FP7-INFRASTRUCTURES-2012-13

Grant Agreement no. 312845

Scoping Study for a

Pan-European Geological Data Infrastructure

D 3.3

Implementation and prioritisation plan for rolling out datasets on the EGDI

Deliverable number	*D3.3*
Dissemination level	*Public*
Delivery date	*28 February 2014*
Status	*Final*
Authors	*K A Lee, K A Linley, R S Lawley, L D Jones, P Turner, H Napier, C Cartwright*

Contents

1 Introduction

This work package (WP3) sets out to prioritise the datasets that will be delivered in the short-, medium and long-term, and the methodologies by which derived datasets will be produced. The broad objectives are to deliver complete geographical coverage and higher resolution baseline geological spatial data in the short term with baseline geophysical and geochemical data where available, to publish pan-European derived datasets in the medium-term, and to progress towards delivery of 3D model data in the longer term.

Work Package 3 has previously evaluated previous and ongoing pan-European projects and their data outputs, and has also assessed currently available important datasets at the national level, which can be used as the backbone of the EGDI (see published reports of D3.1 and D3.2).

Task 3 or WP3 is explained and presented in this document and focuses on potential implementation and prioritisation plans for rolling out datasets on the EGDI. Stakeholder needs were researched and analysed in conjunction with WP2 (see D2.1, D2.2 and D2.3). This information fed into WP3 task3 where the aims were to analyse and identify perhaps one or two derived datasets that are considered high priority in terms of user need, funding requirements, technical capacity requirements, etc. When suitable high priority candidates have been decided work can begin on implementing a methodology for their development.

This document will firstly review all input and source information available to analyse and propose potential methodologies for implementation of the EGDI. It will then identify focus areas taking into account stakeholder requirements and data available, and then use this information to propose some initial methodologies for further development. It concludes with the objectives required to move forward in the next phase of EGDI implementation.

2 Overview of stakeholder needs from WP2

It is essential that conclusions from WP2 inform the priorities and direction of WP3. For this reason, a thorough review of the WP2 deliverables was completed to gain insight into the needs of stakeholders. Only information relevant to WP3 is referred to in this document i.e. it does not report all WP2 conclusions.

WP2 was been divided into 4 main tasks (noted here by their individual deliverable numbers):

- D2.1 Identification of stakeholders
- D2.2 Stakeholder consultation – user needs for datasets and services
- D2.3 Specification of functional requirements and use cases
- D2.4 Stakeholder feedback.

Deliverables D2.2, D2.3 and D2.4 drew on feedback gained from a dynamic group of stakeholders comprising representatives from the European Commission, European projects (EPOS, GeoSeas, PanGeo etc), pan-European institutions such as ESA and EEA, a number of EuroGeoSurveys expert group chairs and private companies such as Insurance Europe.

Stakeholders were engaged through workshops, direct meetings and questionnaires. The results of this stakeholder engagement were documented in the WP2 reports

2.1 Summary of D2.2 - user needs for datasets and services

D2.2 divides stakeholders into 3 broad categories: Policy makers, Public Sector and Private companies. Each category exhibited preferences for EGDI activities and direction.

D2.2 states that policy makers suggested any information provided by the EGDI should:

- Data should be open and freely available and maintained on a sustainable platform (European Commission)
- Data specification should be in line with the INSPIRE specifications (European Commission and data providers (i.e. NGSO representatives))
- Data should be interoperable with data from other communities (European Commission, e.g. Marine Knowledge 2020).
- EGDI should be coordinated with the European Innovative Partnership on Raw Materials (WP 3) (European Commission, DG ENTR)
- Data should be of use in solving societal problems (European Commission)
- The usability of data from past projects should be increased (European Commission - REA)
- EGDI should complement WISE (Water Information System for Europe) and generation of new datasets to include/link into WISE would be welcome (EEA)

D2.2 states that public sector stakeholders suggested any information provided by the EGDI should:

- Spatial data that is downloadable in a range of formats
- searchable and INSPIRE compliant Metadata
- The functionality should respect local (regional/national) data structure and language as well as its English translation.
- There should be immediate hazard information
- Access and download conditions should be clear

D2.2 states that private sector stakeholders suggested any information provided by the EGDI should:

- EGDI should include earthquake data, geological maps, borehole data and hydrogeological maps
- Data storage and –retrieval should be straight forward and quick
    - EGDI should promote availability of the more recent data
    - There should be a good search engine

Private companies had indicated that they tended to get more detailed knowledge locally or from their own national geological survey.

