Bornholm the hydrological base is mainly the top of compact igneous and metamorphic rock or compact sedimentary rocks. For the Island Læsø in the Kattegat Sea, the depth of active layers is defined by the fresh-salt groundwater interface (at 250 mg/l of chloride, which is the maximum level for drinking water in Denmark).

For the use in the Pan-EU groundwater resources map, the mean value of the bottom of the DK-model was calculated for each 10x10 km grid cell from the 100x100 m grid used in the DK-model. The calculation was performed in ArcGIS using a Phyton script programmed for this purpose.

Expert judgement and well-data information was used on the three Islands in The Kattegat Sea and filled in manually.

Layer information

3.1.3 Unsaturated zone thickness, extent & dynamics

Initially the mean thickness and extent of each layer in the DK-model was calculated for each Pan-EU 10x10 km grid cell from the 100x100 m grid used in the DK-model.

The unsaturated and hence the saturated part of each layer in each Pan-EU cell is calculated using a computed 500x500m grid of the unsaturated zone from the DK-model.

The calculation was performed in ArcGIS using a Phyton script programmed for this purpose.

For the three Islands in The Kattegat Sea groundwater level in well data and expert judgement was used and the result was filled in manually in each Pan-EU cell.

The unsaturated zone dynamics was set at N (or Naturally seasonal variability) for all Pan-EU cells in Denmark.

3.1.4 Saturated zone thickness & extent

The saturated zone is the part of the Pan-EU cell which is not unsaturated and hence calculated as described above 3.1.3.

The majority of Pan-EU cells is saturated.

3.1.5 Hydrogeofacies

Generally, the geology in Denmark consists of unconsolidated sediments of Quaternary and Tertiary age or Paleogene and Cretaceous Limestone and Chalk. However, in one part of Denmark on the Island of Bornholm, hard rock geology prevails, with Precambrian compact and fissured igneous and metamorphic rock and Cambrian or younger compact and fissured sedimentary rocks in the main part of the Island.

Hydrogeofacies for the Pan_EU map are based on the lithology of the layers in the DK-model, local groundwater- or geological mapping reports, well-data and expert judgement. (Stisen S. et al, 2019, Naturstyrelsen Aarhus, 2012, Miljøcenter Aalborg, 2010, Ditlefsen et al, 2008, GEUS-Jupiterdatabasen, 2021).

For combined layers, see 3.1.7., the hydrogeofacies of the layer which has the largest volume in the Pan-EU cell is given to the combined layer.

3.1.6 Geological age

Geological age is based on the chrono stratigraphy of the layers in the DK-model, local groundwater- or geological mapping reports well-data and expert judgement. (Stisen S. et al, 2019, Naturstyrelsen Aarhus, 2012, Miljøcenter Aalborg, 2010, Ditlefsen et al, 2008, GEUS-Jupiterdatabasen, 2021).

For combined layers, see 3.1.7., the age of the layer which has the largest volume in the Pan-EU cell is given to the combined layer.

3.1.7 Layer type

The layer type (aquifer/aquitard) is derived from the DK-Model, well-data and expert judgement. (Stisen S. et al, 2019, GEUS-Jupiterdatabasen, 2021)

The DK-model consists of up to 28 hydrogeological units which is divided into aquifers and aquitards respectively. Both on Zealand and Jutland the DK-model consist of more than 10 layers, as was required for the Pan-EU groundwater resources map. Hence a reduction of layers was necessary.

Based on knowledge of thickness and extent of layers, it was initially decided to group together near surface Quaternary layers in Jutland (KS1, KL2, KS2) as well as the deeper lying Quaternary layers (KS5, KL6, KS6). For both Zealand and Jutland, the last Quaternary till unit (KL7) was grouped together with the top Tertiary clay unit (PL1), as there is no aquifer situated between them.

To reduce the number of layers further, a minimum thickness of two meters was decided on for a layer to be added to a cell. After this reduction, all cells with more than 10 layers were located in Jutland.

To reduce the number of layers in Jutland further, it was decided to calculate the volume of the layers based on threshold of the thickness 3 m and the extent 5% in the Pan-EU cell, and hence to remove all layers with a volume less than $15x10^6$ m^3. It was tested to see the effect of a layer reduction by changing the limits of thickness and extent to 5 m and 8%, but this only made a small change in the number of cells with more than 10 layers.

With a threshold set on layer thickness (3 m) and extent (5%) 190 cells had more than 10 layers. Since layer thickness and extent varies greatly within each cell it was necessary to go through the cells manually to reduce the number of layers. It was therefore decided to allow up to 13 layers in a cell, thus bringing the number of cells to go through manually down to 88.

The strategy for reducing layers further within the Pan-EU cells was to make a profile through the DK-model in a Pan-EU cell and then group together close lying aquifers or aquitards. Only if an aquifer or aquitard was considered very small compared to bounding layers would a mix of aquifers and aquitards be made. For the majority of Pan-EU cells with too many layers the reduction was made in the Miocene layers.

3.1.8 Aquifer type

Based on expert judgement, all aquifers have been set to semi-confined except for the aquifers in layer 1 or 2 with an overlying aquifer. These aquifers have been set to unconfined. Aquifers in layer 2 with overlying peat or bog have been set to semi-confined.

3.1.9 Hydrological parameters

Hydrological parameters are calculated based on optimised parameters (kx) from the calibrated DK-model, see Stisen S. et al, 2019.

Horizontal conductivity for the layers is calculated as:

Kh (m/day) = Kx (m/s) x (60 x 60 x 24)

The vertical conductivity for a layer is calculated as:

Kh/Kv = 10, where the 10 is the anisotropy factor.

Kv (m/day) = Kx (m/s) x (60 x 60 x 24) / 10

For the islands Læsø and Anholt Kh/Kv has been calculated as a rough estimate based on pumping data from the Jupiterdatabase. The value was estimated by using the Cooper-Jacob equation to evaluate the transmissivity:

T=2,3Q/(4p∆s)

where Q is the pumping rate, s is the drawdown of a log cycle (time)

From here the K-value is calculated:

K=T/b

where b is the thickness of the aquifer.

For the island of Samsø the model covering the southern part of the island was used (Naturstyrelsen Aarhus, 2012), whereas the northern part was assessed using available borehole data from the Jupiterdatabase.

3.1.10 Artesian/Paleo/Thermal

No cells have been marked as containing thermal water.

The percentage of a cell containing artesian groundwater has been calculated. It was decided that cells with more than 50% artesian groundwater in a layer was marked as artesian in the template.

Paleo water has been identified in 7 boreholes (Hinsby et al., 2001, Meyer et al. 2018), which have been linked to the corresponding cell ID and layer number. For more information on the studies regarding paleo water see /2/ and /3/ and the following link to pilot studies on groundwater age distributions in Southern Jutland and other European pilot areas on EGDI: HOVER WP6 pilot sites

The layers with analyses showing paleo water have been marked in the final template.

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Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata FINLAND

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Finnish template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for Finland was filled in, what data was used, and what choices were made to determine the different parameters. First, an overview table is given, which gives a quick overview of the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Hydrogeological conditions in Finland differ significantly from typical European conditions. Finnish aquifers are small in size and shallow in depth (1 -layer aquifers). There is no detailed hydrogeological data from all the Finnish aquifers so most of the data collected for RESOURCE project is based on general geological/hydrogeological data, literature and expert judgement. Existing detailed hydrogeological data (see lahde.gtk.fi) and models (3D and flow models) were not feasible to apply in RESOURCE project.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the National Land Survey of Finland DEM dataset.	https://www.maanmittauslaitos.fi/en/maps-and-spatial-data/expert-users/product-descriptions/elevation-model-10-m
Total_depth_active_layers	Values were calculated "DEM (National Land Survey of Finland) minus Bedrock surface elevation (GTK 2020)"	https://www.maanmittauslaitos.fi/en/maps-and-spatial-data/expert-users/product-descriptions/elevation-model-10-m http://tupa.gtk.fi/paikkatieto/meta/kallionpinnan_korkeustaso_1m.html
Unsaturated zone thickness and extent	The distance of the groundwater surface from the ground in Finland is usually at a depth of 2 to 5 meters. The used value is 5 meters.	https://www.ymparisto.fi/fi-fi/vesi/Pohjavesien_tila/Pohjaveden_esiintyminen
Saturated zone thickness and extent	Values were calculated ["DEM" (*National Land Survey of Finland*) minus "Unsat Thickness"] minus "Bedrock surface elevation" (*GTK 2020*). If the calculated value was less than 6 meters the used value was 6 meters.	https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161164/OH_3_2018_Pohjavesialueet_opas_nettiin.pdf
Hydrogeofacies	The aquifers in Finland are eskers which have gravel core. All the cells have value "Alteration of Unconsolidated sedimentary hydrogeofacies"	https://www.geologia.fi/2019/12/11/pohjavesi/
Geological age	All of the layers in Finland are Quaternary.	https://www.geologia.fi/2018/05/21/maaperan-synty/
Layer type	If the cell contains classified groundwater formation the cell is classified as an aquifer. Otherwise the cell has no value.	https://www.avoindata.fi/data/en_GB/dataset/pohjavesialueet
Aquifer type	If the cell is classified as an aquifer the value is unconfined. Otherwise the cell has no value.	https://www.geologia.fi/2019/12/11/pohjavesi/

Hydrological parameters	All the hydrogeological parameters are based on expert judgement. These parameters are only used in cells containing aquifers.	*Airaksinen, J.U. 1978*.
Artesian/Paleo/Thermal	No Paleo nor Thermal waters are present in Finland. Artesian groundwater occurs in only a few areas.	https://www.ymparisto.fi/download/noname/%7BD511CB71-0A6E-4559-A174-96E26E96AA71%7D/57054

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 *Altitude_surface_level*

The differences between the N2000 and the EVRF2007 are small, less than one centimetre. (*Poutanen et al. 2011*). The altitude of the surface level (N2000) in Finland is available as a DEM (Digital Elevation Model) produced by the NLS (*National Land Survey of Finland*). The used version has a resolution of 10 m and is available as open data (See https://www.maanmittauslaitos.fi/en/maps-and-spatial-data/expert-users/product-descriptions/elevation-model-10-m).

For the use in the Pan-EU groundwater resources map, the average surface level was calculated for each 10x10 km grid cell from an upscaled version of the dataset with a resolution of 200 m.

3.1.2 *Total_depth_active_layers & Label_maximum_depth active layers*

Values for Total depth active layers were calculated "DEM" (*National Land Survey of Finland*) minus "Bedrock surface elevation" (*GTK 2020*) (See http://tupa.gtk.fi/paikkatieto/meta/kallionpinnan_korkeustaso_1m.html) resulting thickness in meters. The result was converted to a 10x10 km grid. In coastal areas grid value is "1" not to miss groundwater areas and moraine formations near shoreline. Large islands in the Finnish Lakeland have a value "2" meters, so that the groundwater areas of the islands are not ignored.

Values for Label maximum depth active layers is "H" (Hydrogeological boundary) for all cells based on Finnish geology.

3.2 Layer information

3.2.1 *Unsaturated zone thickness, extent & dynamics*

Groundwater surface means the boundary below which all porous space of the soil and bedrock is completely saturated with water. The distance of the groundwater surface from the ground surface (unsaturated zone thickness) in Finland varies from about one to more than 50 meters. It is usually at a depth of 2 to 5 meters below the ground surface. In cells containing an aquifer, a value of "5" (meters) was used. (See Finnish Environmental Institute https://www.ymparisto.fi/fi-fi/vesi/Pohjavesien_tila/Pohjaveden_esiintyminen).

Unsaturated extent is the same as "Saturated extent".

Dynamics is "Naturally seasonal variable" in all cells.

3.2.2 *Saturated zone thickness & extent*

The most usable groundwater resources for water supply are located in sorted gravel and sand formations, such as eskers and large end-moraine formations like Salpausselkä formations. Groundwater resources are unevenly distributed across Finland. Especially in the coastal area, gravel and sand formations are small in area and located partly under large layers of unpermeable clay. In Finland the average groundwater area is only 1–2 km^2 and the thickness of the saturated zone is about 10 meters. (*Britschgi et al. 2018*)

The Saturated zone thickness was calculated with formula:
[“DEM” (*National Land Survey of Finland*) minus “Unsat Thickness”] minus “Bedrock surface elevation” (*GTK 2020*)

If the calculated value was less than six meters, the cells containing aquifer received a value of 6 (meters) based on the expert judgement.

The Saturated zone extent is the same as the Unsaturated zone extent.

3.2.3 Hydrogeofacies

All of the classified aquifers in Finland are eskers which have gravel core surrounded with layers of sandy material. Therefore, all aquifers were classified as “Alteration of Unconsolidated sedimentary hydrogeofacies” based on the generalization and expert judgement (See https://www.geologia.fi/2019/12/11/pohjavesi/).

3.2.4 Geological age

Finnish aquifers date back to Quaternary period (See https://www.geologia.fi/2018/05/21/maaperan-synty/).

3.2.5 Layer type

For the aquifer types, a simple classification was used: in Finland all groundwater areas (mainly eskers) are aquifers If the cell contains classified groundwater formation the cell is classified as an aquifer. Otherwise the cell has no value. (See Finnish Environmental Institute https://www.avoindata.fi/data/en_GB/dataset/pohjavesialueet).

3.2.6 Aquifer type

In Finland all aquifers are unconfined; groundwater is directly recharged, for example by rainfall or snow melt. (See https://www.geologia.fi/2019/12/11/pohjavesi/).

3.2.7 Hydrological parameters

All the used hydrological parameters are based on the Hydrogeofacies list provided by RESOURCE project, literature and expert judgement.

For porosity a value of 0.4 was used. It is a lower limit in the Hydrogeofacies list and a median value for gravel in Finland based on *Airaksinen, J.U. 1978*.

For anisotropy a value of 2 was used as it corresponds to anisotropy value for coarse materials like gravel. (*Airaksinen, J.U. 1978)*

For hydraulic horizontal conductivities a value of 864 (m/day) was used based on the expert judgement and values from the Hydrogeofacies list.

3.2.8 *Artesian/Paleo/Thermal*

Expert judgement for artesian wells based on a study: *Lahermo et al. 1999. One thousand wells – the physical-chemical quality of Finnish well waters in 1999.* (See https://www.ymparisto.fi/download/noname/%7BD511CB71-0A6E-4559-A174-96E26E96AA71%7D/57054) and marked artesian water into a 10x10 km cell only if the area is also a groundwater area.

No Paleo (over 10 000 years old) nor Thermal groundwaters are present in Finland at the depth range of the active groundwater zone.

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GeoERA
RESOURCE GROUNDWATER

Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata France

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the French template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for France was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Generally, the French template is filled by using hydrogeological models which describe the subsurface in vertically stratified units in great detail. Therefore, upscaling was necessary to simplify the model by limiting the maximum amount of layers included in the template, even if numerous superimposed layers are described in Aquitanian and Parisian sedimentary Basins, both considered to be the biggest groundwater resources of the territory. The upscaling was performed based on a combination of stratigraphic/lithological information and thresholds values on thickness and transmissivities for aquifers.

The resulting final dataset is geographically limited to the major sedimentary basins where 5 hydrogeological models (Nord-Aquitanian basin, Poitou-Charentes, Normandie, Chalk in Nord-Pas de Calais and Albian in Parisian basin) and 2 geological models (Centre and Parisian basin) were available as source of data to fill in the grid. The entire extent corresponds to 1/3 of French inland territory. Some of these models are currently included into the national modelling platform Aqui-FR1.

Mountainous and intensely folded areas are not described in the grid due to lack of information.

Other parameters were filled using a combination of model results, information available in the Aquifer reference system BDLISA2, references to background information and expert judgement.

[1] Aqui-FR : http://www.geosciences.ens.fr/recherche/projets/aqui-fr

[2] Base de Données des Limites des Système Aquifères, https://bdlisa.eaufrance.fr/

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the BD ALTI® dataset of IGN	https://geoservices.ign.fr/documentation/donnees/alti/bdalti https://geoservices.ign.fr/sites/default/files/2021-07/IGNF_BDALTIr_2-0.html
Total_depth_active_layers	Hydrogeological base, as determined in the 7 hydrogeological models available	See literature for each models chapitre 4 + http://www.geosciences.ens.fr/recherche/projets/aqui-fr
Unsaturated zone thickness and extent	For hydrogeological models, determined from piezometric head simulated for the period 2000-2010 and layer total thicknesses & extent For superficial aquifers in geological models, determined from the average unsaturated zone thickness grid. For other aquifers in geological models, based on literature and available piezometric data from ADES database	See literature for each models chapitre 4 + http://www.geosciences.ens.fr/recherche/projets/aqui-fr Allier *et al.* (2018) https://ades.eaufrance.fr/
Saturated zone thickness and extent	For hydrogeological models, determined from piezometric head simulated for the period 2000-2010 and layer total thicknesses & extent For other, determined from unsaturated thickness already calculated and layer total thickness	See literature for each models chapitre 4 + http://www.geosciences.ens.fr/recherche/projets/aqui-fr
Hydrogeofacies	Hydrogeofacies are based on layer types described in the literature of each models	See literature for each models chapitre 4 + http://www.geosciences.ens.fr/recherche/projets/aqui-fr
Geological age	Based on known ages of formations which form the layers, when combining layers the youngest age is taken	See literature for each models chapitre 4 + http://www.geosciences.ens.fr/recherche/projets/aqui-fr
Layer type	Layers as described in the hydrogeological models are labelled as aquifers/aquitards, based on kD and c values mostly. Elsewhere, based on BDLISA dataset and background literature	See literature for each models chapitre 4 + http://www.geosciences.ens.fr/recherche/projets/aqui-fr Roux *et al.* (2006) Brugeron *et al.* (2018) + https://bdlisa.eaufrance.fr/
Aquifer type	Based on literature information available for each models. If no information, based on BDLISA dataset and background literature.	See literature for each models chapitre 4 Roux *et al.* (2006) Brugeron *et al.* (2018) + https://bdlisa.eaufrance.fr/
Hydrological parameters	Based on model values, general literature and/or expert knowledge. kh and kv values calculated from model kD and c values, porosity and anisotropy based on background literature or expert knowledge.	See literature for each models chapitre 4 Roux *et al.* (2006)
Artesian/Paleo/Thermal	Only very scattered information, no national datasets available, not filled in attributes.	

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in France is available as a DEM (Digital Elevation Model) through the IGN (Institut national de l'information géographique et forestière). The version that was used for this project is the BD ALTI®, which has a resolution of 25 m and is available as open data to the public (see https://geoservices.ign.fr/bdalti#telechargement). For the use in the Pan-EU groundwater resources map, the average value of the altitude of the surface level was calculated for each 10x10 km grid cell from the original BD ALTI® dataset.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

For France, the total depth of the active zone is defined by one unique type of boundary, the top of the hydrogeological base. This hydrogeological base is defined as a layer with very high vertical resistances, where downward flow is basically absent. The top of this layer is defined by different hydrogeological units in each hydrogeological models. Part of these models are aggregated in the Aqui-FR hydrometeorological modelling platform (http://www.geosciences.ens.fr/recherche/projets/aqui-fr), an important source of information for the Pan-EU groundwater resources map. The average value of the top of this layer was calculated for each 10x10 km grid cell.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

For the calculation of the average thickness of the unsaturated zone, three different methods were carried out, depending on the type of data available.

For areas where hydrogeological models are available, piezometric head was simulated for the period 2000-2010 except for Albian model for which average piezometric head simulated for the entire period available was considered. Then the unsaturated zone thickness were determined by subtracting the saturated thickness (see calculation section 3.2.2) from the layer total thickness. The resulting values were then averaged for each 10x10 km grid cell. Note that, in some places, this method was carried out for several superimposed unconfined aquiferous layers (Aquitanian and Parisian basins).

For superficial aquifers identified in geological models (no piezometric data available), dataset calculated by BRGM (Allier *et al.*, 2018) was used: the national grid of mean unsaturated zone thickness which considered only the uppermost unconfined aquifer and cover the entire country (except mountainous and intensely folded areas). The datasets was averaged for each 10x10 km grid cell to get to the average groundwater level and thus the thickness of the unsaturated zone. All these resulting values are mostly included in the first layer of the French dataset.

For deeper unconfined aquifers identified in geological models (no piezometric data available), the averaged unsaturated thickness was determined based on literature combined with available piezometric data from ADES database.

The extent correspond to the total surface of initial cells with unsaturated thickness superior to 0 divided by 100 (surface in km² of one grid cell).

Except for karstified formation (set at K), the unsaturated zone dynamics was generally set at N (or Naturally seasonal variability) for all cells in France: although the unsaturated zone is impacted by groundwater depletion by pumping, and locally there is still recovery after mining, it is not significant enough on a 10x10 km scale.

3.2.2 Saturated zone thickness & extent

Most of the work into filling the French template for RESOURCE WP6 went into determining the thicknesses of the saturated layers.

For areas where hydrogeological models are available (see references in section 4), the information on the saturated layers is based on the piezometric head that was simulated for the period 2000-2010 (except for Albian model for which average piezometric head simulated for the entire period available was considered). Then the saturated zone thickness were determined by subtracting the piezometric head from the top of the substratum. An important intermediate step was to aggregate these regional hydrogeological models made for different purposes, at different period of time and at different resolution, into one unique and homogeneous template. The most difficult task was to analyse overlapping areas between 2 or 3 models in some areas and to define some rules to combine these different (and sometimes conflicting) information consistently.

Moreover, some of these models have more than 10 superimposed layers (i.e. 28 layers for Nord-Aquitanian model) which is too detailed for the purpose of the RESOURCE WP6 Pan-EU groundwater map, where we aimed to limit the maximum number of units to a reasonable number of layers. During the analysis of such detailed models, attemps were made to reduce their complexity by schematizing the many hydrogeological units into aquifers and aquifers, combining units together based on their hydrogeological characteristics (i.e. equivalent transmissivity for aquifers, equivalent vertical hydraulic resistance for aquitards) or sometimes removing layer with insufficient thickness or extent compared to the 10kmx10km grid cell. Also, layers were only added together if they had similar hydrogeofacies, see the next section for more info. Despite this effort, the upscaling as described above resulted in a limited reduction of described units, in particular in major sedimentary Aquitanian and Parisian basins, where important resources are identified in very deep aquifer formations, separated from each other by important aquitard layers.

For other layers identified in geological models (no piezometric data available), the information on the saturated layers is based on the unsaturated thickness already calculated (see section 3.2.1) and the layer total thickness.

3.2.3 Hydrogeofacies

The hydrogeofacies was mostly determined based on the literature available for each models. Described aquifers for the Pan-EU map are very diversified and, if we look at a more local scale, the intrinsic lithology characterising each aquifer can be very often a combination of several different lithology. For the purpose of this project, it didn’t make much sense to distinguish each different layer based on their specific lithology at local scale since that would take significant time, while not providing much extra detail since the conductivities of the aquifers are included in the modelled layers at a regional scale geohydrological models, and don’t depend on the choice of the hydrogeofacies. As a consequence, Quaternary and Tertiary aquifers are mostly characterized as Alternation of unconsolidated sedimentary hydrogeofacies, Cretaceous and Triassic aquifers as Alternation of compact or fissured sedimentary hydrogeofacies” and Jurassic aquifers as Dual-porosity fissured limestone and dolomite, Fissured limestone and dolomite or Karstified limestone. Aquitards are mostly Clay, clayey loam, mud, silt, marls (Tertiary), Alternation of compact sedimentary hydrogeofacies (Cretaceous) or Siltstone, marlstone (Jurassic).

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations which make up these layers. In the template provided, geological ages generally range from Quaternary (uppermost layer) to Triassic. In Poitou-Charente, Normandie and Northern part of France (Lille-Tourcoing area), some Paleozoic undistinguished formations are also included in the template. When combining layers with different ages, the youngest age was taken for the entire layer.

3.2.5 Layer type

In areas where hydrogeological models are available, each layer can be intrinsically characterized as an aquifer or aquitard. Nevertheless, few simplification have been carried out to fit with the proposed list as described in document 6.2 (Kivits and Broers, 2020) because complex behaviour may be identified locally in models, i.e. layers locally impervious but globally aquifer.

For layer from geological models, an supplementary effort of characterization was made based on background literature on groundwater in France (Roux *et al.*, 2006) and on synthetic information implemented in the national aquifer reference system BDLISA (Brugeron *et al.*, 2018).

