GeoERA
RESOURCE GROUNDWATER

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

Deliverable 6.3

Maps showing the depth and volume of fresh groundwater

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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 (for the participants, see figure 1) where available data is compiled and integrated to produce a map of the fresh groundwater resources of Europe. Work Package 6 is divided in several tasks so that this goal can be achieved:

- Task 6.1: Criteria for harmonization across Europe;
- Task 6.2: Collection of data on depths and volumes;
- Task 6.3: Compilation of the map;
- Task 6.4: First estimate of water balance of EU's principal groundwater resources;
- Task 6.5: Data exchange with the Information Platform.

This document is the deliverable for task 6.3 of Work Package 6. It describes the maps that display the volume and depth of the fresh groundwater in Europe. These maps are made based on the template that was filled by all WP6 partners in task 6.2. More information on the reasoning behind the project and on the structure of the template and on what information was gathered is described in deliverable 6.2: Database with information on volumes and depths at 10x10 and/or 25x25 km grids (Kivits et al., 2020)[1].

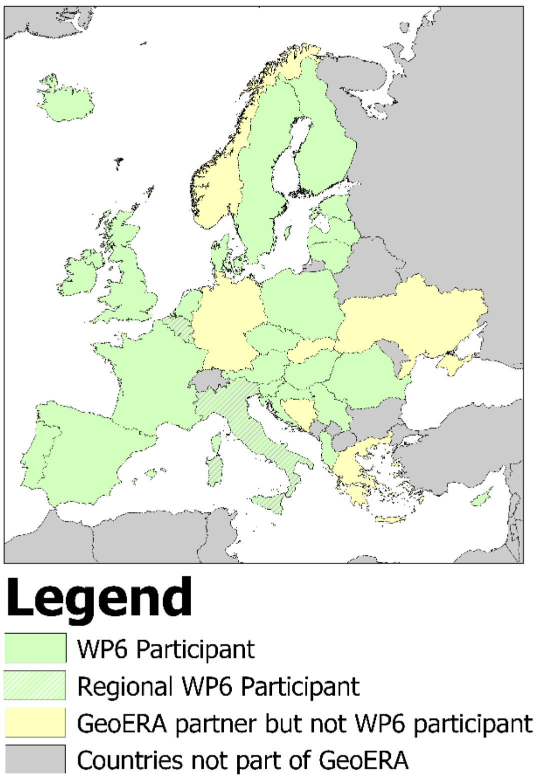

Figure 1 RESOURCE WP6 participants

The maps that are shown in this deliverable are the most recent versions at the time of completion of this deliverable (May 2021). However, it is expected that the content of the maps will still change somewhat, as quality control of the individual country templates is still being carried out. Further data is expected from the UK and Serbia. The final maps will be available on the EGDI platform at a later stage and will be part of deliverable D.6.4: "Dataset to be included in the Information Platform"

In chapter 1, the map of the volume of groundwater (here defined as the total groundwater storage) is showed and explained. Some examples of possible selections on this map are also given, which will eventually will also be available on EGDI.

In chapter 2, the map of the total depth of the active groundwater system is shown and explained, together with a map which shows the definition of the active zone in each cell.

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

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1 MAP SHOWING THE GROUNDWATER STORAGE

One of the main objectives of Work Package 6 of RESOURCE was to create a map displaying the total groundwater volume in aquifers over Europe. The maps that are shown in this chapter give a first quantification of the volume of groundwater, here defined as the estimated groundwater storage in km^3 per 10x10 km grid cell.

1.1 Method

The map of the total groundwater storage is made based on the information that the RESOURCE WP6 participants gathered in the template during task 6.2 – Collection of data on depths and volumes. The template was based on an existing 10x10 km INSPIRE grid which covers Europe. Each survey defined a number of layers within each 10x10 km grid cell in their country, and for each of those layers information on thicknesses, extents, ages, hydrogeofacies, hydrological parameters etc. was gathered. For more information on each of those parameters and how they are defined we refer to Deliverable 6.2: Database with information on volumes and depths at 10x10 and/or 25x25 km grids (Kivits et al., 2020)[1].