The information provided in the D2.2 questionnaire suggests stakeholders require a wide range of geoscience data to cover their anticipated requirements. Whilst this breadth of information is important for eventual population of the full EGDI; for the purposes of this scoping study and prioritisation of datasets, the questionnaires did not elicit any focussed requirements for specific information.

The results of D2.2 already highlight primary interest in base-line geological data, models for geohazards, and atlases of natural resources (covering the themes of mineral, energy and water). This interest was reinforced in the technical requirements and explained in D2.3.

2.2 Summary of D2.3 – technical requirements and use cases

The technical requirements were identified in D2.3 following consultation with key stakeholders. These were highlighted in terms of the usability of portals, ease of access to the data and consistency and uniformity of content.

The most popularly accessed portals provide clues to the sorts of data that are regularly accessed and used by stakeholders. These include:

- OneGeology-Europe
- EuroGeoSource – mineral and energy resources
- GEMAS – geochemical atlas of Europe
- PanGeo – ground stability for large cities
- Promine – information on mineral occurrences across Europe
- Transenergy – geothermal energy portal

Additional useful comments taken from this review included:

- The harmonised nature of OneGeology Europe enables useful data queries but also aids the development of additional datasets derived from the core geological dataset,

- Information on ore type and resource potential of primary and secondary minerals in the Promine portal allows prognostic evaluation and regional prediction of potential
- The Pangeo portal is useful as it provides free and consistent data on urban geohazards.

Note that in these findings, we can again see that natural resources and geohazards are common themes.

Issues of functionality were also explored in WP2. Again, whilst this did not shed light on the specific types of data required by stakeholders, it provided useful information on requirements for data formats/storage which in turn will influence how the different data layers are acquired and developed; therefore influencing the methodologies for their production. The following preferences were expressed:

- On-line overlay of data
- Searchable metadata
- Access via simple map viewer - search by map/geographical extent
- Harmonisation and interoperability
- 3D functionality
- Free access to open data
- Interpreted remote sensing layers
- WMS, WFS, WCS, WCPS
- Display information on data ownership and availability

This information and feedback has been incorporated and taken into account in WP3 in prioritising dataset topics and proposing suitable, realistic methodologies for implementation.

2.2.1 *Use Cases*

WP2 created a number of Use Cases to aid stakeholder engagement and focus for discussion. On reviewing the descriptions of the use cases described in D2.3, it is clear that any derived datasets need to be focussed towards areas that address issues of :

- high societal impact,
- policy development,
- economic growth, and
- climate change.

The following sections review each use case and their relevance to the prioritisation of any Europe wide derived datasets.

2.2.1.1.1 Geohazards Use Case - The evaluation of the risk of ground instability in densely populated areas

The geohazards use case concentrates on the Pangeo project and provides a useful insight into the types of information that are of value to stakeholders:

- Risk and cause of ground instability in a given area

- Landuse types likely to be affected by ground instability – possible source is the European Commission's urban atlas
- Populations likely to be affected by ground instability
- Average annual displacement rates
- Ground motion time series data

This use case also provided some useful information on type of end products and functionality required by stakeholders which, as mentioned earlier, gives firm basis for planning methodologies for derived-dataset development.

Requirements include:

- Printed and interactive maps of a generic ground stability model
- Geohazard descriptions for regions/districts
- Combined Geohazard and demographic information for assessment of vulnerable communities/resilience
- Display of PSI data – average annual velocities and cumulative displacements
- Inquiry tools e.g. mouse click provides graph of movement in time. Reference was made in the report to the Italian portal Geoportale Nazionale which holds PSI data with time series for the whole of Italy.
- Downloadable hazard descriptions
- WMS/WFS services for different user communities
- interoperability with Google Earth type API's

An additional comment in the report suggested that the EGDI provides an opportunity for integration of existing ground instability data by merging and collating outputs of the Pangeo, Terrafirma and SubCoast projects into a collective web service.

As a result of the stakeholder feedback and consultation, the PanGeo exemplar and datasets have been taken forward in WP3 as a priority implementation and example of potential integration with other hazard datasets.

2.2.1.1.2 Rare Earth Elements Use Case

Discussions prompted by this use case suggest that stakeholders feel more collaboration is needed to facilitate the exchange of information to aid policy development in this area. It is acknowledged that mineral occurrence data and statistics are compiled by the parties of the EuroGeoSurveys and suggests that a priority for development of derived datasets should be given to natural resources. The use case highlights detailed information that is currently beyond the scope of EGDI. It was therefore decided to select a more generic and easily implemented mineralogical dataset for a proposed methodology relating to mineral resources – aggregate resources (sand and gravel).