3.2.6 Aquifer type

For each cell coming from hydrogeological models, we looked at the simulated monthly hydraulic head time series over 2000-2010. Based on this source of information, the following methodology was applied:

- When the cell is always captive, “C” was assigned;
- When the cell is always unconfined, “U” was assigned;
- When the cell is alternatively captive and unconfined during this period, “SC” was assigned.

During the filling of the RESSOURCE grid, number of U, C and SC where counted for all the cells inside the polygon of 10 km of side, and the label having the maximum of cells was assigned to the final Resource grid cell. Note that unsaturated layers can be identified below aquitards.

Elsewhere, a simple classification was used for the whole extent of the layer, essentially based on background literature on groundwater in France (Roux *et al.*, 2006) and on synthetic information implemented in the national aquifer reference system BDLISA (Brugeron *et al.*, 2018).

3.2.7 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, and the anisotropy value) were determined based on hydrogeological model values available. Elsewhere, background literature and list of values proposed by hydrogeofacies in RESOURCE document 6.2 (Kivits and Broers, 2020) were used to fill in the template.

3.2.8 Artesian/Paleo/Thermal

For France, no artesian and thermal aquifers were characterized. Although there are artesian and thermal aquifers present in France but very scattered information are available, making very difficult the completion of the template.

Similarly, no national dataset compiling age-dating study results is available to systematically characterize water as paleo water or not. Due to this lack of synthetic information and the too important effort required to gather this information, this attribute was not fill in as well.

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http://sigessn.brgm.fr/

Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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1 INTRODUCTION AND GENERAL BACKGROUND

This report describes the methodology of harmonization of groundwater and geological data from Iceland as described in WP6 of the project “Resources of groundwater harmonized at cross-border and pan-European scale”. It is part of a GeoERA, an ERA-NET Co-fund action program that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166.

The RESOURCE project aims at demonstrating the potentials of the harmonization of information about Europe’s groundwater resources through cross-border demonstrations projects, through harmonized characterization approaches for Karst and Chalk aquifers and through a first information product at Pan-European scale where available data is compiled and integrated to produce a map of the fresh groundwater resources of Europe.

For this purpose, groundwater data from Iceland has been collected, harmonized and presented in the grid layers format provided (Hans P. Broers and Tano Kivits: Deliverable 6.2. Final template that will be used by all participating surveys to collect the required data, dated 15.1.2020). In the following report the metadata, models and approaches used for data fitting are described. As data regarding hydrogeology, groundwater and potable water are collected and stored at various entities in Iceland there has been some effort put into the collection of datasets.

2 OVERVIEW TABLE

Parameter	Short description (2/3 sentences)	Link/reference
Altitude_surface_level	DEM (Digital Elevation Model) through National Land Survey of Iceland's (Landmælingar Íslands, LMI) IS50V dataset. The dataset has a resolution of 20x20 m and is publicly available at the LMI website.	www.lmi.is
Total_depth_active_layers	Total depth from saturated surface level of fresh groundwater down to a level of combination between fresh-salt interface at 2,500 µS and cold-warm interface at 50°C. This equals to the thickness of layer 1 as defined.	Flóvenz and Sæmundsson, 1993. ISOR geothermal gradient model.
Unsaturated zone thickness and extent	A model showing depth to groundwater table is based on data from well measurements of water level, hydrogeological maps and locations of springs.	http://www.eurogeosurveys.org/projects/thermomap/
Saturated zone thickness and extent	Depth from groundwater table down to temperature of 50°C or salinity <2,500 µS/cm.	
Hydrogeofacies	The different facies in the RESOURCE WP6 Hydrogeofacies list were matched with the geological label assigned to different units on the Hydrogeological map of Iceland.	Hjartarson, 1980.
Geological age	The geological age is the same for all layers in each cell. The age is determined from the surface units as described in Geological maps by ÍSOR.	https://en.isor.is/geological-maps-geological-web-map www.jardfraedikort.is
Layer type	Based on expert judgement and uniform bedrock, all layers are labelled as AQF. Layer 1: Fresh cold groundwater temperature <50°C. Layer 2 (in cells close to shore): Warm groundwater from 50 to 200°C or saline water (subterranean sea) >2,500 µS/cm. Layer 3 (in cells where there is saline water: Warm groundwater 50–200°C.	
Aquifer type	Based on expert judgement all aquifers are as unconfined.	
Hydrological parameters	Values of hydraulic conductivity is assigned to different surface areas and this value is then assigned for the cell, not taking into account different values with depth. One of the main attributes affecting the permeability is the age and alteration of the basalt. The data used for Kh for each cell is based expert judgement of values for geological formations from the Icelandic Hydrogeological map.	Water Bodies of Iceland as defined by Environmental agency of Iceland. Hjartarson, 1980.
Artesian/Paleo/Thermal	A model based on heat flow presented as geothermal gradient is used to define the upper boundary at 50°C and lower at 200°C.	Flóvenz and Sæmundsson, 1993. ISOR geothermal gradient model.

3 DETAILED DISCRIPTION OF METADATA

Available hydrogeological data in Iceland was collected from various sources as well as results from research projects that ÍSOR has taken part in. These include the data listed below:

- Geological map of Iceland, bedrock (1:600,000). Árni Hjartarson and Kristján Sæmundsson (2014). Reykjavík: ÍSOR, Iceland GeoSurvey.
- DEM (Digital Elevation Model) through IS50V dataset of LMI. The dataset has a resolution of 20x20 m and can is publicly available at the LMI website (https://lmi.is/).
- Water Bodies of Iceland as defined by Environmental agency of Iceland to fulfilment of law 36/2011 and regulations 535/2011 and 935/2011 according to EU Water Framework Directive. (2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy).
- Permeability estimates based on the 6 different formations presented in hydrogeological definitions of Water Bodies. GIS coverage acquired from National Energy Athority (www.map.is/os) is based on the Hydrogeological map of Iceland (1:1,500,000). Árni Hjartarson (1980).
- Expert judgement of porosity by ÍSOR's hydrogeologists based on ÍSOR data, open source data and products of various projects.
- GIS model of groundwater level of Iceland, grid scale 5 x 5 km. Based on previous work from Thermomap EU project. GIS database of ÍSOR.
- Thermal gradient model of Iceland, grid scale 2.5 x 2.5 km. Based on previous work from NagTec EU project. GIS database of ÍSOR and Flóvenz and Sæmundsson, 1993.
- Map of springs and spring groups of Iceland. Report: Árni Hjartarson, Report ÍSOR-2018/090.
- Various databases of ÍSOR, including data on well logging analysis, temperature and salinity and chemical analysis of groundwater and geothermal water.
- Well registry of Iceland. National Energy Authority web portal (www.os.is).

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Iceland is available as a DEM (Digital Elevation Model) through Landmælingar Íslands (LMI) IS50V dataset. The dataset has a resolution of 20x20 m and can is publicly available at the LMI website (www.lmi.is). For the use in the Pan-EU groundwater resources map, the average value of the altitude of the surface level was calculated for each 10x10 km grid cell from an upscaled version of the IS50V DEM dataset with a grid resolution of 2500 m.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of active zone is defined by two boundaries in Iceland, the first being the fresh-salt groundwater interface (at 2500 µS/cm) and the second being the top of thermal interface (at 50°C). The temperature of 50°C was selected as the reference temperature by expert judgment based on the possibilities of direct use of the warm geothermal water.

In Iceland the low temperature geothermal water is generally of low TDS and for most areas can be used directly without risk of exceeding limits of any potable water standards.
The thermal boundary is the dominant factor of determining the lower level of fresh cold groundwater and no effort was put into defining a hydrogeological base. In general, there is permeability to be found down to 2500-3000 m depth in Iceland through active faults and this depth exceeds the depth to find fresh groundwater.

Some issues that occurred during the preparation and harmonization of the Icelandic hydrogeological datasets were identified as problematic as described in the following list:

- Different resolution of the available source data. Some dataset (for example the DEM) have very high spatial resolution whereas resolution of groundwater data is limited, both spatially and thematically.
- Geological 3D models in Iceland are generally only available at limited locations such as high temperature geothermal areas and volcanically active areas.
- Some hydrogeological models have been developed for limited areas in Iceland by private companies and this data is not available for this study.
- Long term monitoring of water level is scarce (for amplitude est.).

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The depth to the groundwater table in each cell is defined by using a Digital Elevation model to represent the surface elevation and a groundwater level model, based on data from well measurements, hydrogeological maps and locations of springs. This model is based on existing GIS layer produced for the Thermomap EU project. The value presented for each cell is calculated using the GIS models and each cell assigned one value. Due to the difference in the resolution of the DEM and the cell grid size, this can only be considered an approximation in areas where there is a variation in elevation in each cell.

The extent denotes the surface portion of the cell that is on land. Cells that are completely on land have the value 100% but cells intersected by the coastline are assigned a percentage with the use of GIS software. Thus, the cells that extend to the ocean have been re-evaluated and the appropriate % value assigned. Very few cells that intersected the coastline by less than 10% where omitted from the dataset.

3.2.2 Saturated zone thickness & extent

The value for saturated thickness in each cell is based on the depth from groundwater table to a level of a certain temperature (50°C) or salinity (<2,500 µS/cm).
The estimate for the temperature values is from a thermal gradient model for Iceland.
The estimate for the salinity values where conductivity exceeds 2500 µS/cm.
Two methods were used to determine locations and extent of the salinity level; conductivity measurements in wells (1) and saltwater intrusion predictions where data was not readily available (2).
(1): Wells in fissured basalt regions: Data from all wells where conductivity measurements have been performed were gathered, and those which indicate saline water with temperatures below 50°C were identified. These wells were nearly all in or next to fields predominantly covered by fresh (unaltered) fissured basalt. These fields

are on the Reykjanes-, Snæfellsnes- and Melrakkaslétta peninsulas. In some cases, the values were extended to a neighbouring field which was assumed to present very similar hydrogeological characteristics.
(2): Predictions in coastal gravel regions: Coastal gravel regions are assumed to contain saltwater intrusions to some extent, but due to lack of wells in these areas, conductivity measurements could not be relied on. Instead, saltwater intrusions along the coast were assumed to be in accordance with the Ghyben-Herzberg principal, of which the simplification is applied where the groundwater lens is assumed to extend down below sea level 40-fold the height of the groundwater table above sea-level (Fetter, 2018). The calculations rely on groundwater table elevation (GW_{Elev}) and elevation of the top thermal boundary of ($50°C_{Elev}$). These fields are exclusively in coastal gravel regions and located mainly on the south coast, with two locations in the north.

$$z = \frac{\rho_w}{\rho_s \rho_w} h \approx 40h$$

The Ghyben-Herzberg relation (above) for elevation of saltwater intrusion below sea level (z) depends on groundwater table elevation (h) and the density of the saline and fresh groundwater (ρ_s and ρ_w)

$$L2_h = -(GW_{Elev} * 40) - 50°C_{Elev}$$

Based on elevation of groundwater table and temperature gradient models, the latter equation was used to predict the thickness of Layer 2, as the saline layer. All values ≤ 0 were removed, leaving only locations with positive values for the vertical extent of Layer 2.

Extent is the same value as “Unsaturated extent”. Cells that are completely on land have the value 100% but cells intersected by the coastline are assigned a percentage with the use of GIS software. Thus, the cells that extend to the ocean have been re-evaluated and the appropriate % value assigned.

3.2.3 Hydrogeofacies

The different facies assigned by RESOURCE template were matched with the geological units on the Hydrogeological map of Iceland (Hjartarson, 1980) (Table 1, Figure 1). The following table shows the units respectively as well as the colours assigned accordingly.

Table 1. *Groups of geological formations from Hydrogeological map (Hjartarson, 1980) compared to the hydrogeofacies of RESOURCE (Kivits, 2020) and accompanying UNESCO numbering.*

Hydrogeolocial map Árni Hjartarson 1980 - Legend	RESOURCE WP6 Hydrogeofacies	Unesco
Extensive and highly productive intergranular aquifers	Gravel	5
Local or discontinuous intergranular aquifers or extensive but only moderately productive intergranular aquifers	Lava	40, 41
Extensive and highly productive fissured aquifers, including karst aquifers	Lava	40, 41
Local or discontinuous fissured/karst aquifers or extensive but only moderately productive fisstured/karst aquifers	Fissured basalt	41
Minor aquifers with local and limited groundwter resources	Fissured basalt	41
Strata with essentially no groundwater resources	Fissured igneous and metamorphic rock	42-50

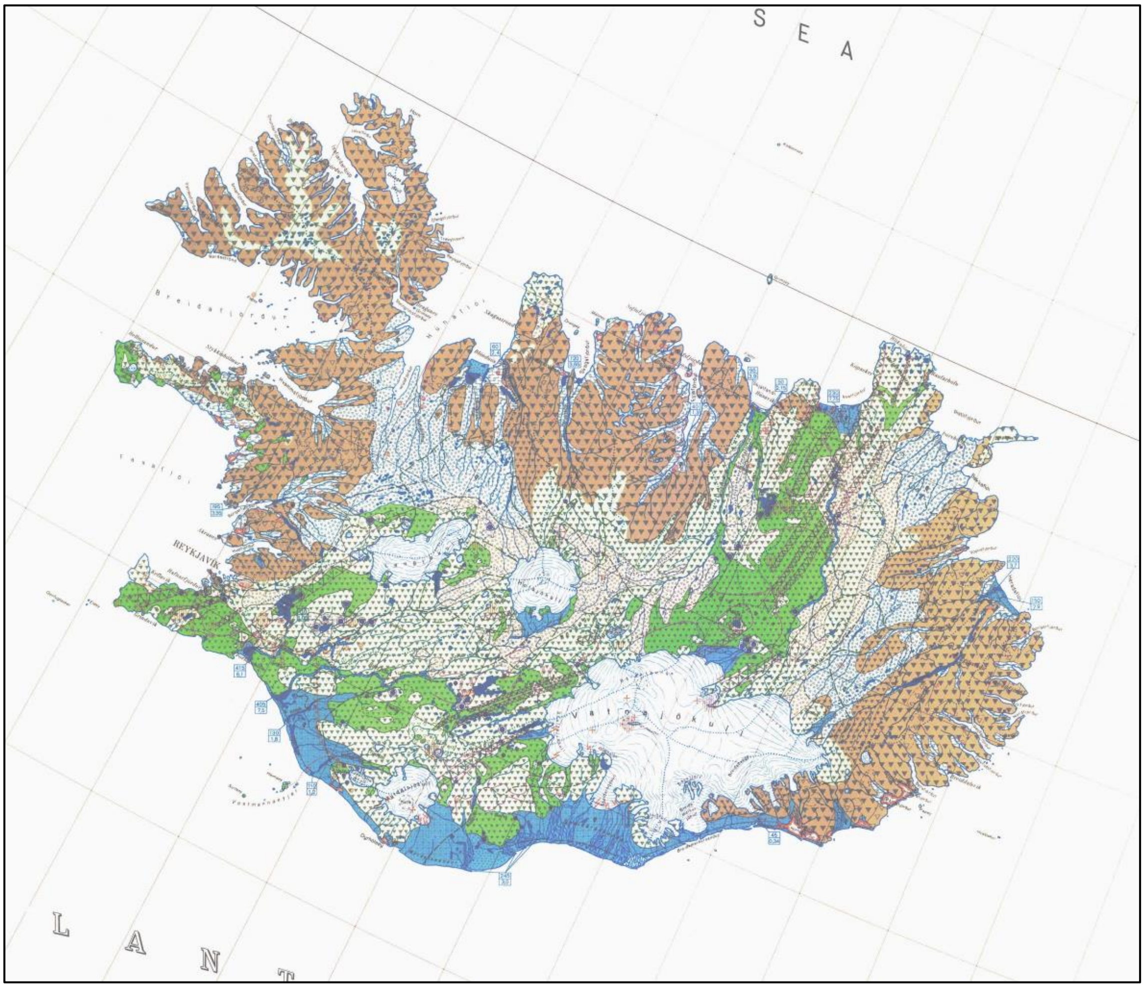

Figure 1. Hydrogeological map of Iceland (Hjartarson, 1980).

3.2.4 Geological age

The geological ages for the layers in each cell is assigned from the age of surface bedrock from Geological maps by ÍSOR (Figure 2. The grid of 10 x 10 km is superimposed onto the 1:600.000 geological map of Iceland (Hjartarson and Sæmundsson, 2014). The maps divide the surface into units of Tertiary and Quarternary ages as presented in maps of scale 1:100.000 and 1:600.000 (www.jardfraedikort.is). The same geological age is estimated for all layers in each cell as approximation as geological models that define different ages for different formations at depth are only available for few areas.

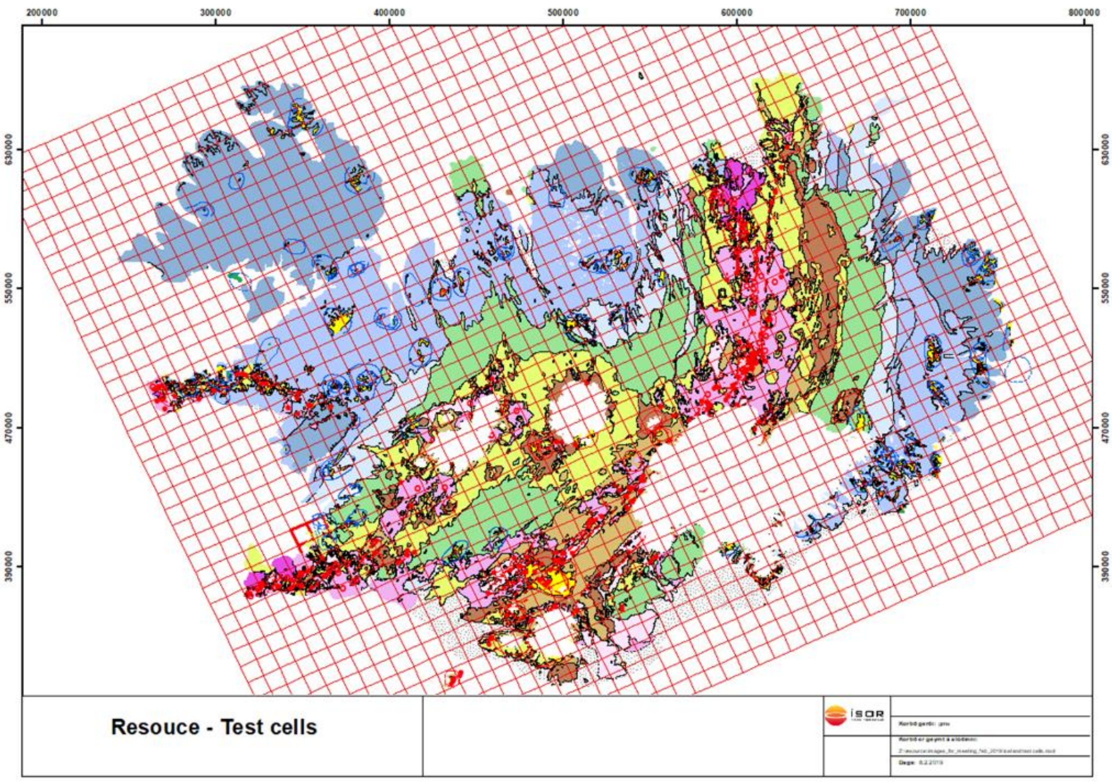

Figure 2. The grid of 10 x 10 km is superimposed onto the 1:600.000 geological map of Iceland (Hjartarson and Sæmundsson, 2014).

3.2.5 Layer type

Due to the unique geological conditions in Iceland in comparison to Europe, there are some challenges in harmonizing the groundwater data and layers to what has been established as the format for the pan-Europe presentation. High thermal gradient in large areas of Iceland limit the vertical extent of groundwater bodies.

The bedrock of Iceland is very uniform, comprising of mainly basaltic lava flows or hyaloclastite, varying in age and alteration. It is mainly these components that affect the hydrological properties of the bed rock and the permeability of the water bodies is based on surface geological mapping. Very limited information exists in the form of cross sections or 3D groundwater models. However, drilling and utilization of groundwater resources have revealed that permeability within geothermal resources is mostly fault/fissure controlled whereas permeability of cold groundwater resources is mostly controlled by primary permeability. In this project, it is assumed that the permeability is uniform down to the depth of where temperature reaches 200°C according to thermal gradient.

Three types of groundwater are defined in this project as listed below and the thickness of the layers in each cell are calculated/estimated according to these definitions:

Layer 1: Fresh cold groundwater temperature <50°C.

Layer 2 (in cells close to shore): Warm groundwater from 50 to 200°C or saline water (subterranean sea) >2,500 µS/cm.

Layer 3 (in cells where there is saline water): Warm groundwater 50–200°C.

3.2.6 Aquifer type

The uniform bedrock of Iceland consists of mostly of basaltic lava and hyaloclastite where porosity and permeability of the formations is mainly dependant on the age and alteration of the rock. It is therefore concluded that the label for all cells is AQF which is the type for aquifers. This choice results in the vertical permeability being equal to the horizontal permeability, but values are provided for the horizontal permeability as well as porosity as described in chapter on hydrological parameters.
Based on the same assumptions as for the layer type the type of the aquifer for each cell is uniformly assigned the value “U” for Unconfined.

3.2.7 Hydrological parameters

The values assigned for the conductivity in the table are based on the Hydrogeologic map of Iceland 1:1.500.00 which was also the main reference for the Water bodies coverage (prepared by Orkustofnun for the Environmental Agency of Iceland – the Water Bodies Coverage). Values of hydraulic conductivity is assigned to different surface areas and this value is then assigned for the cell, not taking into account different values with depth. One of the main attributes affecting the permeability is the age and alteration of the basalt. As geological models are not available for most of Iceland, this method is applied as a first assumption.

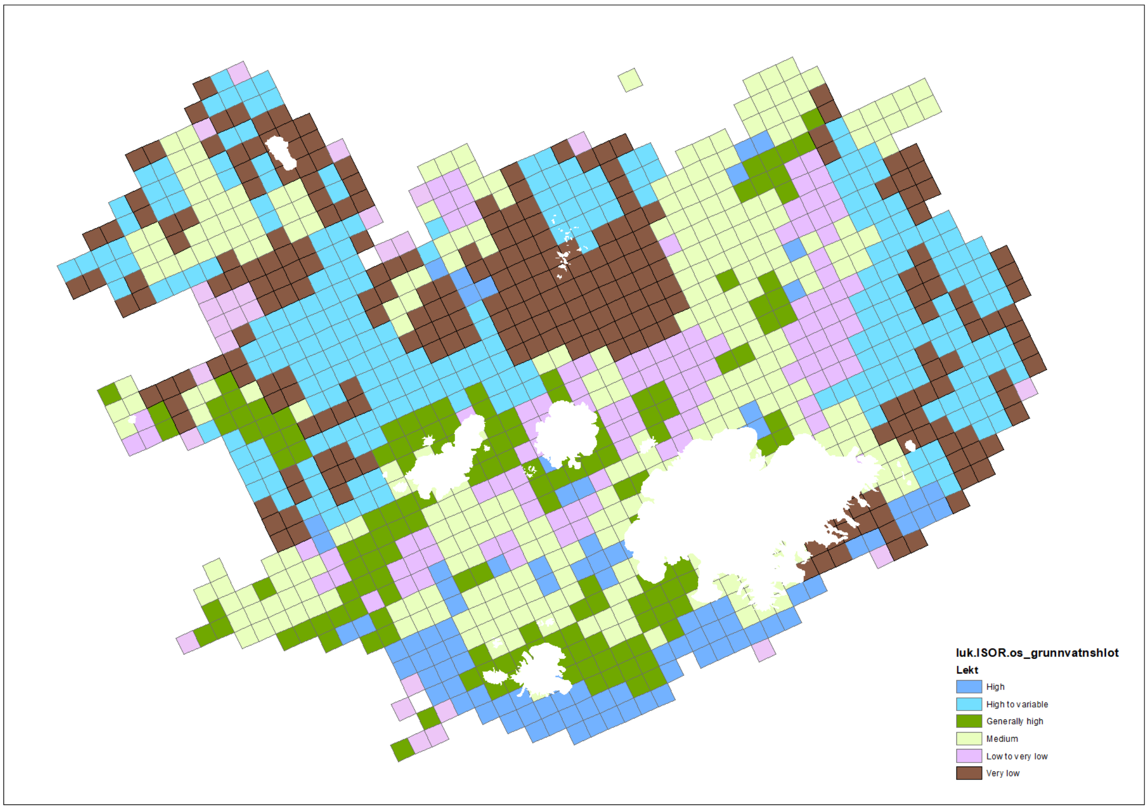

Figure 3. Permeability as assigned to cells based on the hydrogeological map (Hjartarson, 1980).