A number of the parameters defined in the template are used to calculate the total groundwater storage in km^3. Firstly, a selection is made for the saturated layers, as we wanted to exclude the unsaturated zone for the total groundwater volume. Next, the thickness of the saturated layers is multiplied by the extent (the percentage that the layer covers the 10x10 km grid cell) and the porosity. In formula, the calculation looks as follow:

Total groundwater storage = sum((L_n_saturated_thickness/1000) x (L_n_saturated_extent/100 x 10x10 km) x L_n_porosity.

With L_n expressing layer 1 to the total amount of layers defined in each cell. The thickness is divided by 1000 as this parameter is expressed in meters in the template, and the groundwater storage is defined as km^3. The extent is divided by 100 as it is expressed in the template as a percentage, and then multiplied by the area of the grid cell (which is 10x10 km). The volumes of all layers are then summed to get to the total groundwater storage in the 10x10 km grid cell in km^3.

1.2 Total groundwater storage in aquifers

Figure 2 shows the map of the total groundwater storage in aquifers in km^3 per 10x10 grid cell for the countries participating in WP6 of RESOURCE. The map reveals the wide range of groundwater storages in aquifers over Europe. The values range from < 0.1 to approximately 50 km^3 per 10x10km grid cell, with storages generally being high in sedimentary basins and karstified areas. The map gives an overview from the southwest of Spain to the very northeast of Finland, and from the southeast of Cyprus to the northwest of Iceland, covering a large part of Europe.

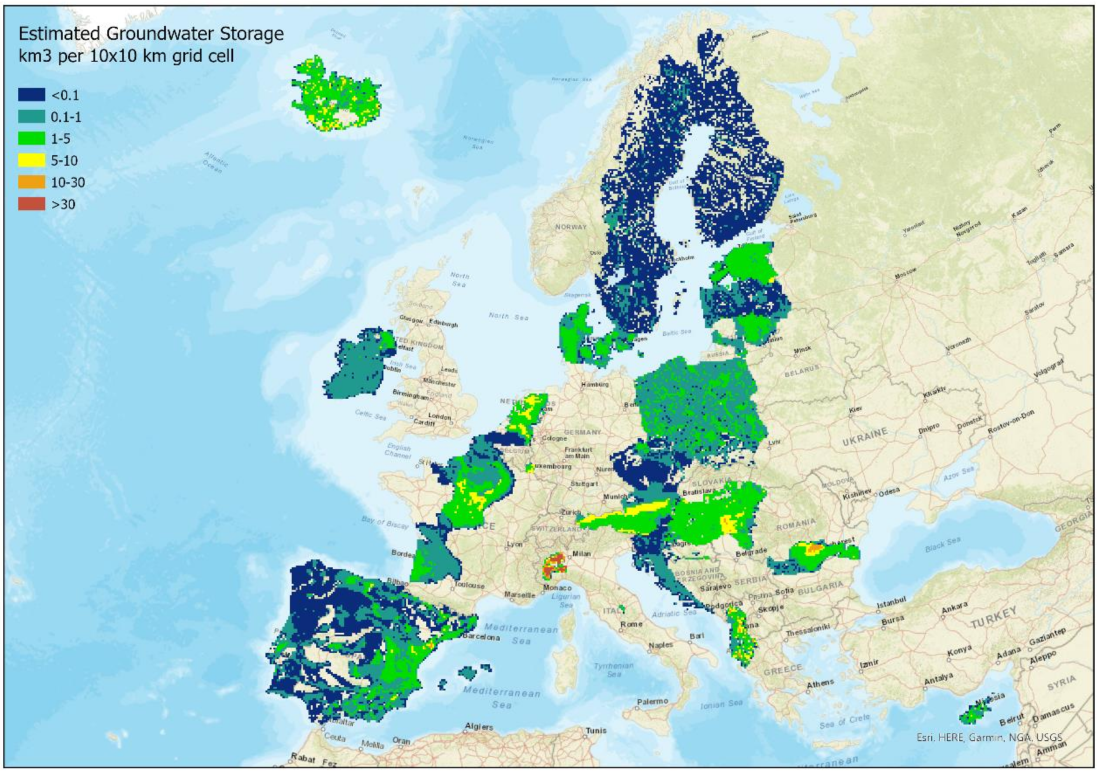

Figure 2 Map showing the total groundwater storage over Europe in km^3 per 10x10 km grid cell. Note that the total storage does not equal the storage available for sustainable abstraction (see section 1.2).