2.2.1.1.3 Renewable energy Use Case

This use case concentrates on how geological data could be used in assessment studies for offshore wind farms and references the Forewind project (http://www.forewind.co.uk/) as an example of how disparate datasets have been successfully compiled into a portal that directly faces stakeholder needs. Data that was considered important in this context included consistent descriptions of sediment type from a range of sources including: boreholes, seabed samples and seismic data, as well as models of waves, tides, and subsequent sediment behaviour. It is possible that the Forewind project experience could indicate how information in the future EGDI might be used. This example recognises that free and open geology/geophysics data will be of high importance to contractors. The report also acknowledges the role that projects such as EMODnet and GeoSeas provide in terms of creating harmonised, underpinning geology and geophysics data from across Europe; it goes on to describe how data from these projects might also be incorporated into a future EGDI. WP3 has not at this time elected to carry this forward due to project constraints.

2.2.1.1.4 Geology and Soils Use Case – Ecosystem mapping

This use case highlights the availability of some baseline, empirical pan-European datasets. The exemplars provided include:

- GEMAS, a dataset of geochemistry from agricultural soils, and
- IHME, the International Hydrogeological Map of Europe, a dataset of aquifer status.

These datasets present a common theme of harmonised geo-data, where the value of the information lies not only in what it says, but also in the implicit underlying quality controls that allow users confidence in its consistency and currency.

The description of the use cases and subsequent report D2.4, provide a clear indication that pan-European derived datasets should include baseline geological data, geohazards and natural resources, and that stakeholders should be confident in deriving further value from the data by virtue of their quality, consistency and availability.

The GEMAS dataset has been identified as a quick-win to include into the initial phase of EGDI.

3 Overview of dataset and projects as compiled in D3.2

The primary objective of Task 3.2 was to review the data available within National Geological Survey Organisation's (NGSO) across Europe, with an aim of producing an inventory of datasets (Cartwright, et al., 2013). The review also included national organisations other than NGSO's that might hold national, and on occasion, trans-national data relevant to the task. Once collated, these data were then analysed for a range of parameters including availability, format, INSPIRE compliance, topic, theme, scale and scope. From these results, priority datasets could be identified.

3.1 Data sources

Data was collected via three sourcing methods:

1) Data resulting from previous and ongoing European projects (Lee & Armstrong, 2012).
2) Pre-volunteered dataset indicators via the INSPIRE Monitoring and Reporting web portal.
3) Data provided directly from organisations via a specifically formulated questionnaire.

Once all appropriate data was collected and reviewed, findings were then collated and assessed to ensure as much completeness as possible was achieved.

3.2 Participation

The resulting database revealed that 28 countries throughout Europe provided data potentially suitable for the task.

The Pan-European datasets (datasets that spatially cover more than one European state) proved difficult to identify in terms of origin and single state ownership. These datasets (identified through Task 3.1) are not represented in the list of participating countries illustrated in Figure 1 due to the ambiguity of their source and ownership.

Further details and a full breakdown of the results can be found in D3.2.

Figure 1: Participating countries

3.2.1 *Summary*

In summary, the most dominant pan-European projects from task 3.1 were Natural Risk/Geohazards and Mineral Resources. These themes also scored highly in both the INSPIRE in-scope datasets and national survey organisation's datasets.

It is clear that INSPIRE data mainly represents baseline scientific data that has a high degree of coverage in-country, available at a range of scales and in a variety of formats. This data would be highly suitable to form the initial baseline input into the EGDI framework and form the foundation of the infrastructure. From this data, a range of 'thematic' products could be derived.

The pan-European projects have, as would be expected, been primarily funded to produce more specific derived or 'thematic' data, but this is still sporadic in spatial distribution. The most dominant natural risk hazard currently available, from across Europe, are flood datasets.

For the purpose of task 3.3 (proposed methodologies for derived datasets), we therefore selected two themes and their sub-topics on which to concentrate further studies; these were **Mineral Resources** and **Geohazards**.