The data used for Kh for each cell is based on hydrogeofacies presented in the Resource WP6 Hydrogeofacies list after matching with the geological formations from the Icelandic Hydrogeological map (Hjartarson, 1980). The following table describes the relationship between the geological formations and the Kh values used which are based on expert judgement of ÍSOR.

Table 2. Values of hydraulic conductivity (Kh) for different geological formations based on the formations of Water bodies and hydrogeological map of Iceland (Hjartarson, 1980).

Hydrogeolocial map Árni Hjartarson 1980 - Legend	RESOURCE WP6 Hydrogeofacies	Hydraulic conductivity (m/day)
Extensive and highly productive intergranular aquifers	Gravel	70
Local or discontinuous intergranular aquifers or extensive but only moderately productive intergranular aquifers	Lava	80
Extensive and highly productive fissured aquifers, including karst aquifers	Lava	80
Local or discontinuous fissured/karst aquifers or extensive but only moderately productive fisstured/karst aquifers	Fissured basalt	7,0
Minor aquifers with local and limited groundwter resources	Fissured basalt	7,0
Strata with essentially no groundwater resources	Fissured igneous and metamorphic rock	0,5

The layers type of conductivity is labelled AQF in the template for Iceland. The Kh is the effective horizontal conductivity, representative of the whole grid cell and layer thickness. Based on the anisotropic factor being generally assumed to be 1, the value of Kv is the same as for Kh.

As outlined above, permeability within geothermal resources is mostly fault/fissure controlled whereas permeability of cold groundwater resources is mostly controlled by primary permeability. In water bodies where primary permeability is controlling the hydraulic properties of the bedrock, Kv and Kh is assumed to be the same, both on large and small scale. In layers where the permeability is fault controlled, expert judgement is used to justify isotropic condition (Kv = Kh) at the cell scale used in this project.

3.2.8 Artesian/Paleo/Thermal

For Iceland there are no paleo or artesian aquifers characterized. Although artesian aquifers are present, they are not significant for the 10x10 scale of the cells.
Thermal waters are abundant in Iceland and actually dominant in defining lower boundaries of fresh groundwater in all cells. A model based on geothermal gradient is used to define the upper boundary of the thermal groundwater at 50°C and lower at 200°C.

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Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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Table of Contents

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Irish template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resource Map). It provides the background information on how the template for Ireland was filled in, what data were used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in Chapter 3 where each parameter is described in detail, giving the process behind filling that parameter and describing the background of the data.

As no national 3D geological or hydrogeological models were available during the project, the Irish template was filled using a combination of expert judgment, Geological Survey Ireland (GSI) datasets such as aquifer, bedrock, and Quaternary geological maps, and groundwater vulnerability maps. The layers in a grid square are modelled as rectangular blocks, with aquifer types present in the grid square being assigned to different layers based on stratigraphic order. The conceptual model for bedrock aquifers in Ireland comprises a shallow, more fractured and more permeable zone, underlain by a deeper less fractured and less permeable zone. Therefore, the simplest grid square comprising one aquifer type would always consist of two layers. Other parameters were filled using a combination of GIS layers, references to background information/scientific literature/academic research, and expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from a digital terrain model for the Republic of Ireland produced by Ordnance Survey Ireland. Resolution of model: 5 m Date accessed: 11/2019	Ordnance Survey Ireland Licence No. EN0047221 © Ordnance Survey Ireland/Government of Ireland https://www.osi.ie/products/professional-mapping/height-data/
Total_depth_active_layers	Based on local and regional data and expert knowledge.	
Unsaturated zone thickness and extent	Determined through a combination of analysis of water strikes from borehole and drilling logs, and expert knowledge.	
Saturated zone thickness and extent	Determined through a combination of analysis of water strikes from borehole and drilling logs, data from the Irish Aquifer parameters database, expert knowledge and scientific literature.	Kelly *et al., 2015* https://www.gsi.ie/en-ie/publications/Pages/IrishAquifersPropertiesAreferencemanualandguideVersion10March2015.aspx
Hydrogeofacies	Hydrogeofacies are based on the hydrostratigraphic rock unit groups map produced by the GSI, the national sand and gravel aquifer map, and the GSI vulnerability map.	Rock unit groups: https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#RUG Sand and Gravel aquifer map: https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Aquifers Vulnerability map: https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Vulnerability
Geological age	Based on known ages of formations which form the layers. When combining layers, the age of the unit which occupies the greatest proportion of a grid square is taken.	
Layer type	Layers are labelled as aquifers/aquitards based on expert judgment and with reference to the GSI aquifer and vulnerability maps.	Bedrock aquifer map: https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Aquifers Vulnerability map: https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Vulnerability
Aquifer type	Based on expert knowledge: aquifers above first aquitard = unconfined, all aquifers below first aquitard = semi-confined or confined	
Hydrological parameters	Mostly based on a bulk analysis of well logs, the Irish Aquifer Parameters database and expert knowledge.	Kelly *et al., 2015* https://www.gsi.ie/en-ie/publications/Pages/IrishAquifersPropertiesAreferencemanualandguideVersion10March2015.aspx
Artesian/Palaeo/Thermal	Artesian and thermal waters are determined by expert knowledge and background research. No palaeo waters are included for the Irish groundwater resource map.	

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Ireland is available as a digital terrain model (DTM) through the Ordnance Survey Ireland (OSI). The resolution of the model is 5 m and the version used for the RESOURCE project was accessed November 2019. For more information, please follow the provided link https://www.osi.ie/products/professional-mapping/height-data/. For the use in the Pan-EU groundwater resources map, the average value of the altitude of the surface level was calculated for each 10 x 10 km.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active fresh groundwater zone is defined as the top of the hydrogeological base which was determined by expert knowledge. Generally, the depth of an active fresh groundwater zone is related to the age of the aquifer or the aquifer types occupying that grid cell, or a combination of both. If a range of aquifer types and ages occupy a grid square, then the total depth of the active layers is taken as the aquifer with the deepest active fresh groundwater zone.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

To explain how the unsaturated zone thickness was determined, an understanding of the conceptual model for bedrock aquifers in Ireland is necessary. The conceptual model comprises a more fractured and more permeable shallow bedrock zone that graduates into a less fractured and less permeable deeper bedrock zone below it. For the RESOURCE project, the shallow bedrock zone ranged in thickness from ~30 – 40 m, with the deep bedrock zone typically ranging from ~160 – 370 m thick. However, this does vary in some grid cells when available data indicate otherwise.

The unsaturated zone thickness is the thickness of the aquifer minus the mean water level in the aquifer. Therefore, to determine the unsaturated zone thickness the GSI groundwater levels database was analysed. Water levels were assigned to aquifer types and further sub-divided into altitude groups with 50 m intervals (from 0 – 50 m, > 50 – 100 m etc.), from which a mean water level was calculated.

Due to a lack of national 3D geological or hydrogeological models, layers are modelled as rectangular blocks. Therefore, the extent of the unsaturated zone is determined by the extent of the aquifer at the surface as defined by the GSI aquifer map.

The unsaturated zone dynamics was set at N (or Natural seasonal variability) for most cells in Ireland. Cells with karst aquifers were set as K (or Karst systems with seasonal groundwater level fluctuation), and two cells are marked with P to signify groundwater depletion by pumping. Cells have only been marked with K or P when these conditions are known to the GSI.

3.2.2 Saturated zone thickness & extent

Due to a lack of available data pertaining to saturated zone thicknesses in Ireland, a simplified process to determine the saturated zone thickness was used, which is based on expert knowledge and academic literature. The process was two-fold: first, the total thickness of an aquifer layer was estimated; then, the mean water level for the unit was subtracted from the total thickness, giving the total saturated thickness of the layer.

The total thickness of the aquifers was based on the conceptual models for the different aquifer categories and rock unit group, unless site-specific information was available. The conceptual models are based on interpretations of local and regional data for different aquifers and rock unit groups. In general, the total thickness of bedrock units is related to the age and type of aquifer, with the older bedrock being less permeable at depth than younger rocks. Bedrock which is generally unproductive except for local zones (Pl aquifers), and bedrock of Ordovician age or older were assigned a total thickness of 200 m. Carboniferous units (excluding Rkc aquifers) and Devonian (Ll) aquifers were assigned a total thickness of 400 m. The total thickness of the unit known as the Kiltorcan-type sandstone (Rf) aquifer was determined through academic literature and varies depending on geographical location. For karst limestone (Rkc), the total thickness was taken as the vertical distance between the elevation of the surface of the aquifer and 200 m below sea level.

Modelling the extent of the saturated zone followed the same approach as modelling the extent of the unsaturated zone.

3.2.3 Hydrogeofacies

Bedrock hydrogeofacies were determined using the GSI hydrostratigraphic rock unit group map as reference. This Hydrostratigraphic Rock Unit Groups map is a reclassification of the 1:100,000 bedrock geology stratigraphy into 27 'Rock Unit Group' categories that, within a category, have similar hydrogeological properties over either the whole country, or a region.

Quaternary sand and gravel aquifers in Ireland typically comprise a variety of sediments, from fine, medium, and coarse sands to gravels. Classifying individual gravel bodies by their dominant sediment type would have been too time consuming and too granular for a 10 x 10 km grid square resolution. Therefore, for the purpose of the RESOURCE project, all sand and gravel aquifers are classified as gravels.

Other Quaternary deposits characterised in the Irish groundwater resource map are 'impermeable' units which act as aquitards — clay-dominated glacial tills, lacustrine deposits, and peat. The GSI groundwater vulnerability map was the primary reference material for these units. Tills, lacustrine sediments, and peats were included as layers to the resource map only in areas marked as "low vulnerability" on the GSI vulnerability map. Such areas roughly equate to ≥ 10 m thickness of low permeability glacial tills, lacustrine sediments, or peats. Furthermore, the low vulnerability area had to be relatively continuous coverage and comprise ≥ 25% surface area of the grid square.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations which comprise these layers. Most of the layers in the Irish resource map are bedrock which range from Precambrian to Carboniferous age. There are only very small areas of Permo-Triassic age, and no significant occurrences of younger deposits. A given bedrock aquifer category within a grid square can comprise two or more different hydrostratigraphic rock units with varying geological ages. Therefore, the age of the rock unit which comprised the greatest proportion of the aquifer type in that grid square was taken. The Quaternary period left behind a layer of protective glacial till and peat bogs over much of the landscape and, in localised areas, glaciofluvial sands and gravels aquifers provide potable groundwater.

3.2.5 Layer type

Layer types were determined using expert knowledge and the following aquifer categories and types as defined by the GSI:

Regionally Important (R) Aquifers:

- Karstified bedrock (Rk)
    - Karstified bedrock dominated by conduit flow (Rkc)
    - Karstified bedrock dominated by diffuse flow (Rkd)
- Fissured bedrock (Rf)
- Extensive sand & gravel (Rg)

Locally Important (L) Aquifers:

- Sand & gravel (Lg)
- Bedrock which is Generally Moderately Productive (Lm)
- Bedrock which is karstified to a limited degree or limited area (Lk)
- Bedrock which is Moderately Productive only in Local Zones (Ll)

Poor (P) Aquifers:

- Bedrock which is Generally Unproductive except for Local Zones (Pl)
- Bedrock which is Generally Unproductive (Pu)

Most bedrock units and all sand and gravel deposits were classified as aquifers in the RESOURCE project. Bedrock which is generally unproductive (Pu) were classified as aquitards, along with non-aquifers glacial tills, lacustrine sediments, and peats.

3.2.6 Aquifer type

Classifying aquifer types was based on expert judgment, using a relatively simple classification system:

- If the first aquifer is above an aquitard, it was classified as an unconfined aquifer.
- If there is between 40-80% of subsoil coverage in a grid square (glacial till or peat), aquifers below this are classified as semi-confined.
- Generally, if there was >80% subsoil coverage then the aquifer would be classified as confined. However, this was considered on a case-by-case basis.

- All aquifers below a bedrock aquitard (Pu bedrock) are classified as confined.

There are a handful of select cases in which aquifers have been classified as confined which do not qualify with the criteria outlined above, such as the Kiltorcan-type sandstones. These cases were informed by literature and expert knowledge.

3.2.7 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, and the anisotropy value) were determined based on a combination of expert judgement and bulk analysis of aquifer transmissivities, hydraulic conductivity and storage parameters collected during groundwater studies and well tests.

Horizontal conductivities (kH) for bedrock aquifers were estimated by analysing water strikes (the depths at which a significant volume of water is intersected during borehole drilling), which provided an estimate for thicknesses of the shallow bedrock and deep bedrock zones. Then, the kH of the shallow and deep bedrock were calculated by dividing a representative transmissivity value by the relative bedrock thickness. All remaining vertical and horizontal hydraulic conductivities were determined by expert judgment. Porosity values were approximated from specific yield values provided by the Irish Aquifer Parameters database.

Finally, an anisotropy value of one was assigned to all aquifers. We acknowledge that this is likely to be inaccurate, as groundwater flow in all of the fractured aquifers is strongly structurally-controlled, and especially for karst aquifers dominated by conduit flow (Rkc). However, aquifer anisotropy is an area which requires further research in Ireland.

3.2.8 Artesian/Palaeo/Thermal

Grid squares have been labelled as artesian or thermal water aquifers when the presence of these conditions is known. If a grid square has been labelled with artesian or thermal waters, it generally refers to a localised area within that square that exhibits these properties, rather than the whole grid square. Cells given the thermal water label are ones that had available temperature data and, therefore, it is possible some cells will be missing from the Irish resource map due to a lack of available data. Generally, these are cells with warm springs. If multiple warm springs occupied the grid square, the spring with the highest temperature was recorded in the template. Warm springs are characterised where the mean annual temperature is greater than 12 °C, which is elevated with respect to the average Irish groundwater temperatures (10 °C to 11 °C) (Blake *et al.,* 2015). No cells have been characterised with palaeo waters.

3.2.9 Limitations of use and disclaimer

We acknowledge that the processes outlined above are relatively simplistic and likely do not capture nuances or heterogeneity of aquifers. However, given the national scale of the output, the 10 x 10 km resolution of the grid squares, and the lack of relevant data, and time and resource restrictions, this was the appropriate solution. This project has been invaluable in highlighting knowledge gaps and providing ideas for areas of future research.

DISCLAIMER

The Geological Survey Ireland makes no representations, warranties, or undertakings about any of the information provided on these maps including, without limitation, their accuracy, their completeness or their quality or fitness for any particular purpose.

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Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Piemonte region (Italy) template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for the Piemonte region was filled in, what data were used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick glance on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

In particular, the Piemonte region template is compiled by using mainly hydrogeological models which describe the subsurface in vertically stratified units on the three main fresh-water reservoirs in Piemonte, the Savigliano and Alessandria Basins, to the south, and the western termination of the Padane Basin to the north, and enlarges the investigations down to 1500-2000 m depth, still unexplored for fresh water research purposes.

The approach adopted to define the hydrostratigraphic framework of the fresh-water aquifers, was based on the reconstruction of the 3D stratigraphic regional framework, through integration of subsurface and surface data, and implementation of a conceptual methodology, suitable to assign hydrogeologic values to the recognized stratigraphic units.

Other parameters were filled using a combination of model results, references to background information and expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	The DTM covers the entire regional territory and was acquired with a uniform methodology (LIDAR) in level 4 standards. The resolution of the grid (step) is 5 m, with an altitude accuracy of ± 0.30 m (± 0.60 m in the of lesser precision, corresponding to wooded and densely urbanized areas)	http://www.geoportale.piemonte.it /geocatalogorp/?sezione=mappa
Total_depth_active_layers	Based on the integration of core and geologic data (i.e.: depositional systems, lithofacies associations and present day position of Aquifer Groups), it was not supported by hydrogeologic data.	Irace et al. 2009 and 2010
Unsaturated zone thickness and extent	Obtained from WMS service hydrogeology data of the Regione Piemonte, acquired on a regional basis and at scales between 100,000 and 250,000. The data are property of the Piedmont Region and distributed through its Geographical Portal	http://www.geoportale.piemonte.it
Saturated zone thickness and extent	Determined from regional models based on the hydrostratigraphic scheme. It has been assumed that each synthem is conceptually equivalent to an "Aquifer Group". Each Aquifer Group is characterized by Hydrogeologic Units defined on the basis of lithofacies associations that display homogeneous hydrogeologic properties (e.g. permeability ratio, storage coefficient.	Regione Emilia Romagna and ENI-AGIP, 1998 and in Regione Lombardia and ENI-AGIP, 2002), Irace et al. 2010.
Hydrogeofacies	Hydrogeofacies are based on layer types. Generally: aquifers = gravels and medium sands, aquitards = clay	Irace et al. 2009 and 2010
Geological age	Based on known ages of geological formations	Piana et al. 2017a and 2017b https://urlsand.esvalabs.com/?u=https%3A%2F%2Fdoi.org%2F10.1080%2F17445647.2017.1316218&e=947aa8cb&h=357fc&f=y&p=n https://urlsand.esvalabs.com/?u=https%3A%2F%2Fwww.accademiadellescienze.it%2Fattivita%2Feditoria%2Fperiodici-e-collane%2Fmemorie%2Ffisiche%2Fvol-41-2017&e=6e5910a5&h=4ddbb351&f=y&p=n
Layer type	Layers as described in the regional models are labelled as aquifers/aquitards based on lithofacies associations that display homogeneous hydrogeologic properties (e.g. permeability ratio, storage coefficient)	Irace et al. 2009 and 2010
Aquifer type	Based on hydrostratigraphic model and expert knowledge:	Irace et al. 2009 and 2010
Hydrological parameters	Based on model values and expert knowledge	Irace et al. 2009 and 2010
Artesian/Paleo/Thermal	Not known	

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in the Regione Pieonte is available as a DEM (Digital Elevation Model) through the GeoPortale of Regione Piemonte. The version that was used for this project covers the entire regional territory and was acquired with a uniform methodology (LIDAR) in level 4 standards. The resolution used for this project has a grid (step) of 5 m, with an altitude accuracy of ± 0.30 m (± 0.60 m in the of lesser precision, corresponding to wooded and densely urbanized areas).

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active zone is defined by an integrated approach to define the hydrostratigraphic framework of the fresh-water aquifers. This was based on the reconstruction of the 3D stratigraphic regional framework, through integration of subsurface and surface data, and development of a conceptual methodology, suitable to assign hydrogeologic value to the recognized stratigraphic units.
The use of stratigraphic constraints (i.e. distribution of depositional systems and lithofacies associations) led to the reconstruction of the geometry of the fresh-salt water interface, also in those areas with scarce well data, and to better estimate the maximum thickness of deep fresh aquifers.
In particular, the hydrostratigraphic framework of the fresh-water aquifers has been obtained through stratigraphic analysis integration of subsurface and surface data. A grid of 17 seismic reflection lines partially published in Mosca et alii (2009) and Rossi et alii (2009), has been re-interpreted (Irace et al., 2009, 2010) for a linear coverage of about 750 km. Some stratigraphic logs of exploration wells (published in AGIP, 1972; AGIP, 1994), have provided a general calibration for seismic interpretation. Because of poor resolution of seismic data in the uppermost 100-200 m, the analysis of uppermost Quaternary deposits has been carried out through the stratigraphic correlations of about 6000 shallow wells, that have been made available by the Department of Earth Sciences of Torino University and Regione Piemonte. Correlation between subsurface and surface geology has been based on local field observations performed along the southern border of the studied basins and integrated with new biostratigraphic analyses, as well as on a critical review of some sheets of the geological maps of Italy:
The value of the top of this layer corresponds to the central value of each 10x10 km grid cell of the boundary level of 3D hydrostratigraphic regional framework model.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

For the calculation of the average thickness of the unsaturated zone has been obtained from WMS service hydrogeology data of the Regione Piemonte, acquired on a regional basis and at scales between 100,000 and 250,000. The information present is the property of the Piedmont Region; the metadocumentation and data are available through the Piedmont Geoportal (http://www.geoportale.piemonte.it). In particular, the data used in the project were: 1. the unsaturated zone thickness in the plain area (scale 1: 250,000); 2. the Piezometry of the surface

water (scale 1: 100.000) 3. the thickness of impermeable lithotypes in the unsaturated area (scale 1: 100,000); 4. Prevailing permeability of the unsaturated zone (scale 1: 100,000); 5. the Map of hydrogeological complexes (scale 1: 1: 100,000).
The value of this layer corresponds to the central value of each 10x10 km grid cell or averaged where present more values. Although in the unsaturated zone there is impacted by groundwater depletion by pumping, it is not significant enough on a 10x10 km scale.

3.2.2 Saturated zone thickness & extent

An integrated stratigraphic approach has been adopted to define the 3D hydrostratigraphic regional framework of the Regione Piemonte (Irace et al., 2009 and 2010).
In this project, the Aquifer Groups represent the "fundamental" hydrostratigraphic units, since they physically correspond to synthems, that have been recognized both in the subsurface and on rock outcrops. Each Aquifer Group is characterized by Hydrogeologic Units (HU) defined on the basis of lithofacies associations that display homogeneous hydrogeologic properties (e.g. permeability ratio, storage coefficient).
Four main typologies of Hydrogeologic Units have been distinguished, on the basis of their hydrogeologic role: HU I) unconfined aquifers, HU II) multi-layered "discontinuous" aquifers, HU III) multi-layered "continuous" aquifers, HU IV) aquitards/aquicludes. It has been assumed that, due to its peculiar stratigraphic architecture (i.e. internal stratal organization) each Aquifer Group has a distinctive response to the regional groundwater flow system. In this sense, each main type of Hydrogeologic Unit will present a peculiar and distinctive instance in each single Aquifer Group. Consequently, the Aquifers Groups were subdivided into lower rank hydrostratigraphic units, here defined as "Synthemic Hydrogeologic Units", i.e. Hydrogeologic Units that inherit the peculiar architectural properties of the Aquifer Group they belong to. In other words, each main type of Hydrogeologic Unit will present a distinct instance in each different Aquifer Groups. Following these criteria, nineteen Synthemic Hydrogeologic Units, grouped into seven Aquifer Groups were recognized within the Savigliano and Alessandria Basins, and eleven Synthemic Hydrogeologic Units, grouped into four Aquifer Groups were recognized in the Padane Basin. The reconstruction of the hydrostratigraphic model allowed to portray, for the first time, the geometry and architecture of the Aquifer Groups of the whole upper Messinian-Quaternary successions in Piemonte and to reconstruct the regional distribution and characteristics of potentially exploitable aquifers. The use of stratigraphic constraints (i.e. distribution of depositional settings and lithofacies associations) led to the reconstruction of the geometry of the fresh-salt water interface, also in those areas with scarce well data, and to better estimate the maximum thickness of deep fresh aquifers that, up to date, are still unexploited.

3.2.3 Hydrogeofacies

The hydrogeofacies was mostly determined on combining the expert knowledge and the 3D hydrostratigraphic regional framework.
Here it has been assumed that the hydrostratigraphic value of synthems mainly depends on their stratigraphic architecture and lithofacies associations. The stratigraphic architecture is defined by the internal geometry (i.e. internal stratal patterns, imaged by seismic reflectors) of synthems, including for example parallel/aggradational, divergent, progradational or chaotic patterns. A generic hydrostratigraphic value has been assigned to the stratigraphic architecture, since it is known that internal stratal pattern represents a prominent factor in controlling main regional groundwater flow directions. Lithofacies associations are volumes of sediments, that show homogeneous lithologic properties such as grain size, composition and bedding style.

Eight different lithofacies associations have been defined on the basis of two criteria:
- grain-size ratio, that is the relative percent of coarse grained (sands and gravel) and fine grained (silts and clays/marls) sediments forming the lithofacies association;
- the degree of lateral persistence of sedimentary bodies (both fine and coarse grained), in alternations.
Lithologic bodies that are more than 2 kilometres long have been considered as “continuous”, whereas those less than 2 kilometres long have been considered as “discontinuous”. In addition, two lithofacies associations have been recognized, that are typical features of Messinian synthem and consist of resedimented evaporite complexes.
The lithofacies associations (or group of lithofacies associations), have been subdivided into 4 main typologies of “Hydrogeologic Units” distinguished on the basis of their hydrogeologic characteristics.
Therefore, on the basis different lithofacies associations the cells were classified in aquifers or aquitards/aquicludes. In the mixed areas between aquitard and aquifer the values of the cells of 10 x 10 km correspond to the one with the greatest extension.