As stated in the introduction this map is not final as some quality control is being carried out. Also, the mainland of the UK and Serbia are expected to be added at a later stage. The current map unfortunately contains some "holes", which is either due to countries/regions not participating in WP6 or a lack of data or available time within this project to finish the complete country grid.

Another important note is that only a relatively small part of the groundwater storage is available for abstraction or other groundwater uses, as the water available for sustainable abstractions is rather determined by the recharge flux from the precipitation surplus, and by (elastic) storage coefficients of the aquifers. Under most conditions, only a small part of the total groundwater storage can be used sustainably without substantial dropping of groundwater heads and/or diminishing groundwater fluxes towards rivers and brooks, potentially affecting environmental flows needs of those. Still, the maps do give an overview on the differences that exist on groundwater storage in Europe. A first estimate of the water balance of Europe's groundwater resources will be carried out under task 6.5: "First estimate of water balance of EU's principal groundwater resources".

1.3 Examples of possible selections on the estimated groundwater storage

Next to the map of the total estimated groundwater storage as shown in Figure 2, the gathered data in the templates allows us to make more specific selections, showing the groundwater storage in more detail. In the template, information was gathered for example on geological ages, hydrogeofacies, aquifer types, and the occurrence of artesian, paleo, and thermal groundwater (see deliverable 6.2 for more details). Based on this information, specific types of aquifers can be selected for display. These more detailed maps will eventually be available through EGDI. Two examples are shown in this paragraph to give an impression of what is possible to display with the information that has been gathered.

A possible first selection that can be made is based on the geological age of the aquifers. All WP6 participant supplied data on the geological age of the different layers, which allows us to, for example, show the quantified total groundwater storage in the Quaternary aquifers (see Figure 3). Other foreseen selections based on geological ages that are going to be available on EGDI are Tertiary, Cretaceous, Jura, and Triassic and older aquifers.

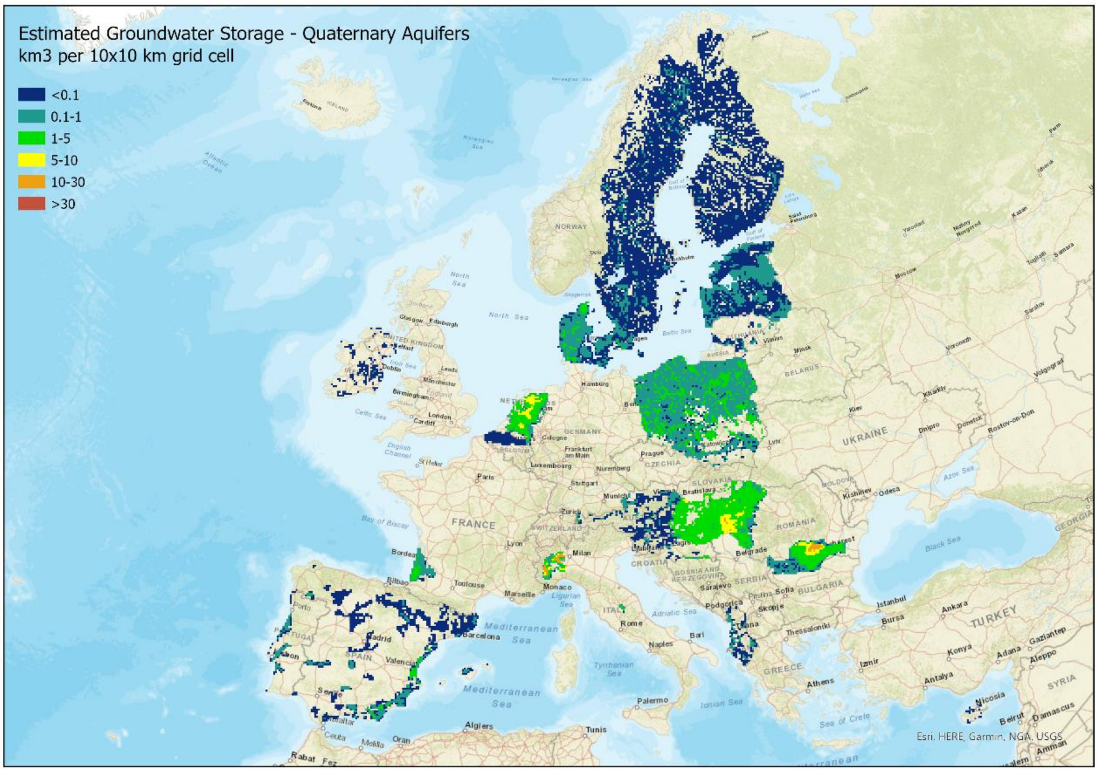

Figure 3 Total groundwater storage in Quaternary aquifers in km^3 per 10x10 km grid cell. Note that the total storage does not equal the storage available for sustainable abstraction (see section 1.2).