4 Focus areas

4.1 Focus overview

The EGDI-scope project has identified and maintained strong links with key stakeholders and users across a range of geosciences disciplines and organisations. These include the national geological surveys, who are both users and data providers, European organisations such as the European Environment Agency, and also policy makers such as the DG's. Throughout the process, WP2 has maintained communications with all of the above (see D2.1. 2.2 and 2.3), whilst WP3 has involved and collaborated with those relevant organisations regarding their datasets and available information. Both work packages have worked closely to share data and information feedback. This task (T3.3) aimed to propose an implementation and prioritisation plan for rolling out datasets on the EGDI. This has been achieved by researching the stakeholder needs in conjunction with WP2 as well as considering the range, type, and accessibility of datasets (and project data) currently available. The task had 3 main objectives:

1. Analyse and identify perhaps one or two derived datasets that are considered high priority in terms of user need, funding, requirements, technical capacity requirements, etc.
2. Align to identified user needs
3. Propose methodologies for derived datasets that could be developed

In addition to stakeholder input from WP2, dataset analyses carried out in WP3 tasks 1 & 2, feedback from a full consortium meeting was used to help 'prioritise' and define potential phases for development of the full EGDI, including quick-win developments and longer-term plans.

Breakout discussions as part of the Full Consortium Meeting in Malta 9th September also discussed priority themes and datasets for incorporation into the EGDI.

Having reviewed and assessed all information available to us, the following priorities, based on *political importance, scientific importance* and *short-term feasibility* were identified as follows:

4.2 Prioritised thematic areas

Baseline data

Geology: it was unanimously agreed that geology (both onshore and offshore) is the most important baseline dataset for the EGDI since many other data can only be properly understood if the underlying geology is known.

- **Data currently available: OneGeologyEurope 1: 1 million surface geology.** This dataset covers a large part of Europe, and the ongoing 1GE+ activity is currently working towards full coverage.
- **Implementation:** can be incorporated into the EGDI immediately. Further development would be required to standardise map content (e.g. bedrock or surficial, consistent lithology classification). A large range of derived datasets could then be created from this baseline data.
- **Data currently available: EMODnet-Geology 1:1 million substrate map.** Coverage includes the northern European seas. **EMODnet-Geology 1:250 000 substrate map.** This

dataset is being produced for all European waters in scope of the EMODnet-Geology II project, which will start later this year and last for three years.

- **Implementation:** can be incorporated into the EGDI immediately.

Thematic areas (applicable to the use cases demonstrated in WP2)

Mineral Resources – this is a highly important topic for the EU at present. Furthermore the newly initiated Minerals4EU project makes this theme very relevant for the first phase of EGDI implementation and close liaison will be undertaken.

- **Data currently available: Promine datasets** (e.g. mineral deposits, anthropogenic concentration layers, mineral potential maps, predictive maps,
- **Implementation:** can be incorporated into the EGDI immediately however, the projects have ceased and data is not being updated. Therefore, it has to be made clear to users that these data are to be considered "archive" versions.
- **Data currently available: EuroGeoSource datasets** (mineral occurrences, mines) however coverage is only for a small number of countries.
- **Implementation:** these can be incorporated into the EGDI as archive data. A new methodology is therefore proposed as part of this task for **aggregate resources – sand and gravel.** This proposed dataset methodology is used as an example of a quick-win and is provided as a 3-option approach for implementation. See chapter 5.

Water Resources – this was identified as another area with high societal impact. There are a number of relevant drivers including the Water Framework Directive.

- **Data currently available:** International Hydrogeological Map of Europe 1:1.5million scale (**IHME** 1500). Borehole data from the **eWater** project, geophysical data is available from the **Geomind** project.
- **Implementation:** datasets can be incorporated into the EGDI immediately however data should be treated as archive as it is not maintained. Long term developments are multiple and could include groundwater flooding, aquifer properties, susceptibility to contamination, etc.

Geohazards – this is a very important topic for many European Geological Surveys, other organisations, policy-makers and planners and affects many European citizens. The geohazards theme can be subdivided into hazards such as flooding, earthquakes, subsidence and landslides. Over recent years, a large amount of detailed research has been carried out across Europe and numerous EU-projects (as identified in task 3.1) have been funded. Two of these include the high-profile **PanGeo** project and the **SubCoast** Project, both of which deal with subsidence related hazards. Therefore it was agreed that these project results would be used and integrated in both the use cases in WP2 and as a potential methodology for incorporation into the EGDI.

- **Data currently available: Terrafirma, PanGeo** and **SubCoast** project output datasets
- **Implementation:** a methodology to further develop the information from SubCoast and PanGeo is proposed in chapter 5. The **Terrafirma** data is currently being incorporated into OneGeology-Eupope Portal format (funded by ESA). Longer-term, these can be incorporated into EGDI.