3.2.4 Geological age

The geological ages of the layers were determined from chronostratigraphic framework of the synthems whose boundaries make up these layers. The layers belonging to the Messinian-Quaternary succession, that have been subdivided into seven and four unconformity bounded stratigraphic units, corresponding to Synthemic Hydrogeologic Units respectively for the south and north Piemonte region. This age subdivision can be found on:
https://webgis.arpa.piemonte.it/Geoviewer2D/index.html?config=other-configs/geologia250k_config.json

3.2.5 Layer type

In the Regione Piemonte hydrogeological model (Irace et al. 2009 and 2010) each Aquifer Group is characterized by Hydrogeologic Units (HU) defined on the basis of lithofacies associations that display homogeneous hydrogeologic properties (e.g. permeability ratio, storage coefficient). Four main typologies of Hydrogeologic Units have been distinguished, on the basis of their hydrogeologic characteristics: I) unconfined aquifers, II) multi-layered “discontinuous” aquifers, III) multi-layered “continuous” aquifers, IV) aquitards/aquicludes.

3.2.6 Aquifer type

For the aquifer types, a simple classification was used: unconfined aquifer for the first level and for all other levels semi-confined aquifers.

3.2.7 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, and the anisotropy value) were determined based on a combination of model values and expert judgement. They were generally obtained by combining the sedimentary hydrogeofacies with the representative parameters known in the literature.

3.2.8 Artesian/Paleo/Thermal

For the Piemonte region, no artesian, paleo waters and thermal aquifers were characterized. Although there are artesian or paleo waters or thermal aquifers present, the data are not known or are not available.

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Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Valle Umbra model for work package 6 of the RESOURCE (Pan-EU Groundwater Resources Map) project. It provides basic information on how the model for the Umbrian Valley was compiled, what data was used and what choices were made to pick the different parameters. First, a summary table is provided, which provides a quick overview of the model building process and the data type used. A more detailed description of each parameter is then given in Chapter 3 providing the process behind filling that particular parameter and describing the background of the data.
The underground –model was reconstructed using real data from boreholes and deep water wells made for drinking water; in our study levels of thickness less than 0.5 m were not considered.
The 2D model and stratigraphy of the case study area was reconstructed with great accuracy: these are alluvial deposits show the alternation of sandy, gravelly and clayey sediments without lateral continuity.
All parameters have been compiled using data from real models, only the hydraulic parameters have a level of accuracy based on expert judgment.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Average of the altitudes of the vertices of the cell 10x10 from the Regional Technical Map in scale 1: 10,000 in meters above sea level	http://www.umbriageo.regione.umbria.it/pagina/distribuzione-carta-tecnica-regionale-raster
Total_depth_active_layers	Obtained from the difference between the share of the average altitude and the share of the waterproof substrate.	Note illustrative carta geologica Regione Umbria 1:10.000 sezione 311_110
Unsaturated zone thickness and extent	It is the thickness of the covering soil whose extension is equal to the percentage of the cell surface covered by the study	(https://www.regione.umbria.it/documents/18/583613/Carta+Idrogeologica+della+Valle+Umbra/b3c0b5df-1995-42dc-8c99-c3691e8381e2?t=1392646084000
Saturated zone thickness and extent	Thickness of saturated sediments obtained from the database of surveys for Google Earth of the Umbria Region and from the isophreatic contour lines of the hydrogeological map of the Umbrian valley	http://storicizzati.territorio.regione.umbria.it/Static/IndaginiGeologicheKmz/Index_kmz.htm (https://www.regione.umbria.it/documents/18/583613/Carta+Idrogeologica+della+Valle+Umbra/b3c0b5df-1995-42dc-8c99-c3691e8381e2?t=1392646084000
Hydrogeofacies	Hydrogeofacies are based on layer types. Generally: aquifers: coarse sand, aquitards: clay.	http://storicizzati.territorio.regione.umbria.it/Static/IndaginiGeologicheKmz/Index_kmz.htm
Geological age	The sediments are all from the Quaternary age	Geologia - Regione Umbria
Layer type	Layers are described on the basis of the hydrogeological map of the Umbrian valley	(https://www.regione.umbria.it/documents/18/583613/Carta+Idrogeologica+della+Valle+Umbra/b3c0b5df-1995-42dc-8c99-c3691e8381e2?t=1392646084000
Aquifer type	Based on geologists database of the region of Umbria: aquifers above the aquitards or above the substrate: semi-confined, aquifers under pressure: confined	http://storicizzati.territorio.regione.umbria.it/Static/IndaginiGeologicheKmz/Index_kmz.htm
Hydrological parameters	kh and kv are based on flow tests on wells, while porosity and anisotropy values are based on expert judgment	E. PREZIOSI, E. ROMANO (2009): From a Hydrostructural analysis to the mathematical modelling of regional aquifers (central Italy)
Artesian/Paleo/Thermal	The artesian aquifers have been identified by the Hydrogeological Map of the Umbrian Valley and by the geological database of the Umbria Region	http://storicizzati.territorio.regione.umbria.it/Static/IndaginiGeologicheKmz/Index_kmz.htm (https://www.regione.umbria.it/documents/18/583613/Carta+Idrogeologica+della+Valle+Umbra/b3c0b5df-1995-42dc-8c99-c3691e8381e2?t=1392646084000

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

3.2.2 Saturated zone thickness & extent

3.2.3 Hydrogeofacies

3.2.4 Geological age

3.2.5 Layer type

3.2.6 Aquifer type

3.2.7 Hydrological parameters

3.2.8 Artesian/Paleo/Thermal

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level was extrapolated from the elevation values indicated in the regional technical map in scale 1: 10000 "Basic cartography of the regional territory made with the photogrammetric method, revised different times between 1985 and 2006"
http://www.umbriageo.regione.umbria.it/pagina/distribuzione-carta-tecnica-regionale-raster-110-0.
For each 10x10km cell, an average was calculated between the elevation values at the corners of the cell itself.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

Umbria is an Italian region that has no outlets to the sea and therefore there is no mixing between the fresh and salt groundwater. The aquifer consists of alluvial deposits covering the Plio-Pleistocene clays in the center of the valley (hydrogeological base), and is confined to the east and west by lacustrine and fluvial-lacustrine deposits that cover the Miocene flysch of the Marnoso-Arenacea Formation.
The Umbrian valley is a narrow and elongated valley in a north-south direction. The total depth of the active zone is defined by the hydrogeological basis represented by the Miocene sediments found through the drilling of the well field for drinking water use (about 150 wells) which allowed, together with other data of a geological and hydrogeological nature, to reconstruct the trend of the isophreatic contour lines for the whole case study area.

(https://www.regione.umbria.it/documents/18/583613/Carta+Idrogeologica+della+Valle+Umbra/b3c0b5df-1995-42dc-8c99-c3691e8381e2?t=1392646084000).

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The unsaturated zone is represented in our geohydrogeological model by layers of average of 1 m thickness in our area where , subsurficial sediments are considered as an aquitard and whose extension in the cell depends mainly on the surface occupied by the area studied in the 10x10km cell.

In the portions of the territory where the aquifer with its alluvial fan sediments emerges instead, we considered the entire thickness of dry coarse materials as unsaturated to the top of piezometric level identified by the studies carried out for the preparation of the hydrogeological map of the Umbrian Valley.

3.2.2 Saturated zone thickness & extent

Most of the territory of the Umbrian valley is characterized by the presence, on the surface, of sediments which hydrogeologically constitute an aquitard saturated by default. The extension of these deposits is shown by the hydrogeological map of the Umbrian Valley at 10x10km cell scale.

Regarding the saturated zone thickness, we have considered the stratigraphy of the deep wells for drinking water use and the data deriving from the borehole database available for ~~of~~ the Umbria Region.

These fine sediments often mixed with silts belong to the group of Clay - Quaternary "Unconsolidated sedimentary hydrogefacies", although we have classified, as coarse sand, belonging to the “Unconsolidated sedimentary hydrogefacies”, the lithology of the aquifers.
This is a simplification since, being sediments of alluvial origin, the sands are never pure but contain variable percentages of silts, clays or gravels inside. However, since it is about introducing large-scale data, they have all been considered coarse sand.
In semi-confined aquifers groundwater level is affected by natural seasonal rising and lowering, while in the artesian aquifer, still keeping the characteristics of a pressurized aquifer, the lowering of groundwater level can be caused by pumping wells.

3.2.3 Hydrogeofacies

The hydrogeofacies were determined by expert knowledge on the basis of data from the database of geognostic surveys of the Umbria Region, through the analysis of stratigraphic log data and laboratory tests carried out on the samples extracted during drilling operations.
The sediments that characterize the aquitards are clayey while those that constitute the aquifer are sandy.

3.2.4 Geological age

All alluvial sediments considered in this study belong to the Quaternary era.

3.2.5 Layer type

In our hydrogeological model only two of the three aquitards, similar from a hydrogeological point of view but different depending on the age of the deposits, were considered for the study.
The three aquitards are characterized as following:

1) The Holocene Aquitard is the most recent and it stretches out throughout the central part of the Umbrian valley.
2) The Plio-Pleistocene Aquitard outcrops are located mainly at the borders of the Umbrian valley and in the south;
3) Pre-Pliocene Aquitard is located in the western area of the study area.

In the template, only the first two were considered for our study, since the third aquitard outcrops, are considered as an hydrogeological base-layer covering directly the Miocene lithoid substrate and therefore not significant for the Resource project.
On the basis of what is reported in the study by E. PREZIOSI, E. ROMANO (2009): From a Hydrostructural analysis to the mathematical modeling of regional aquifers (central Italy and on the basis of expert knowledge the hydraulic parameters have been identified: reported in the Final template deliverable 6.2 of 15/01/2020 for the default aquitards it is necessary to enter, in addition to the porosity, only the vertical hydraulic conductivity (kv) expressed in m / day and not the horizontal conductivity.

As for the aquifers, we considered the thickness of the saturated water through the difference between the isophreatic contour values and the elevation of the bottom of the permeable layer, obtained both from the interpretation of the data in the boreholes database of the Umbria Region and from the stratigraphy of deep wells for drinking water use.

Three types of aquifers were considered:
1) Holocene aquifer;
2) Plio-Pleistocene aquifer;
3) Artesian aquifer.

3.2.6 Aquifer type

As far as groundwater aquifers are concerned, the data available to us make us consider semi-confined aquifers as they are confined at the base by the most ancient aquitards or by the Miocene hydrogeological base layer.

For the aquifer types, a simple classification was used: if the first combined aquifer is above an aquitard, it was included as an unconfined aquifer. All aquifers below the first aquitard are included as semi-confined aquifers.

3.2.7 Hydrological parameters

All the hydrological parameters included in the template (porosity, horizontal and vertical conductivity and the anisotropy value) were determined by the combination of the data in our possession and the expert knowledge.

The porosity values, were obtained through expert knowledge and through data from the boreholes regional database.
The parameters vary from 0.5 for the clayey soils of the aquitards to 0.4 for the sediments of the aquifers, comparable to those reported in the RESOURCE WP6 Hydrogefacies list.
Horizontal and vertical conductivities were determined from well tests, from analyzed with expert knowledge and compared with those determined by RESOURCE WP6 Hydrogefacies list. kh: 10 m / day and anisotropy value = 1 for aquifers, kv = 2×10^{-6} m/day for aquitards.

3.2.8 Artesian/Paleo/Thermal

In the north-western area of the Umbrian valley, an artesian aquifer confined between the upper Plio-Pleistocene aquitard and the Miocene sediments that form the hydrogeological base was identified through a campaign of wells drilled for the research of drinking water.
It is made of Quaternary sandy sediments having the same hydrological characteristics of the groundwater aquifers.

4 LITERATURE

1) Note illustrative carta geologica Regione Umbria 1:10.000 sezione 311_110
2) (https://www.regione.umbria.it/documents/18/583613/Carta+Idrogeologica+della+Valle+Umbra/b3c0b5df-1995-42dc-8c99-c3691e8381e2?t=1392646084000
3) E. PREZIOSI, E. ROMANO (2009): From a Hydrostructural analysis to the mathematical modelling of regional aquifers (central Italy)

Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Latvian template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for Latvia was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Generally, the Latvian template is filled by using hydrogeological models which describe the subsurface in vertically stratified units in great detail. The geometrical properties of the hydrogeological units (distribution, thickens, elevation) were obtained from the geological and hydrogeological model of Baltic artesian basin (Virbulis et al., 2013), distribution of fresh groundwater was obtained from recent overview of Latvian geological resources (Dēliņa, 2018). The unsaturated zone thickness was obtained from the Latvian hydrogeological model LAMO4 (Spalviņš, 2016) while the groundwater head estimation was based on hydrogeological model of Baltic artesian basin (Virbulis et al., 2013). Characterization of the hydrogeofacies and their geological age were largely based on recent overview of sedimentary cover in Baltic artesian basin (Lukševičs et al., 2012), however, labels of distinguished hydrogeofacies according to the RESCOURCE WP6 guidelines were strongly generalized to the typology of the International Hydrogeological Map of Europe 1:15000000. Finally, the hydrogeological properties of aquitards and aquifers were obtained from methodological guidelines issued by Latvian Environment, Geology and Meteorology Center (LVĢMC, 2018) and upscaled where necessary according to the RESCOURCE WP6 guidelines. Other parameters were filled using a combination of model results, references to background information and expert judgement.

To cover the entire territory of Latvia, provided grid template was extended to the extents covering the entire inland territory of Latvia as well as part of the offshore (Figure 1). Identification numbers of cells follows the system provided by the project WP6 coordinator.

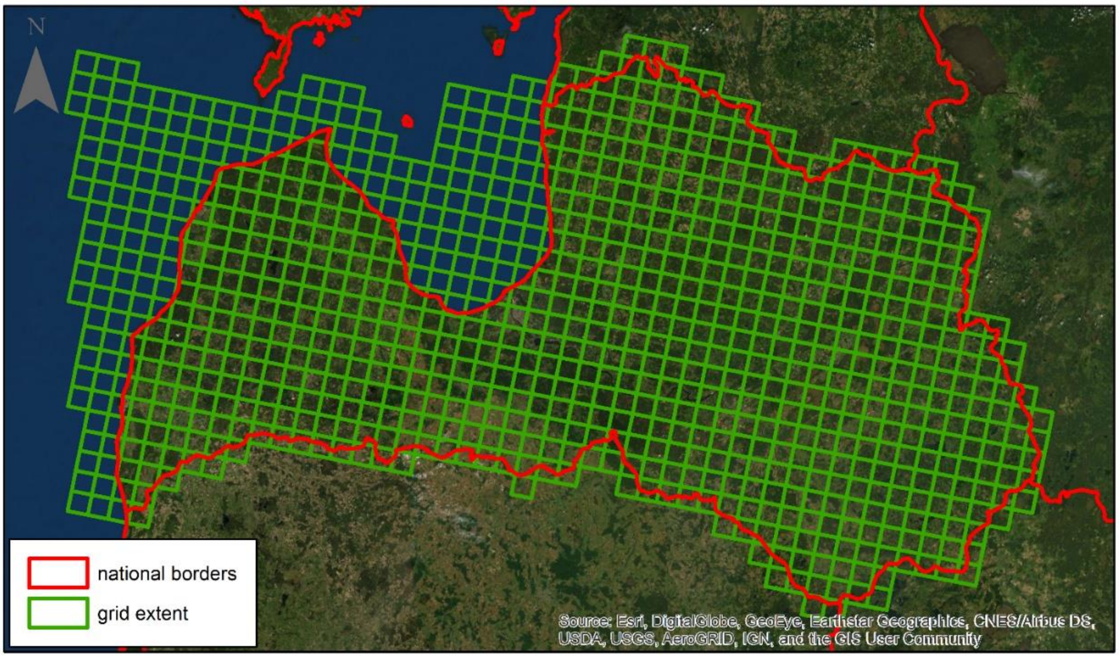

Figure 1 Extent of adopted grid for the territory of Latvia

Also, a simplified hydrogeological stratification based in expert judgement was adopted (Table 1).

Table 1 Adopted hydrogeological stratification

Layer Number	Geological index	Unit description	Unit type
1	Q_1	Quaternary, permeable deposits.	Aquifer
2	Q_2	Quaternary, layering of impermeable glacial tills and sandy deposits	Mixed sequence
3	J-T	Mesozoic: Jurassic and Triassic	Mixed sequence
4	J-D_3fm	Late Palaeozoic: Carboniferous, Permian and Famennian regional stage of upper Devonian	Mixed sequence
5	D_3el	Upper Devonian Eleja formation	Aquitard
6	D_3fr	Upper Devonian Frasnian regional stage (up to the base of Pļaviņas formation)	Mixed sequence
7	D_3am-pl	Upper Devonian base of Pļaviņas and top of Amata formations	Aquitard
8	D_2ar-D_3am	Middle Devonian Arukila to upper Devonian Amata formations	Mixed sequence
9	D_2nr	Middle Devonian Narva formation	Aquitard
10	D_1-D_2pr	Lower to Middle Devonian Pärnu regional stage	Aquifer

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	The geometrical properties of the hydrogeological units and groundwater head distribution were extracted from in-house modelling system (MOSYS, Virbulis et al. 2013) as 3D point cloud where the mean value of the surface level was calculated for the each 10x10 km grid cell and further processed in GIS.	EU-DEM, 2014
Total_depth_active_layers	The geometrical properties of the hydrogeological units and groundwater head distribution were extracted from in-house modelling system (MOSYS, Virbulis et al. 2013) as 3D point cloud and further processed in GIS environment.	Virbulis et al. 2013
Unsaturated zone thickness and extent	The unsaturated zone thickness for first layer was extracted as georeferenced raster file from Latvian hydrogeological model LAMO4 (Spalviņš 2016) and further processed in GIS environment.	Spalviņš 2016
Saturated zone thickness and extent	The geometrical properties of the hydrogeological units and groundwater head distribution were extracted from in-house modelling system (MOSYS, Virbulis et al. 2013) as 3D point could and further processed in ArcGIS environment.	Virbulis et al. 2013
Hydrogeofacies	Derived from recent overview of sedimentary cover of the Baltic artesian basin (Lukševičs et al. 2012), generalized according to the project guidelines.	Lukševičs et al. 2012
Geological age	Derived from recent overview of sedimentary cover of the Baltic artesian basin (Lukševičs et al. 2012), generalized according to the project guidelines.	Lukševičs et al. 2012
Layer type	Expert judgement	
Aquifer type	Expert judgement	
Hydrological parameters	Porosity, kh and KV - For AQF values were derived from national guidelines (LVĢMC 2018), for AQT – expert judgment, for MIX – upscaled according to the project guidelines using AQF and AQT effective porosity values and separate layer thickness from Latvia's hydrogeological model LAMO4 (Spalviņš 2016). Anisotropy - expert judgement. Confidence_label_hydraulic_parameters - following the used methodology	LVĢMC 2018 Spalviņš 2016
Artesian/Paleo/Thermal	Paleo and artesian water occurrence derived from hydrogeological model of Baltic Artesian Basin, only layers where it is known that paleo or artesian water exists are characterized.	Virbulis et al., 2013

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Latvia is retrieved from the hydrogeological model of the Baltic Artesian basin (BAB) (Virbulis et al., 2013) where then land surface elevation was obtained from U-DEM digital relief model with 25 m resolution (EU-DEM, 2014). For the use in the Pan-EU groundwater resources map, data from the BAB model was extracted as a 3D point cloud where the mean value of the surface level was calculated for the each 10x10 km grid cell.

3.1.2 Total_depth_active_layers

The total depth of the active zone is extracted from in in-house modelling system (MOSYS, Virbulis et al. 2013) as 3D point could as the base of deepest freshwater aquifer. From extracted point cloud the mean value for the each 10x10 grid cell is calculated.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The unsaturated zone thickness for first layer was extracted as georeferenced raster file from Latvian hydrogeological model LAMO4 (Spalviņš 2016) and further processed in GIS environment where for each Pan-EU resource grid cell mean thickness is calculated. The unsaturated zone dynamics was set at N (or naturally seasonal variability) for all cells in Latvia. Unsaturated zones within territory of Latvia are present only in topmost Quaternary layer (Layer 1). There are small areas where unsaturated zone is impacted by depletion from pumping and mining, however, it is considered as insignificant within given 10 km scale.

3.2.2 Saturated zone thickness & extent

All layers below groundwater level (depth to the unsaturated thickness of the first layer) within territory of Latvia is considered as saturated. The thickness of each identified layer is calculated as thickness between top and base of it. These interfaces were extracted from the BAB model (Virbulis et al., 2013) as 3D point clouds, where for each point thickness was calculated and mean value of all points falling within each 10x10 km grid cell were assigned.

3.2.3 Hydrogeofacies

The hydrogeofacies was identified by expert knowledge and overview information by Lukševics et al. (2012) and generalized according to the project guidelines. Multiple hydrogeofacies can be distinguished within territory of Latvia – generally these are sandy aquifers within the Quaternary sequence and aquifers composed of mainly sandstone and dolomites within bedrock sequence. Aquitards generally are composed of clayey deposits. In reality aquifers have much larger variation of deposit composition. However, for the purpose of this project and given guidelines there is no possibilities to integrate such lithological variety. Therefore, for Quaternary sequence hydrogeofacies are classified as Medium sand and alternation of unconsolidated sedimentary hydrogeofacies and for bedrock sequence - alternation of compact sedimentary hydrogeofacies.

3.2.4 Geological age

The geological ages of distinguished layers were determined based on the age of these formations, information derived from recent overview of sedimentary cover of the Baltic artesian basin (Lukševičs et al. 2012) andgeneralized according to the project guidelines. Generally uppermost two layers are Quaternary, and the rest belong to the Mesozoic and Paleozoic. Since the distribution and overall significance of the Mesozoic sequences within the resolution of this project was rather unsignificant, these parts were aggregated to the layers belonging to the Paleozoic. Although the age of Paleozoic sequence can be divided even in the resolution of regional stages, following the project guidelines layers younger than Devonian were defined as "Paleozoic undistinguished".

3.2.5 Layer type

Within territory of Latvia, following the information about their lithological properties given by Lukševics et al. (2012) and to the given project guidelines layers were divided into three main types – aquifers, aquitards and mixed sequence of aquifers and aquitards where presence of regionally significant deposits with low permeability is known.

3.2.6 Aquifer type

For the aquifer types, a simple classification was used: if the first combined aquifer is above an aquitard, it was included as an unconfined aquifer. All aquifers below the first aquitard are included as semi-confined aquifers.

3.2.7 Hydrological parameters

The values of hydrogeological parameters (porosity, horizontal and vertical conductivity as well as anisotropy) were determined based on a combination of model values (Spalviņš 2016), national guidelines (LVĢMC 2018) and expert judgement. Considering the porosity and conductivity parameters, for aquifers corresponding values were derived from national guidelines, for aquitards these values were based on expert judgement. For mixed layers these values were upscaled from the calibrated model values and upscaled according to the project guidelines using AQF and AQT effective porosity values and separate layer thickness from Latvia's hydrogeological model (Spalviņš 2016). Anisotropy was assigned by the expert judgement based on knowledge about given hydrogeological system and known other parameters.

3.2.8 Artesian/Paleo/Thermal

For the territory of Latvia, information about the presence of Paleo waters were taken from the hydrogeological model of BAB (Virbulis et al., 2013) and assigned to each grid cell.

Considering artesian waters, according to the project guidelines, checked are those grid cells in which boreholes with groundwater level above ground surface are known. There are no approved freshwater geothermal resources in Latvia, therefore this information is not provided.

4 LITERATURE

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Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata Lithuania

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Lithuania template for work packages 6 of the RESOURCE project. It provides the basic information on the data sources and the methods of their compilation. The metadata are listed both in table form and detailed descript in chapter 3.

This template was filled using the different type of data. However, the main part of them was composed of the deep boreholes dataset. Some information coupled to hydrogeological parameters is taken from the subsurface hydrogeological models are performed for some groundwater basins of Lithuania. Hereby, there is no data on this for some basins since they are not completely modelled yet. The altitudes was composed of the LIDAR measurements.