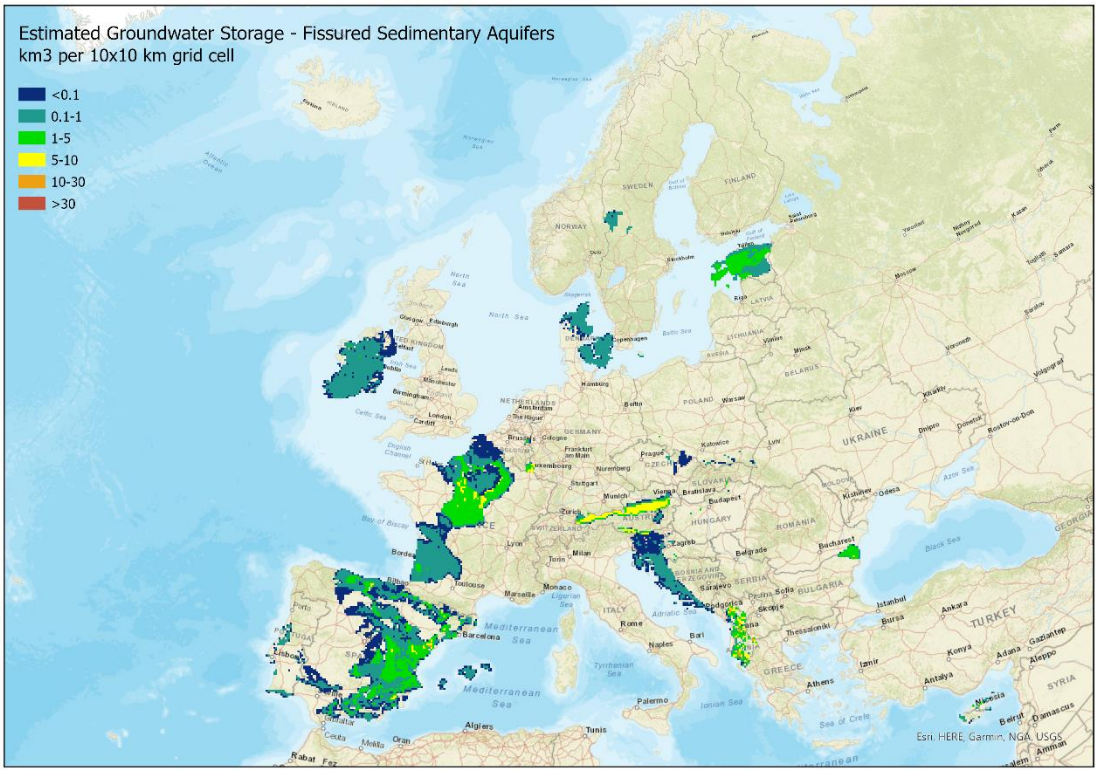

Figure 4 Total groundwater storage in fissured sedimentary aquifers in km^3 per 10x10 km grid cell. Note that the total storage does not equal the storage available for sustainable abstraction (see section 1.2).

Another possibility is to select the aquifers based on their hydrogeofacies. Figure 4 for example shows the groundwater storage in fissured sedimentary aquifers. Other future available selections will show the unconsolidated and compact sedimentary aquifers, and the volcanic and basement aquifers. Next to the selections based on hydrogeofacies and geological ages, we also foresee selections based on aquifer types (confined/unconfined/semi-confined) and aquifers that partly contain paleowater, thermal water of artesian conditions.

2 MAP SHOWING THE TOTAL DEPTH OF THE ACTIVE FRESH GROUNDWATER SYSTEM

Next to the maps showing the volumes of groundwater as described in the previous chapter, another goal of Work Package 6 of RESOURCE was to make maps showing the total depth of the active fresh groundwater system. The map that is shown in this chapter gives a first estimate of this depth.