Soils – this theme generally relates to environmental issues. Primary drivers concern ecosystem mapping, Natural capital assessment, Agri-technology and food security. There are two areas of specific 'cross-over' with EuroGeoSurveys . One concerns Parent Material Mapping (mapping of weathered geological materials from which soil forms), the other concerns soil-geochemistry assessment of geogenic chemical signatures that are measured within soil profiles (e.g projects such as GEMAS or G-Base)

- **Data currently available:** The GEMAS project outputs will be an important contribution to various soil-related use cases, and is considered a good phase-1 demonstrator. A European-wide soil-survey derived parent material database currently exists and is available (http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDB/index.htm). The EGS expert group on surficial deposits is currently developing the scope for delivering an new Parent Material dataset (of higher resolution and more closely aligned with other European outputs for terminology, currency and attribution).
- **Implementation:** GEMAS provides a useful primary layer of baseline geochemical data, in combination with other spatial resources it should be possible to build informative pan-European small scale products. Further development could address multiple issues relating to ecosystem services, soil-informatics and infrastructure resilience. Pan-European development of similar models is possible, but requires some investment developing common terminologies for descriptions of weathered materials.

Land use – this was agreed to be very important on a European level for planning purposes. It may however, not necessarily have to be considered as a separate thematic area since many datasets from the above mentioned categories will indirectly provide valuable information for land use administrators. This is more a longer-term development for looking into the potential for delivery of multiple datasets within the EGDI to provide information for specific user groups.

4.3 Technical capacity requirements

It is envisaged that the first phase of EGDI will incorporate the INSPIRE compliant datasets. Priority should be given to those datasets and pan-European project outputs identified as part of this study (summarised above). In respect to this, the technical aspects of the EGDI need to accommodate and take into account these suggestions.

Each proposed methodology has identified exemplar datasets required for its creation, for example in the case of an aggregate resource map of Europe, three tiers of detail have been identified, beginning with the basic level 1 using OneGeology-Europe map data. Progression form level 1 to levels 2 and 3 (increasing levels of resolution, accuracy, complexity and value) requires agreed:

- **data specifications** for input layers
- **Vocabularies** to translate across input layers and to create alternative definitions and outputs
- **Data Services**: to manage all aspects of ingestion, management, modeling and visualization
- **Metadata** to enable auditing, searching and classification.

5 Proposing methodologies

WP3 is proposing methodologies that take into account the variability of skills and resources available to NGSO's to create new pan-European derived datasets; these must also allow flexibility to permit members to contribute on differing levels according to ability. They will therefore result in multi-scale, multi-scope, multi-user outputs.

The following section presents two scenarios; firstly, a methodology for incorporating existing datasets (e.g. Pangeo, Subcoast) into the EGDI – it is presented as an exemplar of generating pan-

European subsidence classification. Secondly, a methodology for **development of derived/thematic datasets** (possibly creating on the fly datasets from maintained and updated source components). Both these methodologies have been selected based on the previous analyses carried out by the EGDI project and have been identified to be the most appropriate at this time.

5.1 Proposed integration of existing derived/thematic datasets

Subsidence is deformation, movement or collapse of the ground. It occurs where ground material can be mobilised and displaced, either laterally, or into an underground void space or by some form of volume or strength change (usually associated with de-watering). It can be triggered by man-made disturbance (excavation, undermining, loading), a change in drainage patterns, heavy rain, drought or by water abstraction. Subsidence has the potential to cause engineering problems such as damage to foundations, buildings and infrastructure.

Subsidence-related damage to property and infrastructure can be spatially extensive, a source of recurring remedial costs and locally catastrophic in terms of loss (human and material) and is relevant across Europe.

Incorporating the use case for subsidence geohazards and the associated datasets (PanGeo, OneGeology-Europe, SubCoast) the following methodology for implementation and further development is proposed.

5.1.1 *Proposed methodology*

A set of key criteria is required for identification and characterisation of subsidence-related deposits:

- Digital mapping of geological units (e.g. OneGeology-Europe)
- Lithological description – to identify generic, potential, subsidence-related characteristics of deposits
- Subsidence observation (generic > specific)
- Subsidence susceptibility valuation – based on laboratory data and/or expert elicitation