Due to detailed information on the boreholes, some upscaling of the geological layers and aquifers was performed considering the prevailing (in terms of volume) hydrogeofacies. Generally, up to nine layers of the template were filled as a result. Averaging method for filling of quantitative data was chosen as essential.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the LIDAR measurements.	https://www.geoportal.lt/geoportal/duomenu-paieska
Total_depth_active_layers	Based on TDS (1500 mg/l). There are rather approximate or reduced values due to insufficient data in some cells as noted in the supplementary information.	
Unsaturated zone thickness and extent	Determined as the average of the distance between the earth surface and unconfined aquifer table. The table in turn was mostly formed by special hydrogeological modelling when evaluating the regional groundwater resources. In the absence of a proper model average data were taken from the dataset.	
Saturated zone thickness and extent	Based on averaged thickness of the layers are represented by the boreholes within the cells. The extent is set according to the regional maps of the facies however were judged by experts in some cases.	Kadūnas et al., 2018.
Hydrogeofacies	Based on known ages of the layers are placed in boreholes data sets. When upscaling layers the most thickness and spread of layers were concidered.	
Geological age	Based on known ages of the layers are placed in boreholes data sets. When upscaling layers the age of the prevailing thickness was concidered.	Kadūnas et al., 2018. https://www.lgt.lt/epaslaugos/index.xhtml
Layer type	A layer was considered as aquifer in case of being used for groundwater supply. The same is for mixed type providing some thin semipermeable sublayers (but less part of total thickness are available there).	
Aquifer type	Unconfined aquifer is considered just the first aquifer occurring above the first aquitard. There are no semi-confined aquifers set in the Lithuania part of the model due to quite spread of the latter ones.	
Hydrological parameters	The data averaging were chosen from the hydrogeological models. They in turn were performed in order to evaluate the groundwater resources in some Lithuania groundwater basins.	The reports on evaluation of the regional groundwater resources are stored in LGS geological funds.
Artesian/Paleo/Thermal	Artesian water sites are distinguished according to the maps of the risk (hazard) of groundwater leaking wells. The maps were made up for the special project. No proper data on paleo water in the groundwater of Lithuania are available. Also no thermal water in the active layers is available.	https://www.lgt.lt/epaslaugos/index.xhtml

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in the Lithuania was calculated according to the surface model had been created by the LIDAR measurements. These measurements had been performed with density of 10 x 10 m and consequently were recalculated into the proper grid cell average (10 x 10 km). The raw data are accessible in Geoportal datasets (see https://www.geoportal.lt/geoportal/duomenu-paieska).

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active zone was mainly defined by the fresh-salt groundwater interface (at 1500 mg/l of TDS). This interface was considered to coincide with bottom of some aquifer which is the last fresh one in the grid cell. There are some cells however with the reduced depth of active layers due to poor information on that. It means, the last layers were considered to be those layers reached at least by five informative boreholes in the cell. Noteworthy, the certain inversion of groundwater salinity is available in some sites of Northern Lithuania due to Upper Devonian gypsum deposits. However, quite meaningful fresh water aquifers occur below the anomalous zone, therefore the aquifers composed of gypsum was not considered as fresh-salt groundwater interface.
No reference to the mapped interface of active layers is available yet.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

Thickness and extent of unsaturated zone were applied for the first layer only. Two options were chosen for the thickness to be calculated. According to the first one the table of the unconfined aquifer was used in order to compare it to the earth surface. The tables in turn were taken from the hydrogeological models performed for the calculation of the regional groundwater resources. They were performed mostly using the 500 x 500 m grid size. In case of a groundwater basin being not provided with proper model, the data of the dataset of Lithuanian geological survey (LGS) were used instead. Anyway, the averaged values were used when calculating the grid cells information. LGS datasets are not available for free access yet.
Extent of unsaturated zone is considered to be 100 % except for the cells being divided by large bodies of water.
The unsaturated zone dynamics was set at naturally seasonal variability (N) for all grid cells since groundwater supply from the unconfined aquifers being negligible in scale of the cell size.

3.2.2 Saturated zone thickness & extent

The generalized stratigraphic systems and series containing aquifers, aquicludes and aquitards were applied for determination of saturated zone thickness. The thickness was calculated as average values taken from LGS boreholes datasets. If needed the different stratigraphic units were joined according to aquifer system as determined in LGS mapping schemes therefore using total thickness instead.
Saturated zone extent was partially determined according to limits of the hydrogeostratigraphic units (see 'Kadūnas et al., 2018'). Also some expert judgement was done when boundary of a

stratigraphic unit being unclear or hidden. Another boundary type is established for the layers going down and getting TDS of 1500 mg/l. These latter were partially established with performance of the hydrogeological models mentioned above or formed by expert in some cases.

3.2.3 Hydrogeofacies

Filling with hydrogeofacies content is quite complicated since they being quite changeable across the geological strata and even more changeable for aquifers. The only way to fill the cells is upscaling both in vertical and horizontal directions. Since the various sites of Lithuania being researched in the different degree the most representative boreholes were selected only in order to use the proper data. Hereafter, using 'Voronoi' method, total Lithuania territory was divided into some representative areas according to the selected boreholes. On the other hand, there were selected hydrogeofacies of the most thickness in vertical section. These selected facies were attributed to the divided areas. Finally, every grid cell was filled with content of that divided by a borehole area which covered the largest part of the cell. All the performance was done expertly for Resource WP6, therefore no official references are available on that.

3.2.4 Geological age

Once hydrogeofacies were selected for the grid cells, geological age was simply assigned for the cell since geofacies being permanently linked to the certain geological age in the datasets. These are geological age options in the Lithuania geological strata: Quaternary (chosen without detailed division), Paleogene, Cretaceous (Upper Cretaceous and Cenomanian-Albian aquifers), Jurassic, Permian (Upper), Devonian (Upper Devonian Famennian, Upper Devonian Frasnian and Upper-Medium Devonian Šventoji-Upninkai aquifer systems), Silurian, Ordovician. The active zone of two latter ones occur in some sites of Eastern Lithuania only. Neogene and Carboniferous ages were joined to Quaternary and Upper Devonian respectively since being quite negligible as aquifers. However, the ages was generalized according to the selection is established in RESOURCE WP6.
Data on geological ages of Lithuania can be partially found in the hydrogeological map of Lithuania (Kadūnas et al., 2018). Also the same map is accessible on the web site (see https://www.lgt.lt/epaslaugos/index.xhtml).

3.2.5 Layer type

The geological layers was considered to be aquifers when being exploitable for the most part of total thickness. It was considered to be a mixed type in case of layer being intersected with some thin aquitards (that making up the less part of the total strata) but being used for groundwater supply anyway. Remaining layers was considered as aquitards. Needless to say, there are steady custom for the generalized geological layers to be linked to aquifers or aquitards unambiguously in geological practice of Lithuania.

3.2.6 Aquifer type

Unconfined aquifer was considered to be the first aquifer occurring above the first aquitard only. The first layer in the table of Resource WP6 herewith is unconfined aquifer. All remaining aquifers were considered as confined even some small sites to be characterised with a low piezometric head. There were no semi-confined aquifers set in the Lithuania part of RESOURCE WP6 due to quite local spread of the latter ones. No strong legislation on aquifers partition by types was established in Lithuania.

3.2.7 Hydrological parameters

The only sources of the parameters are hydrogeological models as mentioned above. Various parameters were applied for the appropriate property zones of the models with calibration procedure afterwards. As usual they are averaged for the grid cells. Kh values were applied for aquifers and mixed layers while KV being applied for aquitards only. Unfortunately, not all groundwater basin models were provided with hydrological parameters. If so, the corresponding column of the cell is empty.
The parameters values are placed in some reports intended for to evaluating of the regional groundwater resources. The reports in turn are stored in LGS geological funds.

3.2.8 Artesian/Paleo/Thermal

When filling the cells with information on artesian aquifers availability the report of LGS on the special project was used. According to the purposes defined in the project, the zones with the risk (hazard) of leaking wells were mapped all around the Lithuania territory. The risk zones were defined as sites which high level of piezometric table (above the earth surface) was available in. Thereafter, several piezometric tables linked to the different aquifers were joined in order to form the highest piezometric surface location. The filling of compatible cell in the table means simply the risk zone for this aquifer is available somewhere in the grid cell. The report on the risk zones is stored in the LGS geological funds. Also it is accessible in the e-services of the LGS web site (see https://www.lgt.lt/epaslaugos/index.xhtml).
No data on paleo water except some specialized research results are available for Lithuania groundwater. Also there is no thermal water in the active layers was detected for Lithuania. Groundwater temperature does not usually exceed 20^{o} C in the active layers there.

4 LITERATURE

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Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata Luxembourg

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the luxembourgish template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). The document contains all the information about which data has been used to fill in the template.

The groundwater model is a combination of modelled data, internal hydrogeological investigations and expert judgements based on geological maps, hydrogeological maps, borehole data (thickness of layers, aquifers, aquitards etc.), piezometric data (groundwater level, chemistry of groundwater, pumping tests) and a hydrogeological model of the Luxembourg sandstone aquifer.

For the creation a groundwater model, the number of geological layers was sensibly reduced. The upscaling was performed based on the permeability for aquifers and vertical resistances for aquitards. The number of layers was reduced from 22 units to a maximum of 10 layers in the final dataset.

2 OVERVIEW TABLE

Parameter	Short description (2/3 sentences)	Link/reference
Altitude_surface_level	DEM	
Total_depth_active_layers	The hydrogeological base is determined by the upper surface of the basement (devonian shales) (AAIGrid).	Database of the Geological Survey and the document „Grundwassermanagementplan Luxemburger Sandstein“, Björnsen Beratende Ingenieure GmbH (2010)
Unsaturated zone thickness and extent	Based on borehole data and hydrogeological model (average thickness and extent).	Database of the Geological Survey and the documents „Grundwassermanagementplan Luxemburger Sandstein“, Björnsen Beratende Ingenieure GmbH (2010); Hydrogeologisches Modell “Nördliche Trias Luxemburg“, Björnsen Beratende Ingenieure GmbH (Juli 2012)
Saturated zone thickness and extent	Based on borehole data and hydrogeological model (average thickness and extent).	Database of the Geological Survey and the documents „Grundwassermanagementplan Luxemburger Sandstein“, Björnsen Beratende Ingenieure GmbH (2010); Hydrogeologisches Modell “Nördliche Trias Luxemburg“, Björnsen Beratende Ingenieure GmbH (Juli 2012)
Hydrogeofacies	Hydrogeofacies are based on the lithologies: - aquitards: mudstone, marlstone, siltstone, shale, - aquifers: sandstones, limestones, dolomite	
Geological age	Based on (bio)stratigraphic ages of the geological units the layers are based on (When combining layers the age of the thicker layer was taken.)	https://www.geology.lu http://www.geology.lu/geolwiki/
Layer type	Layer were classified as aquifers or aquitards based on their hydrological parameters.	
Aquifer type	Based on expert knowledge: aquifers above first aquitards = unconfined, all aquifers below first aquitards = confined.	
Hydrological parameters	Based on model values and expert knowledge. Kh, kv, porosity, anisotropy values calculated from model or based on expert knowledge.	„Grundwassermanagementplan Luxemburger Sandstein“, (2010); „Hydrogeologisches Modell Nördliche Trias Luxemburg“,Björnsen Beratende Ingenieure GmbH (Juli 2012)
Artesian/Paleo/Thermal	Locally, thermal and paleo waters exist in Luxembourg.	Grundwassermanagementplan Luxemburger Sandstein, Björnsen Beratende Ingenieure GmbH (2010)

3 DETAILED DESCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Luxembourg is available as a DEM (Digital Elevation Model). The version that was used for this project is the 2013 DEM., which has a resolution of 1m. For the use in the Pan-EU groundwater resources map, the average value of the altitude of the surface level was calculated for each 10x10 km grid cell.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active zone is defined by a hydrogeological boundary (upper surface of the Devonian shale). For each of the 10x10 km cells borehole data and models were averaged in order tu to get the depth of the Devonian shales. The hydrogeological base is defined as a layer with very high layer thickness and very high vertical resistances.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The calculation of the average thickness of the unsaturated zone is based on the average highest groundwater level and the average lowest groundwater level. The thickness of the unsaturated zone was averaged for each 10x10 km grid cell. The extent of the unsaturated zone was specified in percent of the 10x10 km grid cell. Geological maps, borehole data and hydrological models were used. The dynamics of the groundwater level are subjected to seasonal variability for all cells.

3.2.2 Saturated zone thickness & extent

The calculation of the average thickness of the saturated zone is based on hydrological data (borehole data, groundwater model). The thickness of the saturated zone was averaged for each 10x10 km grid cell.

3.2.3 Hydrogeofacies

The hydrogeofacies was determined based on expert knowledge. In southern Luxembourg, the aquifers consist mainly of sandstones, limestones or dolomite. The main aquifer is the “Luxembourg Sandstone” with a thickness of up to 100 m. The major aquitards are mudstones, marlstones, siltstones and shales. The north of Luxembourg is determined by Devonian shales.

The classification the layers took place on the basis of the “Hydrogeofacies list”.

3.2.4 Geological age

The basement of the geological layers are the Devonian shales. These are followed by the geologically younger units from Triassic to Middle Jurassic. Tertiary and Quaternary sediments were deposited locally on the high plateaus and in the river valleys. The north of Luxembourg mainly consist of Devonian shales with alluvial deposits in the river valleys. The geological ages for the different formations can be found on https://www.geology.lu.

3.2.5 Aquifer type

For the aquifer types: there are unconfined and confined aquifers. If the first combined aquifer is above an aquitard, it was included as an unconfined aquifer. All aquifers below the first aquitards are included as confined aquifers. Semi-confined aquifers are not significant at a 10x10 km scale.

3.2.6 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, anisotropy value) were determined based on a combination of model values and expert judgement. The horizontal and vertical conductivity from Luxembourg sandstone and the overlaying and subjacent units are based on a groundwater model. In the model, the conductivity was adjusted with depth: with increasing depth, the hydraulic conductivity decreases. The anisotropy value was determined by expert judgement and set at 10 for all aquifers.

3.2.7 Artesian/Paleo/Thermal

Luxembourg has local occurences of thermal and paleo waters. There are also artesian aquifers, but these have no significant extent at a 10x10 km scale. Paleo waters were found in the Luxembourger sandstone. An dating study shows ages of more than 10000 years.

4 LITERATURE

The literature used refers of internal reports by the “Administration de la gestion de l’Eau” (Water management authority) of Luxembourg.

Björnsen Beratende Ingenieure GmbH (2010): Grundwassermanagementplan Luxemburger Sandstein, unpublished

Björnsen Beratende Ingenieure GmbH (2012): Hydrogeologisches Modell “Nördliche Trias Luxemburg“, unpublished

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Polish template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for Poland was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Polish template was filled based on hydrogeological data available from *Hydrogeological Map of Poland (HMP) Main Useful Aquifer* and *Hydrogeological map of Poland First Aquifer – Extent and Hydrodynamics. These maps* cover the area of Poland, divided into 1069 sheets *at a scale of 1:50000.* Hydrogeological Map of Poland: First Aquifer – Extent and Hydrodynamics contains selected elements of a hydrogeological description of the first aquifer, or group of aquifers, beneath the surface, characterised by good hydraulic connection and thickness of at least 2 m at average groundwater retention. The description includes in particular the elements important for establishing the hydraulic connection of the first aquifer with surface waters, groundwater-dependent ecosystems and land development elements. However, the Hydrogeological Map of Poland (HMP) Main Useful Aquifer contains information on useful aquifers of standard groundwater with a broader interpretation of the main aquifer, which is the most important water supply source. The map is uniform as regards the scope and presentation of information layers.
In order to adjust and simply detailed data from the both maps to the project purpose the upscaling of the data was needed.
Such approach determined that only two aquifers (First and Main) were characterized, but it should be noticed that both aquifers might be present as joint aquifer or one of them might be absent at the area. Due to lack of resources (time and manpower) there was no possibility to utilize data from other cartographic studies or databases like Map of Main Groundwater Storages or documentation estimating available groundwater resources (within given catchment/basin).

Common complex geological structures (like glaciotectonic disturbances) and high variability of the formations both horizontally and vertically made it impossible to use *the Detailed Geological Map of Poland (DGMP) at a scale of 1:50000* which also cover entire area of Poland (divided into 1069 sheets). That's why in some cases the *Geological Map of Poland (GMP) at a scale of 1:500000* was used due to 10x10 km grid. But even by using GMP upscaling was necessary.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the NMT (DEM).	http://www.gugik.gov.pl/pzgik/dane-bez-oplat/dane-dotyczace-numerycznego-modelu-terenu-o-interwale-siatki-co-najmniej-100-m-nmt_100
Total_depth_active_layers	Based on depth and thickness of the main useful aquifer taken from *Hydrogeological Map of Poland Main Useful Aquifer (HMP) at scale 1:50000*	HMP that covers entire area of Poland, divided into 1069 sheets *at a scale of 1:50000* *http://epsh.pgi.gov.pl/epsh/* *https://www.pgi.gov.pl/psh/psh-2/kartografia-hydrogeologiczna.html#1-mapa-hydrogeologiczna-polski-1-50-000-mhp*
Unsaturated zone thickness and extent	Based on depth of the first aquifer taken from *Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics at a scale of 1:50000*	HMP that covers entire area of Poland, divided into 1069 sheets *at a scale of 1:50000* *http://epsh.pgi.gov.pl/epsh/* *https://www.pgi.gov.pl/psh/psh-2/kartografia-hydrogeologiczna.html#1-mapa-hydrogeologiczna-polski-1-50-000-mhp*
Saturated zone thickness and extent	Based on depth of the first and/or main useful aquifer (in many cases it's the same aquifer) taken from *Hydrogeological Map of Poland (HMP) Main Useful Aquifer at a scale of 1:50000* and *Hydrogeological map of Poland First Aquifer – Extent and Hydrodynamics at a scale of 1:50000*	HMP that covers entire area of Poland, divided into 1069 sheets *at a scale of 1:50000* *http://epsh.pgi.gov.pl/epsh/* *https://www.pgi.gov.pl/psh/psh-2/kartografia-hydrogeologiczna.html#1-mapa-hydrogeologiczna-polski-1-50-000-mhp*
Hydrogeofacies	Based on data of the first and/or main useful aquifer (in many cases it's the same aquifer) taken from *Hydrogeological Map of Poland Main Useful Aquifer (HMP) at a scale of 1:50000* and *Hydrogeological Map of Poland–First Aquifer – Extent and Hydrodynamics at a scale of 1:50000.* The source of the data for some aquitards were *Geological Map of Poland at a scale of 1:500000 and expert knowledge.*	HMP that covers entire area of Poland, divided into 1069 sheets *at a scale of 1:50000* *http://epsh.pgi.gov.pl/epsh/* *https://www.pgi.gov.pl/psh/psh-2/kartografia-hydrogeologiczna.html#1-mapa-hydrogeologiczna-polski-1-50-000-mhp*
Geological age	Based on data for the first and/or main useful aquifer (in many cases it's the same aquifer) taken from *Hydrogeological Map of Poland (HMP) at a scale of 1:50000 Main Useful Aquifer* and *Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics at scale 1:50000*	HMP that covers entire area of Poland, divided into 1069 sheets *at a scale of 1:50000* *http://epsh.pgi.gov.pl/epsh/* *https://www.pgi.gov.pl/psh/psh-2/kartografia-hydrogeologiczna.html#1-mapa-hydrogeologiczna-polski-1-50-000-mhp*
Layer type	Based on data for the first and/or main useful aquifer (in many cases it's the same aquifer) taken from *Hydrogeological Map of Poland (HMP) at a scale of 1:50000 Main Useful Aquifer* and *Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics at a scale of 1:50000*	HMP that covers entire area of Poland, divided into 1069 sheets *at a scale of 1:50000* *http://epsh.pgi.gov.pl/epsh/* *https://www.pgi.gov.pl/psh/psh-2/kartografia-hydrogeologiczna.html#1-mapa-hydrogeologiczna-polski-1-50-000-mhp*
Aquifer type	Based on data for the first and/or main useful aquifer (in many cases it's the same aquifer) taken from *Hydrogeological Map of Poland (HMP) at a scale of 1:50000 Main Useful Aquifer* and *Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics at a scale of 1:50000*	HMP that covers entire area of Poland, divided into 1069 sheets *at a scale of 1:50000* *http://epsh.pgi.gov.pl/epsh/* *https://www.pgi.gov.pl/psh/psh-2/kartografia-hydrogeologiczna.html#1-mapa-hydrogeologiczna-polski-1-50-000-mhp*
Hydrological parameters	Based on literature values and expert knowledge.	PAZDROZ., KOZERSKI B., 1990 – Hydrogeologia ogólna. Wyd. Geol., Warszawa.

		DAVIS S.N., 1969 - Porosity and permeability of natural materials. Flow through porous media, ed. R.J.M. De Wiest, Academic Press, New York, 54-89. KREFT A., LENDA A., TUREK A., ZUBER A., CZAUDERNA K., 1974 - Determination of effective porosities by the two-well pulse method, Isot. Tech. Groundwater Hydrol., Proc. Symp., 2, 295-312. MERCADO A., 1966 - Underground Water Storage Study: Recharge and mixing tests ant Yavne 20 well field, Technical Report 12, Tel Aviv: TAHAL - Water Planning for Israel Ltd. MORRIS D.A., JOHNSON A.I., 1967 - Summary of hydrologic and physical properties of rock and soil materials, as analysed by the Hydrologic Laboratories of the U.S. Geological Survey 1948-1960. U.S. Geol. Surv. Water Supply Paper, 1839-D, 42p. NERETNIEKS, I., MORENO L., ABELIN H., BIRGERSSON L., WIDEN H., AGREN T., 1990 - A large scale flow and tracer experiment in granite, in Hydrology of Low Permeability Environments, Nuclear Energy Agency, 75 - Paris (France); 331 p; ISBN 92-64-03333-5.
Artesian/Paleo/Thermal	No artesian and thermal waters were included in the template for Poland.	

3 DETAILED DESCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Poland is available as a NMT_ (Numeryczny model terenu – eng. DEM - Digital Elevation Model) through the GUGiK (Główny Urząd Geodezji I Kartografii, eng Main Office of Geodesy and Cartography). The version that was used for this project is the NMT_100 which has a resolution of 100 m and is available as open data to the public (see http://www.gugik.gov.pl/pzgik/dane-bez-oplat/dane-dotyczace-numerycznego-modelu-terenu-o-interwale-siatki-co-najmniej-100-m-nmt_100). For the use in the Pan-EU groundwater resources map, the average value of the altitude of the surface level was calculated for each 10x10 km grid cell from an upscaled version of the NMT_100 (with a resolution of 100 m).

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active zone is defined by the bottom of the hydrogeological Main Useful Aquifer. The data was taken from depth and thickness of the main useful aquifer taken from *Hydrogeological map of Poland (HMP) at a scale of 1:50000 Main Useful Aquifer. HMP is the serial map, consisting of a number of sheets made on a 1:50 000 topographic base map. Each map sheet is a separate GIS hydrogeological database. HMP covers entire area of Poland, divided into 1069.* The average value of the top of this layer was calculated for each 10x10 km grid cell.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The calculation of the average thickness of the unsaturated zone were based on data from the first and/or main useful aquifer (in many cases it’s the same aquifer) taken from Hydrogeological Map of Poland (HMP) at a scale of 1:50000 Main Useful Aquifer and Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics at a scale of 1:50000. In some regions the source for aquitard’s data was Geological Map of Poland at a scale of 1:500000. The average value of the top of this layer was calculated for each 10x10 km grid cell.

3.2.2 Saturated zone thickness & extent

The calculation of the average saturated zone thickness and extent were based on data from the first and/or main useful aquifer (in many cases it’s the same aquifer) taken from Hydrogeological Map of Poland (HMP) at a scale of 1:50000 Main Useful Aquifer and Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics at a scale of 1:50000. For some regions aquitard data came from Geological Map of Poland at a scale of 1:500000. The average value of the top of this layer was calculated for each 10x10 km grid cell.

3.2.3 Hydrogeofacies

The hydrogeofacies were mostly based on data from the first and/or main useful aquifer (in many cases it’s the same aquifer)from Hydrogeological Map of Poland Main Useful Aquifer (HMP) at a scale of 1:50000, Hydrogeological Map of Poland (HMP) First Aquifer – Extent and Hydrodynamics at a scale of 1:50000 and Geological Map of Poland at a scale of 1:500000 as well as expert knowledge.

Majority of the aquifers in Poland are sandy, but in many regions (central, south-east, and south parts of the country) aquifers are located in fractured sedimentary rocks (sandstones, limestones, marls ect.) or fractured igneous and metamorphic rocks. Aquitards are dominated by glacial till (sandy) but locally may coexist or be replaced by silts and clays.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations which make up these layers (HMP at a scale of 1:50000). Majority of the layers are the Quaternary age, with some deeper layers belonging to Tertiary, Mesozoic or Paleozoic formations.

3.2.5 Layer type

The layer type was taken from Hydrogeological Map of Poland Main Useful Aquifer (HMP) and Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics, both at a scale of 1:50000. The dominating tape of aquifer in given grid cell (10x10 km) was assigned.