2.1 Method

Along with the information on each layer within the 10x10 km cells, the WP6 participants also supplied data on the total depth of the active groundwater system. This total depth of the active groundwater system was defined as the maximum depth of the layers that are of importance considering the total available fresh groundwater volume in each cell. This depth could be the top of a layer with a very high vertical resistance (hydrogeological base) or a fresh-salt interface if this falls above the hydrogeological base. The total depth of the active system was gathered as a single value, therefore no calculations are needed to produce this map. Along with this maximum depth, the surveys supplied a label for each cell which describes what the total depth of the active system was based on. After some discussions during the various WP6 workshops, the following boundaries were implemented:

- Boundary based on a hydrogeolocal setting
- Boundary based on the chloride concentration (1000 mg/l)
- Boundary based on the TDS concentration (1500 mg/l)
- Boundary based on the EC (2500 µS/cm, EU drinking water standard)

Since the general goal of the RESOURCE WP 6 project is to provide a map with the volumes and depths of fresh groundwater, we stop at the depth that is relevant for the total amount of available flowing fresh groundwater. This could either be the fresh-salt water interface or the top of a layer with very low conductivity that prevents further downward flow and effectively creates a boundary for the fresh groundwater flow system. Alternatively, for karst systems, the active zone boundary could be defined as the vertical extent of the fractured zone, instead of a change in lithology.

For the fresh-salt interface it became apparent that each country has their own threshold, which could be generally be divided in three groups: 1. based on chloride concentrations, 2. based on Total Dissolved Solids (TDS), and 3. based on Electrical Conductivity (EC). For chloride, the threshold concentration was set at 1000 mg/l, for TDS a concentration of 1500 mg/l is generally used, and for EC the boundary between fresh and salt is 2500 µS/cm. It was agreed that each participating survey picks one of these three thresholds based on which best fits their current data.

Figure 5 shows for each 10x10 km cell which boundary was used to limit the total depth of the active groundwater system. Hydrogeological boundaries are most commonly used, together with salinity-based boundaries in some coastal zones.