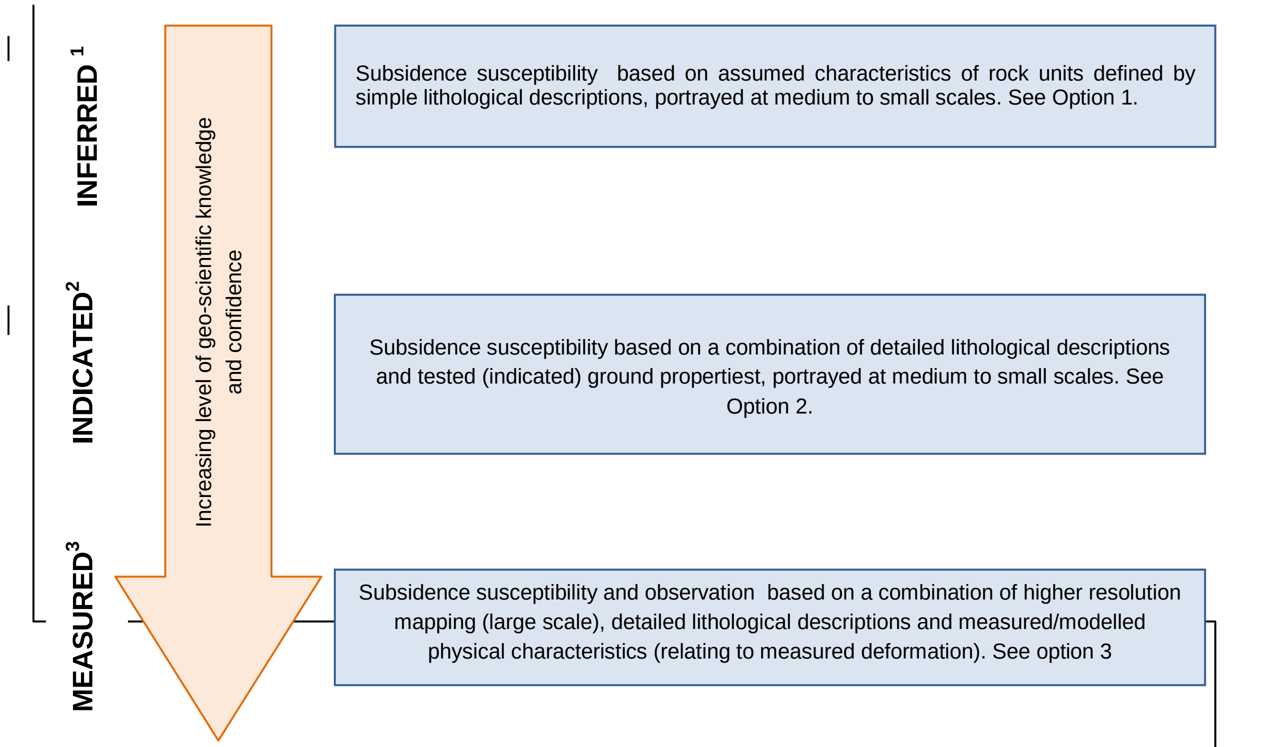
Depending on the datasets available, three methodologies are proposed to show how a spatial extent for subsidence-potential can be determined using digital geological data at different scales:

Option 1. All encompassing, basic, methodology using a pan-European dataset (e.g. OneGeology-Europe), which has lithology attributes for each rock unit and makes generic assumptions of key behaviours and susceptibilities (SubCoast is an example of this)

Option 2. A more refined methodology or output (refinement being defined as using either larger scale litho-stratigraphical data, at national or trans- scales (e.g. BGS GeoSure) or refining classification, modelling precision or uncertainty.

Option 3. A highly-detailed local scale methodology combining elements of options 1 and 2 (elements being either outputs and/or methods) with additional observational data (e.g. from PanGeo) to create multiscale thematic coverage.

Therefore the proposed methodology can be adjusted to provide alternative levels of contribution. The contributions can be produced at differing scales of resolution, depending on the scope, scale and interpolation of the attributes available in the input dataset and stakeholder requirements. To illustrate the three options, examples are provided from ongoing European and UK projects.



[1] **Inferred subsidence susceptibility** assumes generic characteristics of lithological behaviour at small scales. For example, all Peat deposits will exhibit dewatering characteristics when drained or loaded, with a subsequent ground deformation. Such inferences can be self evident, but at the scales proposed and with little or no supporting information from a local-scale, have to be treated with a lower level of confidence. It should be assumed that subsidence is a possibility given the evidence presented and the collective knowledge available

[2] **Indicated subsidence characteristics** are based on exploration, sampling and testing information gathered through appropriate techniques (e.g Plasticity indexes for clays) from distributed locations. The locations are too widely or inappropriately spaced to fully confirm spatial continuity (and specific geological cause) but continuity and cause can be reasonably assumed.

[3] **Measured subsidence characteristics** are based on combining estimated properties with sampling and testing information (gathered through appropriate techniques). There is sufficient spatial coherency and statistical confidence to identify geological cause and characteristic 'domains' of subsidence behaviours, which is reinforced by integrating (and moderating) with observed ground deformation data gathered over sequential time periods (e.g PSI).