3.2.6 Aquifer type

The aquifer type was taken from the serial maps at a scale of 1:50000 - *Hydrogeological Map of Poland Main Useful Aquifer (HMP)* and *Hydrogeological Map of Poland First Aquifer – Extent and Hydrodynamics.* The dominating type of aquifer in given grid cell (10x10 km) was assigned.

3.2.7 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, and the anisotropy value) were determined based on a combination of model values and expert judgement. The anisotropy value was determined by expert judgement and set at 10 for all aquifers.

3.2.8 Artesian/Paleo/Thermal

For -Poland, no artesian and thermal aquifers were characterized. Although there are artesian aquifers present in the Poland, these are not significantly large enough at a 10x10 km scale. Thermal waters are not present in Poland at the depth range of the active groundwater zone.

4 LITERATURE

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Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata PORTUGAL

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

In this document, LNEG describes the methodology used to fill the Portugal database for work package WP6 of the RESOURCE project (Pan-EU Groundwater Resources Map).

The distribution of groundwater resources in mainland Portugal is closely related to the geological framework.

The most productive aquifers with abundant resources are located in the Meso-Cenozoic basins (Western, Southern and Tejo-Sado), occupied essentially by detritical or carbonate rocks. In the Western Mesocenozoic Basin the main aquifer systems are supported by Tertiary and Quaternary detritical formations (sands, dune sands, terraces, alluvium, clays), Cretaceous sandstones, limestones and argillites, and Jurassic limestones and marls. In the Southern Mesocenozoic Basin the aquifer systems are supported by Quaternary deposits (continental sands and gravels, and dune sands), Miocene formations (fundamentally of marine facies), Cretaceous detritical and carbonate formations and Jurassic limestone and dolomitic formations. In the Tejo-Sado Basin the aquifer systems are supported by Quaternary formations (alluvium and terraces), Tertiary formations, mainly Pliocene and Miocene (sandstones and limestones).

The Ancient Massif is mainly composed by fissured aquifers supported by granitic and schistose rocks, which may show relevant resources on a local scale, related with intense fractured or lithological contact zones. In this Massif, there are also some Paleozoic formations (limestones, quartzites and gabbros) and Quaternary and Tertiary deposits, which constitute important aquifers systems at regional scale.

The Portugal template is filled essentially using expert judgment. The main source of the information was the report entitled “Sistemas Aquíferos de Portugal Continental” (Almeida et al., 2000), which makes the compilation and systematization of the hydrogeological settings for all mainland country. However, for most of the territory without individualized aquifers (which corresponds to great part of the 10x10 km grid cells), the hydrogeological data are scarce and other sources of information were needed, such as geological maps and cross-sections, boreholes logs, technical reports, publications, doctoral and master’s thesis.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Average altitude over the grid cell in meters relative to the Copernicus European Digital Elevation Model (EU-DEM), version 1.1.	http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1/view)
Total_depth_active_layers	Based on expert judgment.	
Unsaturated zone thickness and extent	Unsatured zone thickness - Defined from the piezometric monitoring network data of National Water Resources Information System (snirh.pt) provided by Portuguese Environment Agency (APA). Unsaturated zone extent - Defined from the Geological Map of Portugal, at scales 1:1 000 000 and 1:500 000.	https://snirh.apambiente.pt/index.php?idMain=2&idItem=1 https://geoportal.lneg.pt/en/open_data/wms_services/
Saturated zone thickness and extent	Saturated zone thickness - Based on expert knowledge and interpretation of geological cross-sections. Saturated zone extent - Based on the Geological Map of Portugal, at scales 1:1 000 000 and 1:500 000.	https://geoportal.lneg.pt/en/open_data/wms_services/
Hydrogeofacies	Based on expert knowledge and on Geological Map of Portugal, at scales 1:1 000 000 and 1:500 000.	https://geoportal.lneg.pt/en/open_data/wms_services/
Geological age	Basead on the Geological Map of Portugal, scale 1:1 000 000.	https://geoportal.lneg.pt/en/open_data/wms_services/
Layer type	Based on expert knowledge and on the report “Sistemas Aquíferos de Portugal Continental”.	https://snirh.apambiente.pt/index.php?idMain=4&idItem=3&idISubtem=link4
Aquifer type	Based on expert knowledge and on the report “Sistemas Aquíferos de Portugal Continental”.	https://snirh.apambiente.pt/index.php?idMain=4&idItem=3&idISubtem=link4
Hydrological parameters	Based on expert knowledge and on the report “Sistemas Aquíferos de Portugal Continental”.	https://snirh.apambiente.pt/index.php?idMain=4&idItem=3&idISubtem=link4
Artesian/Paleo/Thermal	Based on the thermal occurrence database – LNEG’s GeoPortal and Hidrogenoma website of the General Directorate of Energy and Geology (DGEG).	https://geoportal.lneg.pt/en/databases/termalbase/#!/ https://hidrogenoma.javali.pt/aguas-minerais-naturais/mapa?utilizacao=All&quimismo=All&distrito=All&concelho=All

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

For the Pan-EU groundwater resources map, it was used the Copernicus European Digital Elevation Model (EU-DEM), version 1.1 (25m resolution with vertical accuracy: ± 7 meters RMSE). The mean surface level altitude was calculated using ArcMap tools, for each 10x10 km grid cell.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth active layers were determined based on hydrogeological boundary (H). In fissured and karstic aquifers was considered the vertical extend of the fissured and karstified zones. In porous aquifers, the depth of the geological formation with lower hydraulic conductivity was considered. Sometimes the total depth active layers were estimated from knowledge of borehole depths, logs and geological cross-sections.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The unsaturated zone thickness as obtained from the statistical analysis of the piezometric level network series available on the National Water Resources Information System (snirh.pt) managed by Portuguese Environment Agency (APA). However, in Portugal, most of the piezometers are concentrated in the main aquifer systems, so many cells (10x10 km) don't have piezometric information available and, in this case, layers are labelled as "no data".
In each 10x10 km cell, the extend of the unsaturated zone of each layer corresponds to the respective extension of the outcropping geological formation and was obtained from the geological maps of Portugal (scales 1:1 000 000 and 1:500 000).
Thus, there are many cells where the unsaturated zones are equal in number to the different geological formations.
The unsaturated zone dynamics was set at N (Naturally seasonal variability) for almost all layers, except for karst aquifers, which was set at K (Karst systems with seasonal groundwater level fluctuation). Sometimes, namely in Meso-Cenozoic basins, there is locally depletion by pumping (P), but that will not be significant at the scale of the Pan-EU groundwater resources map.

3.2.2 Saturated zone thickness & extent

The saturated zone thickness was mostly determined based on expert knowledge.
For both porous and karst aquifer systems, the estimation of aquifer thickness was based on geological maps and logs, technical reports, doctoral and master's thesis. For fissured aquifers it was considered that the saturated thickness is the vertical extent of weathered and/or the dense fissured layers.
The extend of the saturated zone was obtained from the geological maps of Portugal (scales 1:1 000 000 and 1:500 000) and geological cross-sections.

3.2.3 Hydrogeofacies

Mainland Portugal has great geological complexity and considerable lithological diversity, resulting in a high number of layers, spending long time on data processing. Moreover, high levels of detail would not have cartographic expression on a Pan-European map. As such, a lithological simplification was applied by grouping dominant lithologies by age in the aquifer systems.

The Quaternary and Tertiary unconsolidated-deposit aquifers was set as alternation of unconsolidated sedimentary hydrogeofacies.

The consolidated sedimentary rocks of the Tertiary, Cretaceous and Jurassic age was set as alternation of compact sedimentary hydrogeofacies

The Jurassic carbonated rocks with karstification was set as Karstified limestone.

Igneous and metamorphic rocks of the Ancient Massif was set as fissured igneous and metamorphic rock. The exceptions are the Paleozoic crystalline limestones with karstification (Karstified limestone) and the weathering layer of the gabbros (weathered gabbro).

In the Lisboa area the Cretaceous basalt rocks was set as fissured basalts.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations considered in the official geological maps of Portugal.

The part of the country corresponding to the Ancient Massif is formed by igneous and metamorphic rocks of the Paleozoic (Cambrian to Permian), as well as of the Precambrian.

In the western and southern sedimentary borders of the country corresponding to the Meso-Cenozoic basins there are outcrops with ages from the Quaternary to the Triassic.

In the sedimentary Tejo-Sado basin there are outcrops of the Holocene to Paleogene.

3.2.5 Layer type

The layer type was determined based on expert knowledge.

In the particular case of porous aquifers was adopted MIX classification (aquifers and aquitards), because at the scale of the Pan-EU groundwater resources map it isn’t feasible distinguishing the aquifer and aquitard layers in the cells (10x10 km).

In the remaining cases (karst and fissured aquifers) the layers were set as AQF (aquifers).

3.2.6 Aquifer type

The aquifer type is determined based on expert knowledge.

In cells (10x10 km) where the aquifers are both unconfined (U) and confined (C) and it isn’t feasible to distinguish them, it was decided to consider the most representative aquifer type.

3.2.7 Hydrological parameters

The hydrological parameters effective porosity, horizontal and vertical hydraulic conductivity, and the anisotropy value were determined based on expert judgement (EJ).

In general, for the effective porosity the following values were considered: 0.01 to 0.03 for igneous and metamorphic fissured rocks; 0.07 for weathered gabbro; 0.04 and 0.05 for karstified limestone; 0.04 to 0.1 for Tertiary and Cretaceous sedimentary formations; 0.15 for Quaternary sedimentary deposits.

The horizontal hydraulic conductivity (k_h) was calculated by the ratio between the average transmissivity and the adopted saturated thickness.

The anisotropy value was set at 10 for all aquifers, except in the Aveiro Quaternary and Cretaceous aquifers systems located in the Western Basin, where it was set at 100, according to the parameters for the flow model developed by Condesso de Melo (2002) http://hdl.handle.net/10773/2753

3.2.8 Artesian/Paleo/Thermal

In Portugal database, the cells (10x10 km) with artesian, paleo and thermal waters were marked. However, the paleowaters (age < 10 000 years) and thermal waters (temperature ≥ 20º C) were assigned to the restricted cases of the hydromineral or thermal aquifers.
Technical information for the thermal and natural mineral waters can be found on Geoportal LNEG https://geoportal.lneg.pt/en/databases/termalbase/#!/ and Website Hidrogenoma of the General Directorate of Energy and Geology (DGEG) https://hidrogenoma.javali.pt/aguas-minerais-naturais/mapa?utilizacao=All&quimismo=All&distrito=All&concelho=All

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Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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Serbia

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Serbian template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for the Republic of Serbia, specifically Nothern Part of Serbia (Vojvodina Province – Backa) was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Generally, the Serbian template is filled by using information from Basic Hydrogeological Map of Serbia, scale 1:100.000 and Geological Map of Serbia, scale 1:300.000 and explanatory booklet, and information from published literature. Other parameters were filled using a combination of references, Geological Map of the Republic od Serbia, scale 1:300.000 and preliminary Basic Hydrogeological Map of the Republic od Serbia, scale 1:100.000 and expert judgement. The layers were identified in vertical direction by the expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Topographic maps, Digital Elevation Model (by GSS)	http://www.vgi.mod.gov.rs/
Total_depth_active_layers	Based on hydrogeological maps and literature; Boundaries based on hydrogeological setting;	Basic Hydrogeological Map of Serbia, scale 1:100.000 (Project from Geological Survey of Serbia) – Petrovic et al., 2017; Josipovic & Soro, 2012
Unsaturated zone thickness and extent	Determined from literature and projects	Josipovic & Soro, 2012
Saturated zone thickness and extent	Determined based on the national Basic hydrogeological map of the Republic of Serbia and by using references.	Josipovic & Soro, 2012, Petrovic et al., 2017
Hydrogeofacies	Hydrogeofacies are based on layer types. Generally: aquifers = loess, gravel, sands; aquitards = clay, clayey loam, mud, silt, marls – Nothern part of the country.	Basic Hydrogeological Map of Serbia, scale 1:100.000 (Project from Geological Survey of Serbia) - Petrovic et al., 2017; Geological Map of Serbia, 1:300.000 (Kalenic et al., 2015)
Geological age	Based on known ages of formations which form the layers	Geological Map of Serbia, 1:300.000 (Kalenic et al., 2015)
Layer type	Layers as described on the Basic Hydrogeological Map are labeled as aquifers/aquitards based on *kD* and *c* values.	Basic Hydrogeological Map of Serbia, scale 1:100.000 (Project from Geological Survey of Serbia) – Petrovic et al., 2017;
Aquifer type	Based on expert knowledge	
Hydrological parameters	Based on expert knowledge	
Artesian/Paleo/Thermal	Occurrence of thermal water based on geothermal database. Only layers where it is known that thermal water exist are characterized. Pale waters are not included, and only one artesian was included.	Petrovic Pantic et al., 2019

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Serbia is available as a DEM (Digital Elevation Model). The staff from Geological Survey of Serbia created the version that was used for this project. The average value of the altitude of the surface level was calculated for each 10x10 km grid cell.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

Based on borehole lithology and expert judgment the total depth of the active zone is defined. The information was collected from references and from explanatory booklet for Basic Geological Maps, scale 1:100.000. The top layer was defined based on maps and the average value of the top of this layer was calculated for 10x10 km grid cell.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

Based on literature, maps and cross-sections, and expert judgment unsaturated zone thickness, extent and dynamics were defined.

3.2.2 Saturated zone thickness & extent

Since Serbia does not have a hydrogeological model, determination of saturated thickness and the extent was a challenge. In general, the information on the saturated layers is based on the preliminary hydrogeological maps of Serbia, and information from cross-sections and borehole data. Based on literature and expert judgment geological layers were distinguished as hydrogeological units, aquifers and aquitards.

3.2.3 Hydrogeofacies

The hydrogeofacies was mostly determined based on expert knowledge. Generally, most of the aquifers used for the template from Vojvodina are sandy and aquitards are clayey. In the hydrogeofacies list provided with this project, 4 types of sands are classified: fine, silt size grains – Loess, medium and coarse sands and gravel. All aquitards are classified as clay, clayey loam, mud, silt, marls. Although this is a simplification of reality (there are much more types of sediment besides sand and clay), on a 10x10 scale this made the most sense. The region used for the Project is geologically very different from the rest of the country. However, available and precise data was provided for the RESOURCE WP 6.

3.2.4 *Geological age*

The geological ages of the layers were determined from the ages of the formations, which make up these layers. Generally, most of the layers are Quaternary, with some deeper layers belonging to Tertiary Neogene.

3.2.5 *Layer type*

Based on information from Geological Map, boreholes, and literature the four layers are included in the template. However, complete and precise information are for the layer one.

3.2.6 *Aquifer type*

For the aquifer types, a simple classification was used: if the first combined aquifer is above an aquitard, it was included as an unconfined aquifer. All aquifers below the first aquitard are included as semi-confined and confined aquifers.

3.2.7 *Hydrological parameters*

The hydrological parameters included in the template (porosity, horizontal and vertical conductivity, and the anisotropy value) were determined based on a combination of references and expert judgment. The porosity is based on expert judgment, with a value of 0.25 for sandy aquifers, 0.18 for gravel, 0.14 for medium sand, and 0.08 for loess, and 0.45 for clayey aquitards. Horizontal and vertical conductivities were determined from the model values. The *kD and* k_h values were taken from the literature. The anisotropy value was determined by expert judgment.

3.2.8 *Artesian/Paleo/Thermal*

Artesian and paleo aquifers were not characterized for Serbia. Although there are artesian aquifers present in Serbia, these are not significantly large enough at a 10x10 km scale. Only one artesian aquifer is included in the template based on the information from the borehole. Paleo waters are present in Serbia as well; however, the age-dating information is currently unavailable for use.

4 LITERATURE

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Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata Slovenia

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Slovenian template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for Slovenia was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

Generally, the Slovenian template for vertical delineation was filled using 3D hydrogeological models for alluvial aquifers and 3D hydrogeological model for geothermal aquifer in north-east part of Slovenia. The rest of the area where 3D models doesn’t exist, surface (hydro)geological maps and borehole data with combination of expert judgment was applied to estimate the geological layer depth and extension. Other parameters were filled using a combination of model results, references to background information and expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Average from digital elevation model resolution 25 x 25 m	https://www.e-prostor.gov.si/zbirke-prostorskih-podatkov/topografski-in-kartografski-podatki/digitalni-model-visin/digitalni-model-visin-z-locljivostjo-dmv-125-dmv-25-dmv-100/
Total_depth_active_layers	Combination between 3D geological models and expert judgment	Buser and Komac (2002), Rman and Šram (2019), GeoZS (2005, 2020).
Unsaturated zone thickness and extent	Determination from hydraulic contours constructed based on GWL measurements.	
Saturated zone thickness and extent	Layers are extracted based on surface hydrogeological map, 3D model of NE Slovenia and groundwater level	Buser and Komac (2002), Rman and Šram (2019), GeoZS (2020).
Hydrogeofacies	Hydrogeofacies are simplified to RESOURCE template based on geological and hydrogeological map.	Hydrogeological map 1 : 250 000 Buser and Komac (2002) Rman and Šram (2019)
Geological age	Based on known ages of formations which form the layers	Buser and Komac (2002)
Layer type	Layers as described in the hydrogeological map of Slovenia are labelled as aquifers/aquitards.	Hydrogeological map 1 : 250 000
Aquifer type	Majority of the layers are set to unconfined except deep geothermal aquifers which are confined.	
Hydrological parameters	Based on hydrogeological models, borehole data and expert judgment parameters for porosity, horizontal conductivity and anisotropy were derived	GeoZS (2004, 2005)
Artesian/Paleo/Thermal	Layers with thermal water are characterised. No artesian and paleo layers are included in Slovenian template.	Rman and Šram (2019)

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Slovenia is available as a DEM (Digital Elevation Model) from the Ministry of the environment and spatial planning, the surveying and mapping authority of the Republic of Slovenia. It its available in different resolution (5 m, 12.5 m, 25 m and 100 m). For RESORUCE project we have used DEM 25 m which we have averaged on 10 x 10 km cell.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of active zone is defined on two criteria. First is defined based on the top of hydrogeological base on areas where non-carbonate rocks occur (alluvial aquifers, NE part of Slovenia). In general, the total depth on alluvial aquifers is defined by total depth of the aquifer, on NE Slovenia several Neogene geothermal aquifers are developed where total depth reaches several km.
Second on areas where carbonate aquifers are developed the total depth is defined based on expert judgment (GeoZS, 2004) where thickness is estimated based on surface geological map, borehole data etc.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

Groundwater level maps are available for majority of alluvial aquifers in Slovenia in shapefile at archive of Geological Survey of Slovenia which were used for calculation of unsaturated zone thickness. On the rest of the non-carbonate areas expert judgment were used to estimate the unsaturated zone (GeoZS, 2005). The dynamic was set at N (or Naturally seasonal variability) for all those cells.
At the carbonate areas the dynamic was set at K (or Karst systems with seasonal groundwater level fluctuation) and were used the average minimum water level at cell 10 x 10 km for calculation of unsaturated zone.

3.2.2 Saturated zone thickness & extent

Majority of the time was dedicated to determining all water bearing layers. For that we have used the following shapefiles:

1. groundwater bodies,
2. hydrogeological map in scale 1 : 250 000,
3. outline of Ptuj-Grad Formation and Mura Formation (Rman and Šram, 2019),
4. hydrogeological parameters (porosity, hydraulic conductivity etc) required for calculation of infiltration and surface runoff based on Kennessy (GeoZS, 2004) and
5. shape of RESOURCE 10 x 10 km grid.

All shapefiles were intersected in ArcMap 10.8 so we got for each cell 10 x 10 km the information of groundwater body and hydrological layer based on surface hydrological map. Polygons or layers which covered less than 5% of the area in the cell were excluded from further processing. Further the characterisation for all Slovenia was done based on stratigraphic age of the unit in the cell 10 x 10 km, on the NE part of Slovenia 3D geological model was also used for layer delineation. Example is explained for cell ID 457_255. Cell intersects groundwater bodies (GWB) with ID 1001 and 1008 and several hydrogeological units (Figure 2):

1. 1001 III.c (Aquitard III.c GWB 1001)
2. 1001 I.a (Alluvial aquifer I.a GWB 1001)
3. 1008 II.a (Carbonate aquifer II.a GWB 1008)
4. 1008 II.b (Carbonate aquifer II.b GWB 1008)
5. 1008 III.a (Minor aquifer with limited groundwater resources III.a GWB 1008)

Based on RESOURCE chronostratigraphic methodology (Figure 1) the final result for selected cell is shown in Figure 2 and Table 1. Figure 3 shows the total number of layers for each cell 10 x 10 km.

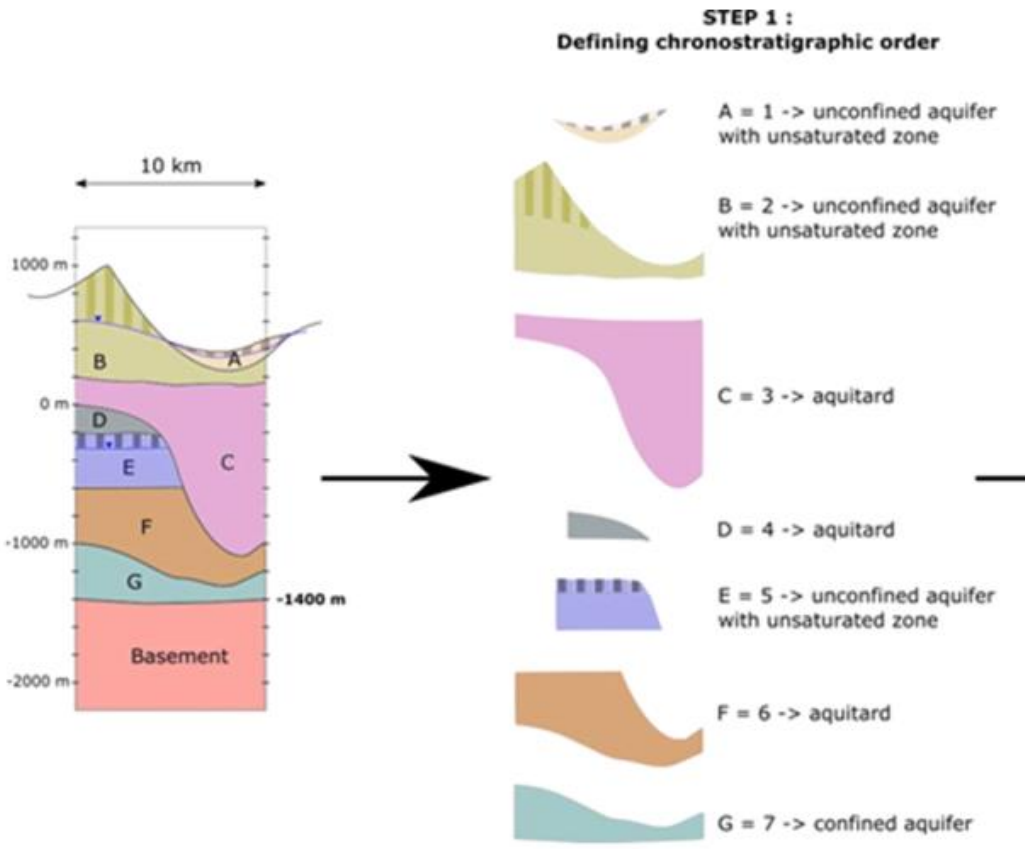

Figure 1: Defining layers chronostratigraphic order in RESOURCE project.