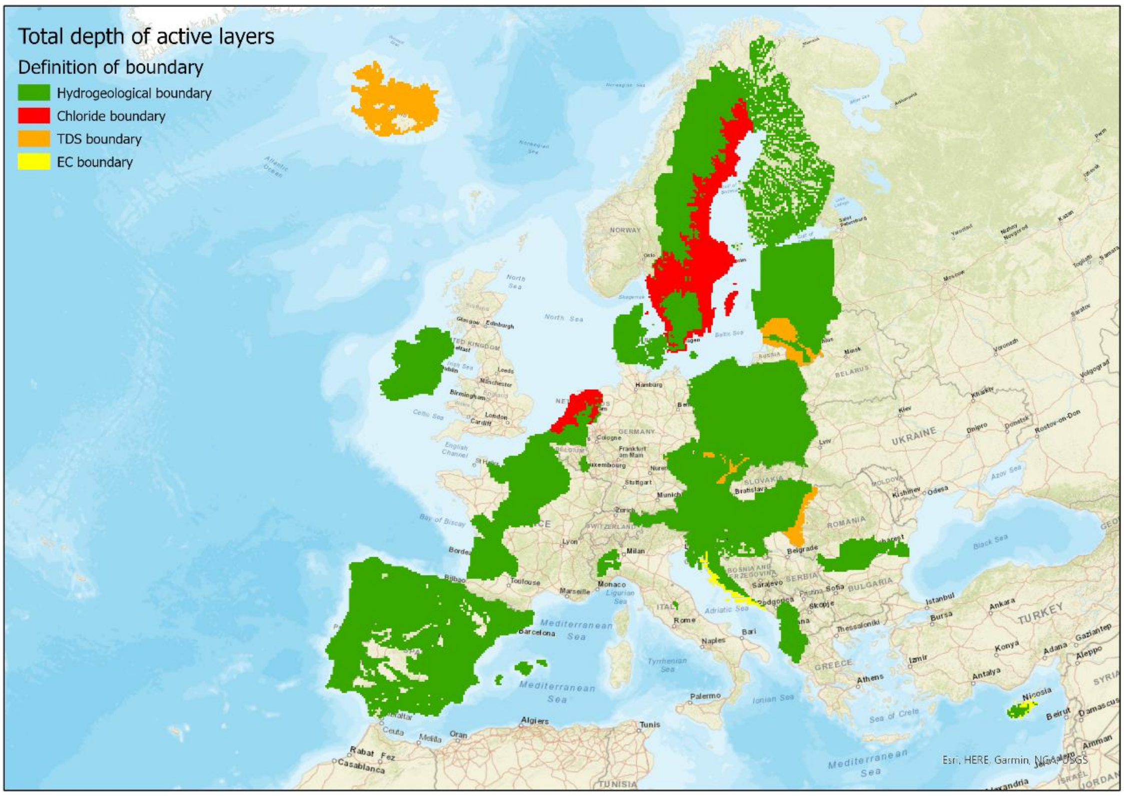

Figure 5 Definition of the boundary used for the total depth of the active groundwater system for each 10x10 km cell

2.2 Total depth of the active fresh groundwater system

Figure 6 shows the map of the total depth of the active fresh groundwater system. As with the other maps shown in this deliverable, this in not yet the final version that will be included in EGDI since quality control by the surveys is still taking part. However, the map already gives an overview on the large variety of depths that are present in all countries. In some cases, borders between countries are cleary visible since each survey uses different thresholds to deliniate the active groundwater system. Generally, the deepest groundwater system are in the Paris basin (France) and the Pannonian basin (Hungary) with maximum depths reaching up to 2500 meters below surface.

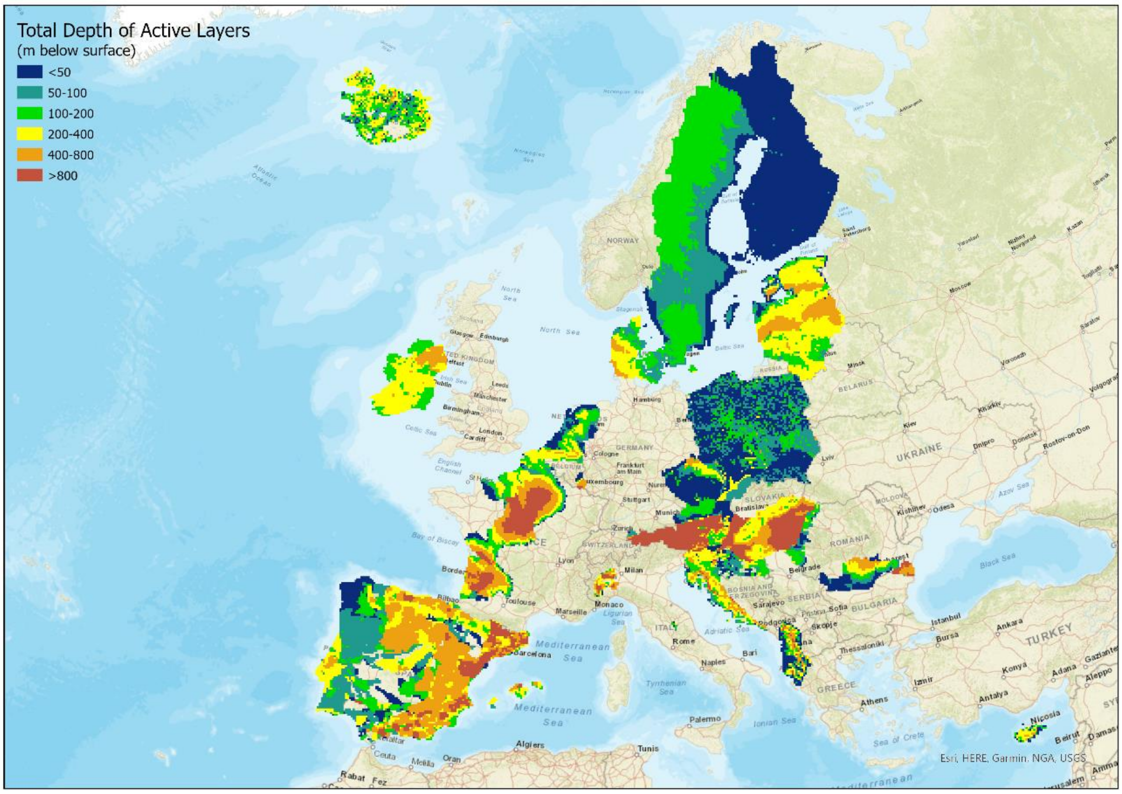

Figure 6 Total depth of the active groundwater system in m below surface level