5.1.2 *Option 1 – Pan-European Scale, semi quantified data (e.g the SubCoast project)*

The SubCoast project created a pan-European model of generic subsidence susceptibility, spatially constrained to coastal environments, but with obvious potential for extrapolation across the European landmass (and therefore of potential 'baseline' use within EGDI). Its methodology is comprised of a spatial framework (derived from the baseline OneGeology-Europe 1:1 million surface polygon dataset), semi-quantitatively redefined by 'look-up' tables of subsidence-susceptibility and locally calibrated to statistics from observed ground motion (derived from Persistent Scatterer Interferometry).

The underlying premise of SubCoast was robust, yet simple; OneGeology-Europe polygon data provides generic lithology attributes (see figure 2), that can be ascribed (using expert judgement and analogy) a range of physical and chemical properties and thus a classification for subsidence characteristics. For example, Peat is a recently formed, water-logged, organic deposit with weak mechanical properties and a propensity to flow, compress and shrink under loading or drainage. Its propensity to be an underlying geological cause of subsidence can be considered to be 'high', compared with other geological materials, such as meta-sandstones or Granites.

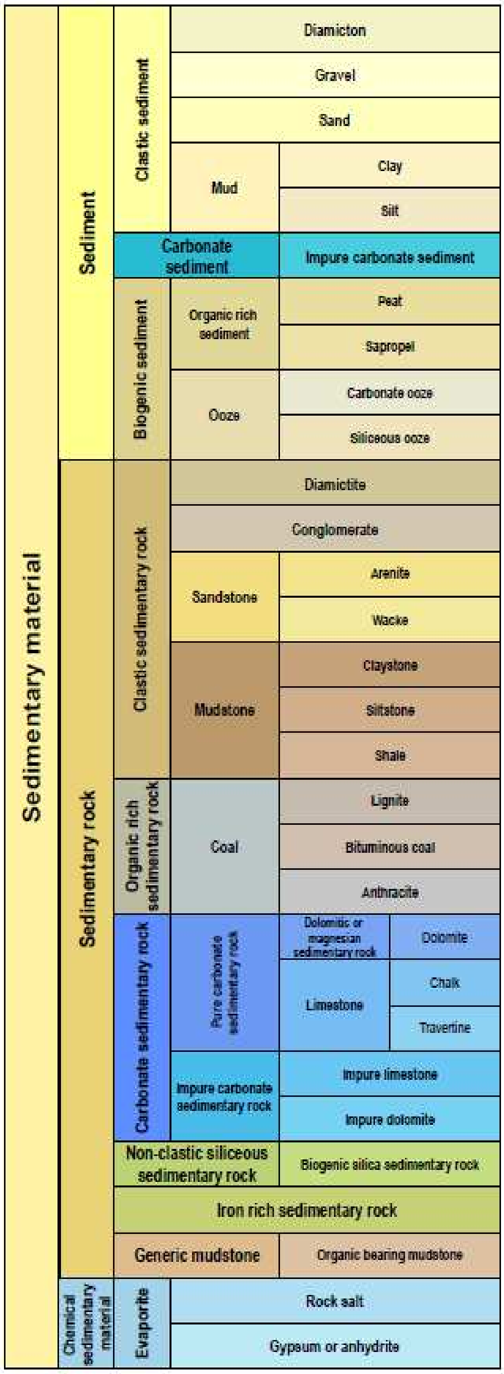


Figure 2: OneGeology sedimentary material lithology definition

For the SubCoast project, each lithology mapped in OneGeology-Europe was considered for its potential to exhibit characteristics of Compressibility, Dissolution or Shrink–Swell and ranked (qualitatively) for the expected severity of the behaviour (1-severe, 12- minimal). Having established the range of potential susceptibilities for each basic lithology the data was populated with the relative ranking and classifications and assigned a semi-quantitative score. This was based on the units assumed susceptibility to the hazard as shown in Table 1.