Table 1: Example of defined layers for cell ID 457_255

cell_id	Layer1	Layer2	Layer3	Layer4	Layer5
467_255	1001 III.c	1001 I.a	1008 II.a	1008 II.b	1008 III.a

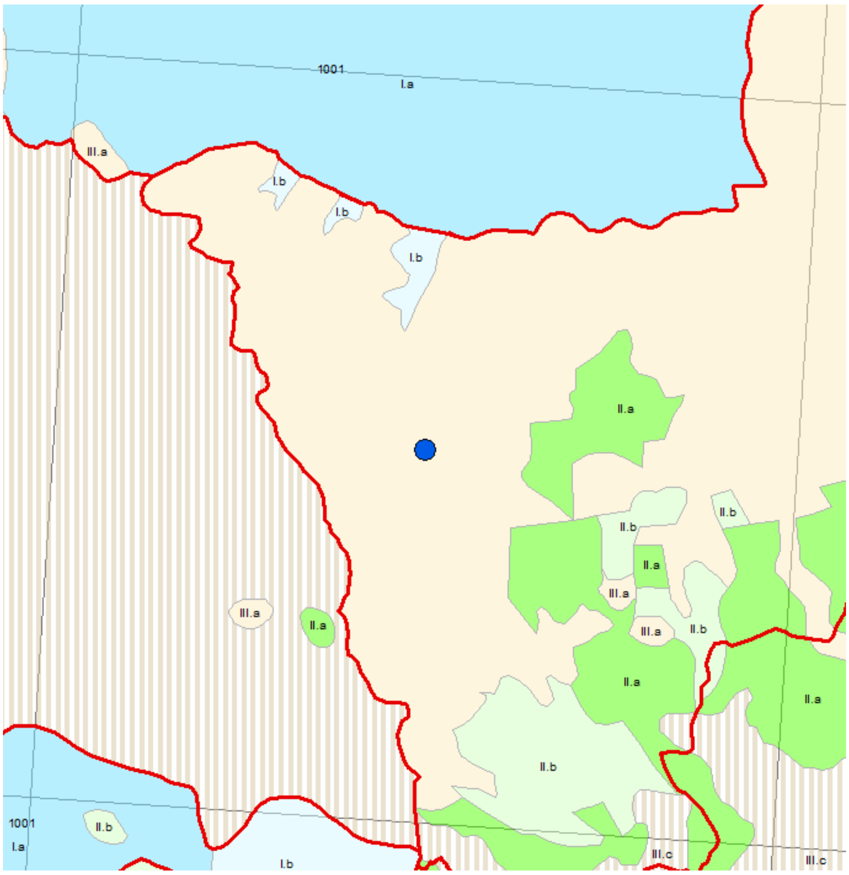

Figure 2: example of layers for cell ID 457_255.

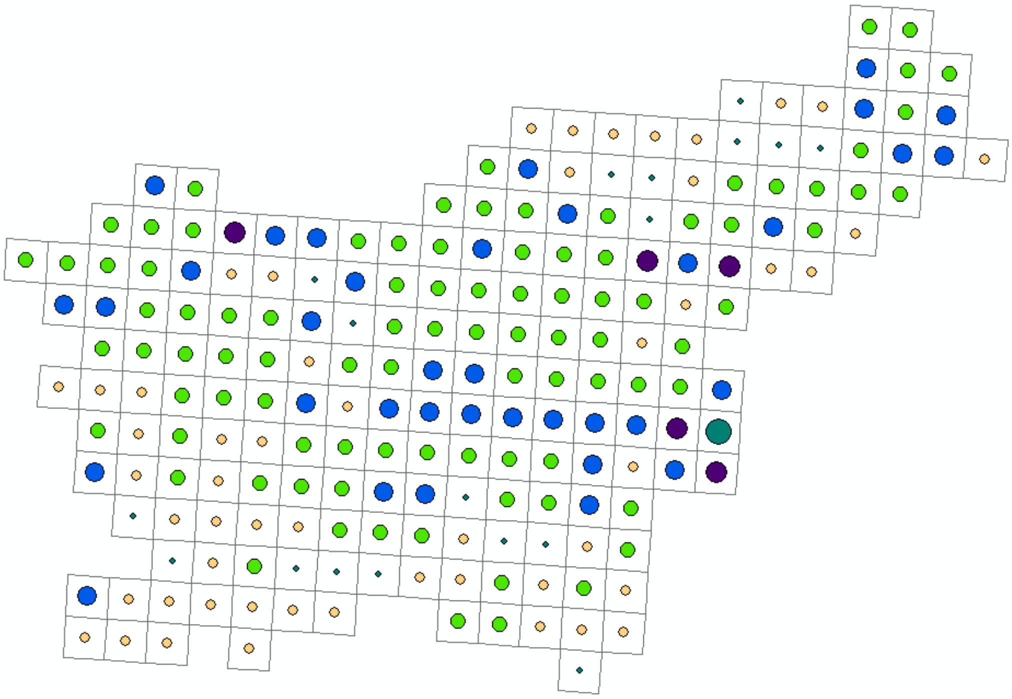

Figure 3: numbers of layers for each cell 10 x 10 km (black dot – 1 layer, brown dot – 2 layers, green dot – 3 layers, blue dot – 4 layers, purple dot – 5 layers and dark green dot – 6 layers).

Zone thickness was defined based on 3D models (GeoZS, 2020, Rman and Šram, 2019) and expert judgment (GeoZS, 2005).

3.2.3 Hydrogeofacies

Hydrogeofacies was determined based on description from hydrogeological maps, reports and expert knowledge. Description of hydrogefacies were simplified and adjusted to correspond the RESOURCE template. Highly productive alluvial aquifers are composed from gravel, sand, conglomerate, etc. They were downscaled and categorised as gravel which is the most prevailing component and most suitable to describe those layers. Thermal aquifers in NE Slovenia are defined as medium sand or gravel which is the prevailing component.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations which make up these layers. Age is quite diverse from the youngest Quaternary age of alluvial aquifers, tertiary in NE Slovenia of deep thermal aquifers, Mesozoic carbonate aquifers towards Paleozoic igneous and metamorphic layers.

3.2.5 Layer type

Layer type we defined as aquifer (AQF) or aquitard (AQT) based on hydrogeological map of Slovenia as follows:

Aquifer (AQF):

I: AQUIFERS IN WHICH FLOW IS MAINLY INTERGRANULAR (POROUS FORMATIONS GENERALLY NOT CONSOLIDATED)

- Extensive and highly productive aquifers
- Local or discontinuous productive aquifers, or extensive but only moderately productive aquifers

II: FISURED AQUIFERS, INCLUDED KARST AQUIFERS (FISSURED AND COMPACTED FORMATIONS)

- Extensive and highly productive aquifers
- Local or discontinuous productive aquifers, or extensive but only moderately productive aquifers

III: AQUIFERS IN WHICH FLOW IS MAINLY INTERGRANULAR (POROUS FORMATIONS GENERALLY NOT CONSOLIDATED)

- Minor aquifers with local and limited groundwater resources

Aquitard (AQT):

OVERLYING AQUITARDS

- Aquitards overlying aquifers of types I or II

3.2.6 Aquifer type

For aquifer type we used the unconfined category except for deep thermal aquifers in NE Slovenia of Mura Formation, Krško basin and Savinja valley and some cells where Flysch occurs were categorised as confined aquifers.

3.2.7 Hydrological parameters

The hydrological parameters included in the template (porosity, horizontal conductivity, and the anisotropy value) were determined based on a combination of model values (Rman and Šram, 2019), boreholes data and expert judgement (GeoZS, 2004 and 2005). In general, the porosity and hydraulic conductivity are derived from data which were used to calculate infiltration and surface runoff based on methodology presented by Kennessy (GeoZS, 2004). Except in NE Slovenia values were derived from numerical model. Anisotropy was based on expert judgment and factor 10 was used as a ratio between values of hydrological parameters in horizontal and vertical direction.

3.2.8 Artesian/Paleo/Thermal

For Slovenia, no artesian and paleo aquifers where characterized. Thermal waters where characterised in NE Slovenia (Mura Formation and Ptuj-Grad formation), Krško basin and in Savinja region. Temperature range is up to 70 deg C except for Mura formation where temperature can reach up to 130 deg C (Rman and Šram, 2019).

4 LITERATURE

Buser, Stanko, Komac, Marko (2002). Geološka karta Slovenije 1:250.000. *Geologija, letnik 45, številka 2, str. 335-340*

Hydrogeological map 1:250.000 (IAH) : http://gis.arso.gov.si/geoportal/catalog/search/resource/details.page?uuid=%7BD0A9674F-16B8-45A1-9E30-34B00F3A1C45%7D

Rman N., Šram D. (2019): Izdelava hidrogeloškega matematičnega modela toka podzemne vode in prenosa toplote v globokem geotermalnem telesu podzemne vode severovzhodne Slovenije – novelacija v letu 2019.

GeoZS (2004): Nacionalna baza hidrogeoloških podatkov za opredelitev teles podzemne vode Republike Slovenije – December 2004 (Opis metodolgije za oceno višine infiltracije in površinskega odtoka po Kennessyu).

GeoZS (2005): Nacionalna baza hidrogeoloških podatkov za opredelitev teles podzemne vode 2005.

GeoZS (2020): Raster datasets of alluvial aquifers bedrock.

Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata
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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Spanish template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for Spain (except Catalonia which has been done by the ICGC) was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

For the Spanish template we have tried a slightly modified methodology based on the information available on the main aquifer formations (MAF). Typically each groundwater (GW) body has one or two main aquifer formations which are relevant according to the amount of water resources. These geological formations usually consist of a group of single layers. So the values for the different parameters in the group of layers would be a mean value for the whole set. Then, the first step of the modified methodology is to organize the main aquifer formations (instead of single layers) in a cell by chronostratigraphic order. Different GW bodies (and their MAFs) within a cell are considered as different layers for the template. So, for the distinction of layers we have considered a lateral/horizontal approach (different GW bodies in a cell), combined with a vertical approach for different MAFs in a GW body.

Most of the information for each MAF was obtained from a data base developed for a national planning model (SIMPA), which has been updated by IGME based on a combination of models results, other available information (wells, projects…) and expert judgement. In Spain there are a total of 4610 active cells (10x10 km), 4285 are the aim of IGME and the other 325 of ICGC

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the DEM 100 dataset of the IGN	http://centrodedescargas.cnig.es/CentroDescargas/index.jsp
Total_depth_active_layers	Deepest hydrogeological base in the cell. From internal IGME project.	IGME-DGA, 2021
Unsaturated zone thickness and extent	Average for each hydrogeological sector in a GW body. From internal IGME project.	IGME-DGA, 2021
Saturated zone thickness and extent	Average for each hydrogeological sector in a GW body. From internal IGME project.	IGME-DGA, 2021
Hydrogeofacies	Simplified lithology from the lithostratigraphic map of Spain 200	http://info.igme.es/cartografiadigital/geologica/mapa.aspx?parent=../tematica/tematicossingulares.aspx&Id=15&language=es
Geological age	Youngest for each hydrogeological sector from the lithostratigraphic map of Spain 200	http://info.igme.es/cartografiadigital/geologica/mapa.aspx?parent=../tematica/tematicossingulares.aspx&Id=15&language=es
Layer type	Layers are labelled as aquifers/aquitards based on kD and c values. From internal IGME project.	IGME-DGA, 2021
Aquifer type	Based on description of GW bodies and hydrogeological sectors. From internal IGME project.	IGME-DGA, 2021
Hydrological parameters	Based on model values, pumping tests and expert knowledge. From internal IGME project.	IGME-DGA, 2021
Artesian/Paleo/Thermal	Artesian and thermal waters occurrence from IGME databases. Few data for paleo waters.	

3 DETAILED DESCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Spain has been obtained from a DEM (Digital Elevation Model) provided by the IGN (Instituto Geografico Nacional). The version that was used for this project has a resolution of 100 m. This and other resolution DEMs are available as open data to the public in http://centrodedescargas.cnig.es/CentroDescargas/index.jsp. The average value of the altitude of the surface level was calculated for each 10x10 km grid cell from that DEM 100.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active layers is preferably defined in Spain by the deepest top of the hydrogeological base in a cell (for the different layers). This basement consists of a very low permeability geological formation. In cases of very deep hydrogeological base (>1000m), a conventional depth limit has been considered taking into account a reasonable exploitable depth attending to an expert judgment.
The database used to obtain the information is part of an IGME-DGA project (IGME-DGA, 2021) which aims to update the SIMPA model (Ruiz, 1999; Estrela & Quintas, 1996). This is a national distributed balance model for estimation of water resources (surface and groundwater) for planning purposes at national scale.
In that database the information about aquifers is organized by hydrogeological sectors (HS) within the GW bodies. Those HSs are horizontal (more frequently) or vertical subdivisions of GW bodies attending to hydrogeological criteria, and they have a main aquifer formation associated to each one.
For the RESOURCE project we have considered one layer corresponding to each HS. The result is a horizontal subdivision of cells in not overlapping layers, sometimes with also a vertical subdivision (overlapping layers).
So, the total depth of active layers in Spain have been obtained by the deepest top of the hydrogeological base in the different layers within a cell.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The unsaturated zone thickness was calculated considering the mean piezometric level for the layer. This information was obtained from the database referred in the previous section (IGME-DGA, 2021), organized by hydrogeological sectors. So, the average unsaturated zone thickness is calculated in a cell as the mean unsaturated zone thickness of the HS within that cell.
The extent was calculated from the area of HSs within the cell. The label of dynamics was set according to the evolution of GW levels in the representative piezometers of each layer.

3.2.2 Saturated zone thickness & extent

The saturated zone thickness was also calculated considering the mean piezometric level for each layer (hydrogeological sector). This information was also obtained from the database referred in the previous section (IGME-DGA, 2021), organized by hydrogeological sectors. So, the average saturated zone thickness is calculated for a

layer in a cell as the mean saturated zone thicknesses of the corresponding HS within that cell.
The extent was calculated from the area of HSs within the cell.

3.2.3 *Hydrogeofacies*

The hydrogeofacies was determined comparing the list of classes established for RESOURCE with the lithofacies of the Lithostratigraphic Map of Spain 1:200.000 performed by IGME, which is available for the public at the link: http://mapas.igme.es/Servicios/default.aspx#IGME_Litoestratigrafico200.
The predominant lithofacies for the main aquifer formation of each layer/hydrogeological sector was obtained from that map, and then linked to a hydrogeofacies from the RESOURCE list.

3.2.4 *Geological age*

The geological ages of the layers were also obtained from the Lithostratigraphic Map of Spain 1:200.000 (http://mapas.igme.es/Servicios/default.aspx#IGME_Litoestratigrafico200) for the main aquifer formation of each layer/hydrogeological sector.

3.2.5 *Layer type*

Since most of the information derive from the IGME previously referred database (IGME-DGA, 2021), which is organized by hydrogeological sectors of the GW bodies and associated to their main aquifer formations, most layer types are considered as aquifers. However, in cases with very low hydraulic conductivities (<0.001 m/d), they have been considered as aquitards.
For those aquifer formations consisting of alternating layers of aquifers and aquitards the mixed type has been assigned.

3.2.6 *Aquifer type*

Most uppermost layers in a cell (with our methodology a horizontal division of layers is obtained) has been considered as unconfined aquifers. It has been verified with the descriptions of GW bodies in different reports performed by IGME (IGME-DGA, 2009), and then reclassified as semiconfined or confined aquifers if necessary. For the underlying layers/hydrogeological sectors the confined type has been considered.

3.2.7 *Hydrological parameters*

Most of the information for the hydrological parameters included in the template (porosity, and horizontal conductivity) has been obtained from the IGME previously referred database (IGME-DGA, 2021), which reflect data from different sources: models, pumping tests, reports, expert judgment, etc. Since very few data on vertical hydraulic conductivity are available, a conventional anisotropy value of 10 has been considered for all layers. So, the vertical hydraulic conductivity has been calculated applying this anisotropy value (kv=kh/10).

3.2.8 *Artesian/Paleo/Thermal*

For the occurrence of artesian wells in aquifers the IGME water points database (https://info.igme.es/BDAguas/) has been consulted. The existence of thermal waters has been obtained from the mineral and thermal waters database of IGME, with restricted access (http://aguasmineralesytermales.igme.es/datos-estadisticos). Since very few data are available on paleo waters, they have not been considered in our template.

4 LITERATURE

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Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata Catalonia

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TABLE OF CONTENTS

1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the template filled for Catalonia for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for Catalonia was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling that particular parameter and describing the background of the data.

For the case of Catalonia, the main unit of work was the aquifer, understood as a set of geological units grouped according to their hydrogeological characteristics. The base aquifers map used for Catalonia was developed by the Catalan Water Agency (ACA) at 1:50.000 scale (ACA, 2013). To attribute hydrogeological and geometric features to these aquifers, two main data sources among others were gathered: the information generated by the ACA for the characterization of water bodies was used, as well as the information included in the database that complements the SIMPA model (Spanish acronym meaning "Integrated System for Rainfall-Runoff Modelling") The SIMPA is a distributed hydrological model used for the evaluation of water resources in a natural regime. It was developed by the Center for Hydrographic Studies of the CEDEX (Center for Studies and Experimentation of Public Works) within the Ministry of Development (https://www.miteco.gob.es/es/agua/temas/evaluacion-de-los-recursos-hidricos/evaluacion-recursos-hidricos-regimen-natural/). The database of the SIMPA model referring to the internal basins of Catalonia was provided by ACA and for the Ebro basins it was provided by the Geological and Mining Institute of Spain (IGME). Additionally, it was necessary to gather information also from the hydrogeological maps of Catalonia developed by the ICGC at different scales (1:25K and 1:250K), the ICGC hydrogeological database, and the refence data of the recently published "Intrinsic vulnerability to pollution map of the Aquifers of Catalonia" (MVIAC) at 1:100.000 scale (ICGC, 2020).

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	Averaged from the DTM of 15x15 meters resolution (ICGC, 2011)	https://www.icgc.cat/en/Downloads/Elevations/15x15-m-Terrain-elevation-model
Total_depth_active_layers	Defined from depths of deep wells in each cell (SDIM-ACA), the thickness data of the water bodies from the database of SIMPA model, the estimated depths of the boundary between fresh and salt water in coastal areas and the hydrogeological description areas reports from ACA (non-accessible).	http://aca-web.gencat.cat/sdim21/
Unsaturated zone thickness and extent	Treatment of databases from ICGC, SDIM-ACA and SIMPA. Treatment of the reference data used to develop the layer "D" (Depth to water table) carried out for the Intrinsic vulnerability to pollution map of the Aquifers of Catalonia (MVIAC) (ICGC, 2020).	http://aca-web.gencat.cat/sdim21/ https://www.icgc.cat/en/Public-Administration-and-Enterprises/Tools/Geoindex-viewers/Geoindex-Intrinsic-vulnerability-to-pollution-map-of-the-aquifers
Saturated zone thickness and extent	Treatment of databases from ICGC, SDIM-ACA and SIMPA. Treatment of the reference data used to develop the layer "D" (Depth to water table) carried out for the Intrinsic vulnerability to pollution map of the Aquifers of Catalonia (MVIAC) (ICGC, 2020).	http://aca-web.gencat.cat/sdim21/ https://www.icgc.cat/en/Public-Administration-and-Enterprises/Tools/Geoindex-viewers/Geoindex-Intrinsic-vulnerability-to-pollution-map-of-the-aquifers
Hydrogeofacies	Defined from the Aquifer map of Catalonia at 1:50.000 scale (ACA, 2013).	http://aca.gencat.cat/ca/laigua/consulta-de-dades/descarrega-cartografica/index.html#googtrans(ca|en)
Geological age	Based on the geological age of the aquifers included in the Aquifer map of Catalonia at 1: 50.000 scale (ACA, 2013), which is based on the geological cartography of Catalonia at a scale of 1:50.000 (ICGC, 2016).	http://aca-web.gencat.cat/aca/cartografia/AcaExportacioDades.html https://www.icgc.cat/en/Public-Administration-and-Enterprises/Downloads/Geological-and-geothematic-cartography/Geological-cartography/Geological-map-1-50-000
Layer type	Defined from the Aquifer map of Catalonia at 1:50.000 scale (ACA, 2013).	http://aca-web.gencat.cat/aca/cartografia/AcaExportacioDades.html
Aquifer type	Defined from the Aquifer map of Catalonia at 1:50.000 scale (ACA, 2013).	http://aca-web.gencat.cat/aca/cartografia/AcaExportacioDades.html
Hydrological parameters	Defined from the data included in the database of the SIMPA model, the SDIM-ACA database, and the hydrogeological maps of Catalonia at 1:25.000 scale (ICGC, 2009-2017). Treatment of the reference data used to develop the layer "C" (hydraulic Conductivity) carried out for the Intrinsic vulnerability to pollution map of the Aquifers of Catalonia (MVIAC) (ICGC, 2020).	https://www.icgc.cat/en/Public-Administration-and-Enterprises/Downloads/Geological-and-geothematic-cartography/Hydrogeological-cartography/GT-V.-Hydrogeological-map-1-25-000 https://www.icgc.cat/en/Public-Administration-and-Enterprises/Tools/Geoindex-viewers/Geoindex-Intrinsic-vulnerability-to-pollution-map-of-the-aquifers http://aca-web.gencat.cat/sdim21/
Artesian/Paleo/Thermal	Defined from the data included in the hydrogeological databases of SDIM-ACA and ICGC (water points with indicators of special and/or thermal waters dataset from the ICGC shallow and deep geothermal viewers)	http://aca-web.gencat.cat/sdim21/ https://www.icgc.cat/en/Public-Administration-and-Enterprises/Tools/Geoindex-viewers/Geoindex-Deep-geothermal-energy https://www.icgc.cat/en/Public-Administration-and-Enterprises/Tools/Geoindex-viewers/Geoindex-Shallow-geothermal-energy

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The altitude of the surface level in Catalonia is available as a DEM (Digital Elevation Model) through the ICGC. The version that was used for this project was the 15X15m resolution. It is available as open access data (see https://www.icgc.cat/en/Downloads/Elevations/15x15-m-Terrain-elevation-model). For the use in the Pan-EU groundwater resource map, the average value of the altitude of the surface level was calculated for each 10x10Km grid cell from the 15X15m DEM.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth to active layers (TDAL) was one of the most difficult parameters to evaluate due to the complexity of the geological and hydrogeological environment of Catalonia. In this sense the meaning of this parameter is questionable for areas as hydrogeologically heterogeneous as Catalonia. To define this parameter, the thicknesses of the different layers contained in each cell (aquifers) was defined based on the data available in the databases generated for the SIMPA model, from the hydrogeological areas reports of ACA and from ICGC database. The geological map of Catalonia at 1:50.000 scale (ICGC, 2016) and the hydrogeological available maps at 1:25.000 scale (ICGC, 2009-2017) were also considered.

In most cases the layers (aquifers) included in each cell are not superimposed, therefore the sum of the different thicknesses could not be directly applied. In order to define a reasonable TDAL value, different criteria were applied:

- In some areas where no information was available, the maximum depth of the wells and piezometers present in each cell were considered as the "known exploitable limit".
- In areas where the well or boreholes information did not provide reliable data, the available information from database of SIMPA model was considered. Furthermore, this information was verified and modified, if necessary, with expert judgment.
- In areas close to the coastline, the limit between fresh and salty water was estimated with expert judgment since the available data is very scarce.

Finally, given the high geological and hydrogeological heterogeneity throughout the territory of Catalonia, it was necessary to carry out a simplification. Therefore, upscaling was necessary by limiting the maximum number of layers included in the template. In this sense, aquifers with similar hydrogeological and geological characteristics were grouped and treated jointly.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

To define the thickness of the unsaturated zone, the reference data to develop the "D" layer (Depth to water table) for the Intrinsic vulnerability to pollution map of the Aquifers of Catalonia (MVIAC) (ICGC, 2021) was used. It was made considering water table

measurements from the hydrogeological ICGC and SDIM-ACA databases. From this information, a depth to water surface was generated with interpolation methods.
For the basement aquifers, the average depth of the water table was calculated for each 10X10Km cell. For quaternary aquifers, the thickness of the unsaturated zone was obtained from the reference data to develop the "D" layer (Depth to water table) for the Intrinsic vulnerability to pollution map of the Aquifers of Catalonia (MVIAC) (ICGC, 2020), taking an average value for the entire aquifer. The extension of each layer for each cell, was calculated from the percentage of extension in 2D, since a 3D model is not available, and it is only possible to calculate it from 2D cartography.

3.2.2 Saturated zone thickness & extent

To define the thickness of the saturated zone, the information obtained in the previous section was considered. The saturated thickness was calculated as the thickness of each layer, extracted from the information sources mentioned in the sections "Total depth of active layers" and the “Unsaturated zone thickness”. Furthermore, in the layers that represent confined aquifers the entire thickness of the layer was considered as saturated. Finally, in some cases, the saturated thickness was reviewed with expert judgment. The extension of each layer for each cell was calculated from the percentage of extension in 2D, since a 3D model is not available, and it is only possible to calculate it from 2D cartography.

3.2.3 Hydrogeofacies

To characterize the hydrogeofacies of each layer, the information included in the Aquifer map of Catalonia at 1:50.000 scale developed by ACA (ACA, 2013) was considered. Subsequently, the hydrogeofacies included in this cartography were related to the RESOURCE WP6 hydrogeofacies list included in deliverable 6.2.

Taking into account the geological and hydrogeological heterogeneity existing in Catalonia, there are numerous multi-layer aquifers, in which different hydrogeofacies are included. In these cases, the hydrogeofacies of greatest importance in terms of thickness were considered.

3.2.4 Geological age

For the geological age, the age of the aquifers included in the Aquifer map of Catalonia at 1: 50.000 scale (ACA, 2013) was considered. This map is based on the Geological map of Catalonia at 1: 50.000 scale carried out by ICGC (ICGC, 2016). In the case of aquifers with geological units of different ages, a broader geochronological classification was considered.

3.2.5 Layer type

To include the layer type in each layer, Aquifer map of Catalonia at 1: 50.000 scale (ACA, 2013) was considered. In this sense, this map includes groups of geological units with very low hydraulic conductivity, but which can act as aquifers in a very local way. These clusters are characterized and named as "local aquifers in low permeability media" and they were classified as aquitards. Local aquifers in low permeability media include, in general, igneous and metamorphic Palaeozoic materials, and poorly permeable media such as clays or marls. Aquifers in alluvial and non-alluvial detrital media and also aquifers in carbonate media were classified as aquifers while multilayer aquifers were classified into mixed.

The relationship with the values proposed and included in the template described in deliverable 6.2 was made as follows:

AQF: Aquifers in alluvial and non-alluvial detrital media, aquifers in carbonate media.
MIX: Multilayer aquifers
AQT: Local aquifers in low permeability media

3.2.6 Aquifer type

To characterize the aquifer type according to the values proposed in the template described in deliverable 6.2, the information contained in the Aquifer map of Catalonia at 1:50.000 scale (ACA, 2013) was used. In addition, the ACA and ICGC databases were consulted to include the water level measurements information on confined levels in the aquifer type in order to contrast and verify the initial information considered.

3.2.7 Hydrological parameters

Characterizing the hydraulic parameters and porosity was again a difficult task given the heterogeneity of geology and hydrogeology in Catalonia. For the characterization of hydraulic conductivity, the information included in the Hydrogeological map of Catalonia at 1: 25.000 scale developed by ICGC was used (ICGC, 2017).
This map is only available in some areas of the territory. Therefore, it was necessary to use other sources of information as the hydrogeological areas reports from the ACA and the database from the SIMPA model. In this case, a review with expert judgment of the values obtained was also carried out, since the SIMPA model characterizes water masses and the work unit in this project was the aquifer.
Also the reference data used for the development of the layer "C" (hydraulic Conductivity) for the Intrinsic vulnerability to pollution map of the Aquifers of Catalonia (MVIAC) was considered (ICGC, 2020).
The bibliographic data included in deliverable 6.2 was also applied for aquifers for which no information was available.

3.2.8 Artesian/Paleo/Thermal

The aquifers characterized as confined in the Aquifer map of Catalonia at 1:50.000 scale (ACA, 2013) were firstly identified. However, not all the aquifers characterized as “confined” are artesian aquifers. In this sense, a detailed review was necessary, taking into account the water table measurements available in the ICGC and SDIM-ACA databases.

About Paleo waters, in Catalonia, there is no available information regarding paleo waters.

About thermal layers, in Catalonia there are no aquifers characterized as thermal as a whole. Even so, there are several very well-known thermal springs and wells included in the shallow and deep geothermal viewers developed by ICGC (ICGC, 2020 & ICGC, 2021). Thus, only the part of the layer included in the cell in which the thermal springs and wells are located were characterized as thermal.

4 REFERENCES

ICGC, 2011. Model d'Elevacions del Terreny de Catalunya 15x15 metres (MET-15). Available at https://www.icgc.cat/en/Downloads/Elevations/15x15-m-Terrain-elevation-model

ICGC, 2020. Intrinsic vulnerability to pollution map of the Aquifers of Catalonia (MVIAC), at 1:100.000 scale. Available at https://www.icgc.cat/en/Public-Administration-and-Enterprises/Tools/Geoindex-viewers/Geoindex-Intrinsic-vulnerability-to-pollution-map-of-the-aquifers

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Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the Swedish template for work package 6 of the RESOURCE project (Pan-EU groundwater Resources Map). It provides the background information on how the template for Sweden was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in detail, giving the process behind filling the particular parameter and describing the background of the data.

Generally, the Swedish template is filled by using hydrogeological data from mainly regional data sets which describe the hydrogeological conditions in a overview scale.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	No data included	
Total_depth_active_layers	Based on regional hydrogeological maps	https://apps.sgu.se/kartvisare/kartvisare-grundvattenmagasin.html
Unsaturated zone thickness and extent	Based on regional hydrogeological maps	https://apps.sgu.se/kartvisare/kartvisare-grundvattenmagasin.html
Saturated zone thickness and extent	Based on regional hydrogeological maps	https://apps.sgu.se/kartvisare/kartvisare-grundvattenmagasin.html
Hydrogeofacies	Based on regional hydrogeological and geological maps	https://apps.sgu.se/kartvisare/kartvisare-jordarter-25-100.html https://apps.sgu.se/kartvisare/kartvisare-grundvattenmagasin.html https://apps.sgu.se/kartvisare/kartvisare-berg-50-250-tusen.html
Geological age	Based on known ages of formations which form the layer	
Layer type	Based on regional hydrogeological maps	https://apps.sgu.se/kartvisare/kartvisare-grundvattenmagasin.html
Aquifer type	Based on regional hydrogeological maps	https://apps.sgu.se/kartvisare/kartvisare-grundvattenmagasin.html
Hydrological parameters	Based on expert knowledge.	
Artesian/Paleo/Thermal	No artesian, paleo or thermal aquifers were characterized	

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

No data on the altitude surface level in Sweden is delivered.

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

The total depth of the active zone I defined by two boundaries in Sweden, for areas that has been covered by saltwater during the deglaciation, older relict saltwater is often present in the crystallin bedrock. In these areas, and in coastal areas the active zone is defined to between 50 and 150 meters depending on the local conditions. For areas not covered by saltwater during the deglaciation, the active zone is set to 200 meters. For most aquifers, the total thickness of the eskers is less than the depth to the saline groundwater. Problems with relict saline groundwater most occur in private wells drilled into the crystallin bedrock, which is not included as a groundwater resource in a European scale.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

For unconfined esker aquifers with a high content of gravel the unsaturated zone is set to 5 meters, in unconfined sandy esker aquifers the unsaturated zone is set to 3 meters. The unsaturated zone in confined or semiconfined aquifers in both quaternary sediments and in sedimentary bedrock is set to 0 meters.

In the cells, the extent of aquifers in the regional hydrogeological maps in the 10x10 km cells were calculated. In most cases, the upper most aquifers in the eskers covers less than 10 percent of the cells. In areas where sedimentary bedrock is present, or in some areas with icemarginal deltas or icelake areas the aquifers cover more the 50 percent of the cells.

All cells are coded as Natural seasonal variability. There are no areas In Sweden were groundwater levels in a 10x10 km scale is affected by mining or depletions by pumping.

3.2.2 Saturated zone thickness & extent

The extent of the saturated zones is the same as for the unsaturated zones. The thickness of the saturated zone is based on information from well drillings or on expert judgements. kD values is based on expert judgements, and set to 40 m^2/d for quaternary aquifers with a saturated zone of 10 meters and 500 m^2/d for quaternary aquifers with an saturated zone with more than 10 m.

3.2.3 Hydrogeofacies

The hydrogeofacies was mostly determined based on expert knowledge. Generally, most of the aquifers in Sweden are in eskers with sand or gravel. In order to harmonizes the map in a European scale, Sweden and Finland decided to classify all aquifers in sand and gravel as alternation of unconsolidated sedimentary hydrogeofacies. The sedimentary aquifers are classified from the regional hydrogeological maps as Limestone, Sandstone or Fissured Sandstone.

3.2.4 Geological age

The geological age of the layers was determined from the ages of the formations which make up these layers. Generally, most of the layers are Quaternary. Some aquifers in sedimentary bedrock have been included in the template. These are mainly Cretaceous, Jurassic or Silurian. Some fissured sandstones and sandstones are Cambrian or Precambrian. The Swedish bedrock mainly consist of crystallin bedrock with poor yield and is not included as a groundwater resource.

3.2.5 Layer type

All of the layers in the template are classified as aquifers, the information comes from regional hydrogeological maps of Sweden.

3.2.6 Aquifer type

Most of the upper aquifers (Layer 1) in Sweden is classified as unconfined aquifers. If the aquifer is covered by clay and the hydrogeological maps indicate confined conditions these cells are classified as confined. Aquifers in the sedimentary bedrock are classified as semiconfined or confined depending on the surface geological conditions. Areas with mainly poorly permeable sediments as clay is classified as confined and areas with more permeable soil types in the surface is classified as semiconfined.

3.2.7 Hydrological parameters

The hydrogeological parameters included in the template (porosity, horizontal and vertical conductivity and anisotropy value) are all based on expert judgement. The porosity is based on expert judgement with values of 0.3 for sand aquifers, 0.4 for gravel aquifers, 0.04 or 0.1 for Cambrian sandstones depending on the local conditions, 0.05 for fissured sandstones (both Precambrian and Silurian), 0.1 for Ordovician limestones, 0.15 or 0.2 for Cretaceous limestones depending on the local conditions and 0.2 for Jurassic sandstones.

The anisotropy value was set by expert judgement to 1 for all aquifers, even thus it may differ, especially in the sedimentary bedrock.

3.2.8 Artesian/Paleo/Thermal

For Sweden, no artesian, paleo or thermal aquifers were characterized. There are some partly artesian aquifers in Sweden, but these are not significantly large enough to be shown in a 10x10 km scale. Paleo and thermal waters are not present in Sweden.

4 LITERATURE

Hydrogeological maps: https://apps.sgu.se/kartvisare/kartvisare-grundvattenmagasin.html

Quaternary soil maps: https://apps.sgu.se/kartvisare/kartvisare-jordarter-25-100.html

Bedrock maps: https://apps.sgu.se/kartvisare/kartvisare-berg-50-250-tusen.html

Resources of groundwater, harmonized at
Cross-Border and Pan-European Scale

RESOURCE WP6 – Pan-EU Groundwater Resources Map

Metadata
United Kingdom

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1 INTRODUCTION AND GENERAL BACKGROUND

This document describes the metadata information for the United Kingdom (including the Isle of Man and the Channel Islands (Crown Dependencies)) template for work package 6 of the RESOURCE project (Pan-EU Groundwater Resources Map). It provides the background information on how the template for the UK was filled in, what data was used, and what choices were made to determine the different parameters. First an overview table is given, which gives a quick overview on the process of filling in the template and types of data used. After that a more detailed description is given in chapter 3 where each parameter is described in more detail, giving the process behind filling that particular parameter and describing the background to the data.

The extents and depths in the United Kingdom template were mostly filled in by using a 3D geological model of Great Britain (excluding the Orkney and Shetland Isles) which describes the subsurface bedrock in 19 vertically stratified units. For Northern Ireland, the Isle of Man and the Channel Islands (plus the Orkney and Shetland Isles) no 3D geological models are available and the bedrock units mapped as present below the Quaternary superficial deposits on the geological map were grouped on the basis of their aquifer properties and assumed to be present to their total thickness. Overlying superficial deposits over 4 m in thickness were classified on the basis of their lithology. The thickness of the unsaturated zone was based on depth to water models. The other aquifer parameters were filled in using a combination of published and grey literature and expert judgement.

2 OVERVIEW TABLE

Parameter	Short description	Link/reference
Altitude_surface_level	NEXTMap British Digital Terrain Model dataset for Great Britain (England, Scotland and Wales). Shuttle Radar Topography Mission dataset for the Isle of Man and Channel Islands. OS Open data DTM for Northern Ireland.	https://catalogue.ceda.ac.uk/uuid/8f6e1598372c058f07b0aeac2442366d https://www2.jpl.nasa.gov/srtm/ https://www.nidirect.gov.uk/node/3736
Total_depth_active_layers	Generally based on depth of aquifers, apart from where chlorides in Middle Jurassic limestones exceed 1000 mg/l inland. Everywhere except N Ireland - Maximum depth of 400 m for Devonian or younger age rocks and 200 m for Silurian and older age and intrusive igneous and metamorphic rocks. N Ireland - Maximum depth of 400 m plus superficial deposits thickness for Devonian or younger age rocks and 200 m plus superficial deposits thickness for Silurian and older age and intrusive igneous and metamorphic rocks.	Water Resources Board, 1969 https://www.bgs.ac.uk/datasets/wellmaster-hydrogeological-database/ UKTAG, 2012
Unsaturated zone thickness and extent	Depth to water model averaged for area of each of the superficial deposits classes, and where applicable bedrock units, over each 10 km grid cell	https://www.bgs.ac.uk/datasets/depth-to-groundwater/
Saturated zone thickness and extent	GB-Model thickness minus unsaturated zone thickness. Extent from model. N Ireland, Channel Islands and Isle of Man – Thickness minus unsaturated zone thickness. Extent from outcrop on geological maps.	https://www.bgs.ac.uk/datasets/superficial-thickness-model/ https://www.bgs.ac.uk/datasets/buried-valleys/ Coxon et al, 2020 Institute of Geological Sciences (1982; 1986) Bishop and Bisson, 1989 Newell, 2018 https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/ McConvey, 2015 https://www.bgs.ac.uk/datasets/bgs-geology-50k-digmapgb/
Hydrogeofacies	Predominant lithology from national geological map and Lexicon	https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/ https://www.bgs.ac.uk/technologies/the-bgs-lexicon-of-named-rock-units/
Geological age	Predominant age from national geological map and Lexicon	https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/ https://www.bgs.ac.uk/technologies/the-bgs-lexicon-of-named-rock-units/
Layer type	Attributed as aquifer, mixed or aquitard from combination of lithologies present in each model layer (GB) or geological unit (elsewhere) based on expert knowledge and literature review	
Aquifer type	Generally unconfined; locally where there is data from expert knowledge and geological maps, shown as semi-confined or confined.	https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/
Hydrological parameters	Based on expert knowledge and literature review. Horizontal hydraulic conductivity values based on transmissivity values and layer thicknesses	Allen et al, 1997; Jones et al, 2000; Wilson et al. (in preparation); Ó Dochataigh et al, 2015; Robins and Smedley, 1998; Kivits et al, 2020; published and grey literature,

Parameter	Short description	Link/reference
Artesian/Paleo/Thermal	Artesian - derived from published hydrogeological maps, reports and limited site specific information Paleo - from age dating Thermal	https://webapps.bgs.ac.uk/data/maps/maps.cfc?method=listResults&MapName=&series=HYDRO&scale=&pageSize=100; Water Resources Board reports; https://www.bgs.ac.uk/datasets/wellmaster-hydrogeological-database/ Published literature Published literature

3 DETAILED DISCRIPTION OF METADATA

3.1 Main information

3.1.1 Altitude_surface_level

The average ground surface elevation for Great Britain (England, Scotland and Wales) was calculated using the NEXTMap British Digital Terrain Model 2009 50 m DTM dataset (Intermap Technologies, 2007). This model does not cover Northern Ireland and so the 50 m Digital Terrain Model height dataset was used, which is an Ordnance Survey Northern Ireland Open Data product (https://www.nidirect.gov.uk/node/3736). For the Isle of Man and the Channel Islands, the ground elevation data were averaged using the Shuttle Radar Topography Mission (SRTM) 30 m dataset (https://www2.jpl.nasa.gov/srtm/).

3.1.2 Total_depth_active_layers & Label_maximum_depth active layers

For all of the United Kingdom (except Northern Ireland), the maximum depth of the active layers was 400 m in any cell which contained some bedrock younger than Silurian in age. The depth of active layers in cells containing only bedrock of Silurian and older age and intrusive igneous and metamorphic rocks was 200 m. In Northern Ireland, the maximum depth of the active layers was 400 m plus the superficial deposits thickness for Devonian or younger age rocks and 200 m plus the superficial deposits thickness for Silurian and older age and intrusive igneous and metamorphic rocks. The basis of this was the UKTAG (2012) recommended maximum depth of aquifers. Shallower depths were applied where the chloride ion concentrations exceeded 1000 mg/l inland in the Middle Jurassic limestones (Water Resources Board (1969) and Wellmaster database (https://www.bgs.ac.uk/datasets/wellmaster-hydrogeological-database/)). Where the chloride ion concentration exceeded 1000 mg/l at shallow depths in formations along the coast, the full thickness of the aquifer formation was removed from the appropriate grid cells.

3.2 Layer information

3.2.1 Unsaturated zone thickness, extent & dynamics

The extents and thicknesses of both the superficial deposits and bedrock units present within a 10 km grid cell were defined (see 3.2.2) and then the unsaturated zone thicknesses were calculated. Superficial deposits less than 4 m in thickness were not included.

For Great Britain the unsaturated zone thicknesses were derived using the British Geological Survey's depth to groundwater dataset (https://www.bgs.ac.uk/datasets/depth-to-groundwater/). This is a 50 x 50 m pixel raster grid, which gives an estimated maximum depth to groundwater, modelled using topographic elevation and hydrology. The model assumes that groundwater and surface water are connected hydraulically and is based on an interpolated river base level not groundwater level observations. As this gives a maximum depth to groundwater, it is a representative estimate. A similar model was used to derive the unsaturated zone thicknesses in Northern Ireland and Jersey, this used the same type of data, but is based on less extensive hydrological information. For the Isle of Man and the Bailiwick of Guernsey, depth to groundwater was modelled using only topographic data (DTM/6). The average depth to water was calculated across the area of each superficial deposits unit present, and where applicable for the underlying bedrock units, within every 10 km grid cell.

3.2.2 Saturated zone thickness & extent

The extents and thicknesses of both the superficial deposits and bedrock units present within a 10 km grid cell were defined and then the saturated zone thicknesses were calculated, by subtracting the unsaturated zone thickness for the superficial deposits unit, and where applicable the underlying bedrock units. Superficial deposits less than 4 m in thickness were not included.

The superficial deposits were classified into five distinctive hydrogeological units, based on their probable overall lithological composition. Their thickness was derived from the advanced superficial thickness model for Great Britain https://www.bgs.ac.uk/datasets/superficial-thickness-model/). Other datasets used were the glacial limits, buried valleys (https://www.bgs.ac.uk/datasets/buried-valleys/), a new superficial deposits productivity map developed for Coxon et al (2020) and the outcrop of the Crag Group. For Northern Ireland thickness information was available from the groundwater vulnerability screening methodology (Ball et al, 2005). For the Channel Islands the 1:25,000 scale geological maps (Institute of Geological Sciences, 1982; 1986) and Bishop and Bisson (1989) were used to obtain information on thicknesses. For the Isle of Man the thickness of the superficial deposits was taken from borehole data, with the thick sequence of deposits in the north of the island depicted as a buried glacial channel.

The bedrock unit thicknesses and extents for Great Britain (England, Scotland and Wales), were calculated from the simplified GB mainland geological model (Newell, 2018) with 19 geological units. The Permo-Triassic basins in SW England, SW Scotland and N Wales, were not delineated in the 3D model and were added in, using their extent from the 1:625,000 bedrock geology map (https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/) and typical thicknesses for each. Similarly some areas in SW England were poorly delineated by the model and the 1:625,00 bedrock geology map and formation thickness contours were used to estimate the extent and thickness of the units.

The 3D geological model for Great Britain does not include Northern Ireland, the Isle of Man, the Channel Islands or the Orkney and Shetland Isles. Expert judgement was used to estimate unit extents for the Orkney and Shetlands Isles. Geological maps attributed with an aquifer classification (McConvey, 2015) was used to indicate extents in Northern Ireland and BGS Geology 50k (https://www.bgs.ac.uk/datasets/bgs-geology-50k-digmapgb/) for the Isle of Man. For the Channel Islands extents were taken from the published 1:25,000 scale geological maps (Institute of Geological Sciences 1982; 1986). For all these areas, mapped bedrock units were assumed to be present to the base of the active layer; apart from two thinner formations in Northern Ireland (Ulster White Limestone and Hibernian Greensand; Belfast Group).

3.2.3 Hydrogeofacies

The hydrogeofacies of the layers were chosen using expert judgement to simplify the lithological information from the national geological map https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/ and the Lexicon https://www.bgs.ac.uk/technologies/the-bgs-lexicon-of-named-rock-units/. Often considerable generalisations were made, as few lithologies apart from the Chalk fitted exactly the options on the RESOURCE WP6 list (Kivits et al, 2020). For example most Quaternary aquifers comprise sand and gravel, but were coded as gravel. Similarly Permian rocks comprising a mixture of sandstones, breccias and conglomerates were coded as whichever of sandstone or conglomerate was most prevalent. Where there was a conflict, priority was given to attributing the appropriate flow type, and this took precedence over the aquifer's importance; so the Sherwood Sandstone Group was coded as a sandstone (local or only moderately productive intergranular aquifers, compact sedimentary hydrogeofacies) rather than a fissured sandstone (extensive and highly productive fissured aquifers, fissured sedimentary hydrogeofacies) as the predominant flow mechanism is intergranular, despite it being highly productive and the second most important aquifer in the United Kingdom. Similarly the Bracklesham Group of the London Basin predominantly comprises 'fine sand' (extensive and highly productive intergranular aquifers, unconsolidated sedimentary hydrogeofacies) but is only a local aquifer.

3.2.4 Geological age

The geological ages of the layers were determined from the ages of the formations which make up these layers. Deposits in the United Kingdom range in age from Quaternary to Archaean. Each layer was assigned an age from the RESOURCE WP6 list (Kivits et al, 2020) based on the the national geological map https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/ and the Lexicon https://www.bgs.ac.uk/technologies/the-bgs-lexicon-of-named-rock-units/.

3.2.5 Layer type

The layers in the Great Britain geological model were geological units rather than hydrogeological ones. Hence some contained a mixture of aquifers and aquitards, these were combined to produce mixed layers. Elsewhere the hydrogeofacies were defined as aquifers or aquitards; apart from one mixed unit identified on the Isle of Man. Rocks older than Permian in age are generally consolidated and hence have some fracture permeability, irrespective of lithology, and were all considered as aquifers.

3.2.6 Aquifer type

The default aquifer type was unconfined. However, for the main aquifers (Chalk, , Greensands, Corallian, Middle Jurassic limestones, Sherwood Sandstone and Zechstein), where the whole of a 10 km cell was overlain by an aquitard (https://www.bgs.ac.uk/datasets/bgs-geology-625k-digmapgb/) it was classed as confined. Some of the Permo-Triassic basins were shown as semi-confined, due to the near ubiquitous cover of superficial deposits.

3.2.7 Hydrological parameters

There are two reports on the physical properties of the major and minor aquifers of England and Wales (Allen et al, 1997; Jones et al, 2000) that formed the basis of the hydrological parameters used. These reports summarised all the available information on laboratory measured porosity and permeability and field derived values of transmissivity and storage coefficients, at the time of their publication. The reports do not cover the superficial deposits or clay and mudstone aquitard formations. There are also reports on Scottish aquifers (Ó Dochartaigh et al, 2015), Northern Ireland (in preparation) and Jersey (Robins and Smedley, 1998). However, the laboratory values derived from small core plugs require consolidated samples but do not include the secondary porosity and permeability from the majority of fractures. Similarly the field derived values are biased towards higher yielding sites where it was worth carrying out a pumping test. Therefore the data does not provide effective porosity values for all the units required, and the horizontal hydraulic conductivity values are generally too high. The data was supplemented by default values in Kivits et al (2020) and information from published and grey literature.

3.2.8 Artesian/Paleo/Thermal

Data on overflowing artesian conditions were primarily derived from the areas delineated as artesian on hydrogeological maps of the UK which ranged in date from 1967-1980 (https://webapps.bgs.ac.uk/data/maps/maps.cfc?method=listResults&MapName=&series=HYDRO&scale=&pageSize=100.); this was supplemented by data from Water Resources Board publications and some data from the Wellmaster database (https://www.bgs.ac.uk/datasets/wellmaster-hydrogeological-database/). There was some data for the Chalk, Lower Greensand, Middle Jurassic limestones, Sherwood Sandstone and Zechstein aquifers.

Paleowaters have been identified from published literature, with waters over 10,000 years old identified in four of the aquifer horizon units (Chalk, Lower Greensand and Spilsby Sandstone, Lincolnshire Limestone (Inferior Oolite) and Sherwood Sandstone).

Thermal waters in the United Kingdom are defined as springs emerging from the ground surface at more than 15°C, as below the zone of seasonal fluctuation, all groundwaters increase in temperature with depth. Thermal waters only occur in Dinantian age, Carboniferous Limestone in England and Wales.

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