Table 1: Qualitative and Semi-quantitative valuations, based on individual datasets

Compressible	Qualitative	Semi-Quantitative	Dissolution	Qualitative	Semi-Quantitative	Shrink-Swell	Qualitative	Semi-Quantitative
Peat	1	100	Salt	1	100	Peat	1	100
Organic Rich	2	70	Anhydrite	2	70	Clay	2	90
Sapropel	3	50	Gypsum	2	70	Claystone	3	50
Ooze	4	10	Chalk	3	40	Diamicton	4	45
Clay	4	10	Limestone	5	30	Mudstone	5	40
Mud	6	8	Travertine	5	30	Diamictite	6	30
Silt	7	5	Dolomite	7	10	Lignite	6	30
Sand	8	1	Other	8	0	Ooze	8	20
Other	9	0				Mud	9	19
						Shale	10	5
						Wacke	11	1
						Other	12	0

Explanation:

- **Compressible** – Peat deposits have the highest value (1), as it is considered to be the most susceptible to this particular hazard, followed by Organic Rich Sediment (2) down to Sand (8), which due to granular packing and cohesion properties is considered to have a much lower susceptibility. All 'non-susceptible' lithologies (e.g. lithified materials have the lowest value (9).
- **Dissolution** - Salt has the highest value (1), followed by Anhydrite (2) down to Dolomite (7). All 'non-susceptible' lithologies (e.g siliciclastics) have the lowest value (8).
- **Shrink–Swell** – Peat has the highest value (1), followed by Clay (2) down to Wacke (11). All 'non-susceptible' lithologies (e.g. granular or chrystaline units) have the lowest value (12).

When mapped at pan-European scale, few rock and deposits comprise singular lithologies. Most deposits are collections of genetically related units. The OneGeology-Europe polygon data includes a total of five lithological fields, named 'urn_litho1' to 'urn_litho5'. These fields are based on dominant lithologies (urn_litho1), secondary lithologies (urn_litho2), down to minor lithologies (urn_litho5). Given that this five-fold classification implies a relative dominance for the occurrence of a unit, the SubCoast methodology allowed multi-lithic (heterogenous) deposits to also ranked for subsidence potential by the relative presence of the subsidence prone units identified in Table 1.

The final semi-quantitative scoring of lithologies SubCoast utilises expert judgement (which can be derived by many methods) and in a European-collaborative context, allows for intuitive inclusion of local knowledge, whilst compensating for the typical pan-Europe variability of data density, sample analysis techniques, language and empirical observations.

As a final modelling factor, SubCoast applied Persistent Scatterer Interferometry (PSI) data from selected coastal observatories. This established average ground motion rates for the three different subsidence classes (and their principal underlying geology). The final SubCoast output is a coastal-environment model that shows:

1. ***potential*** subsidence zones (expert judgement),
2. ***observed*** ground deformation (PSI) and
3. ***extrapolated*** ground motions (combined from 1 and 2).

Any GIS platform can be used to replicate the SubCoast reclassification of OneGeology-Europe.

Coupled with sea-level models (climate change or storm surge), land use data, demography informatics, habitat analysis or agricultural informatics the SubCoast data could provide significant forecast models for subsidence/inundation related metrics. Improving spatial resolution, accuracy and uncertainty of such metrics requires deployment of proposed methodology-options 2 or 3 to build on the basic SubCoast ethos.

This data is available for the coastal zones of Europe, the EGDI could take the methodology and extend the classification inland to cover the entire European land mass. This would be a quick-win development, see conclusions.

5.1.3 *Option 2 – Larger scale national-regional enhancement*

EGDI would use the methodologies employed on the European scale in option 1 (above) which can be adjusted to provide data interpretation at larger scales. For example, in the UK, the BGS has developed a 1:50,000 scale model of subsidence called GeoSure (http://www.bgs.ac.uk/products/geosure/). As per SubCoast, this model considers generic characteristics of lithology on broad subsidence types including Shrink-Swell.

Using larger scale mapping data, EGDI could offer not only more detailed spatial information, but can also define domains of characteristics that can be measured from additional sources such as Site investigation reports, insurance claims data, and laboratory analysis of systematic/random sampling programs. The increased spatial resolution provides a more 'real-world' prognosis to be created and a better understanding of uncertainty/variability. For example, rather than relying just on expert judgement of generic lithological characteristics, the shrink–swell layer of the BGS GeoSure Project (see figure 5) uses a number of domain-based and lab-testing datasets in order to determine the propensity for shrink–swell hazard for each geological formation.

The Shrink-swell dataset therefore would require many input components that originate at differing scales and scope. For the UK, laboratory testing has identified the London Clay Formation, is particularly prone to shrink–swell behaviour. This geological unit is widespread (it has lithological equivalents across Europe) However, its mechanical characteristics, derived by lab testing random sampling (e.g. sample Plasticity and volume change potential) can be used to further subdivide its spatial extent and subsidence impact (see Figure 5 for an example of zonation of Volume Change potentials).

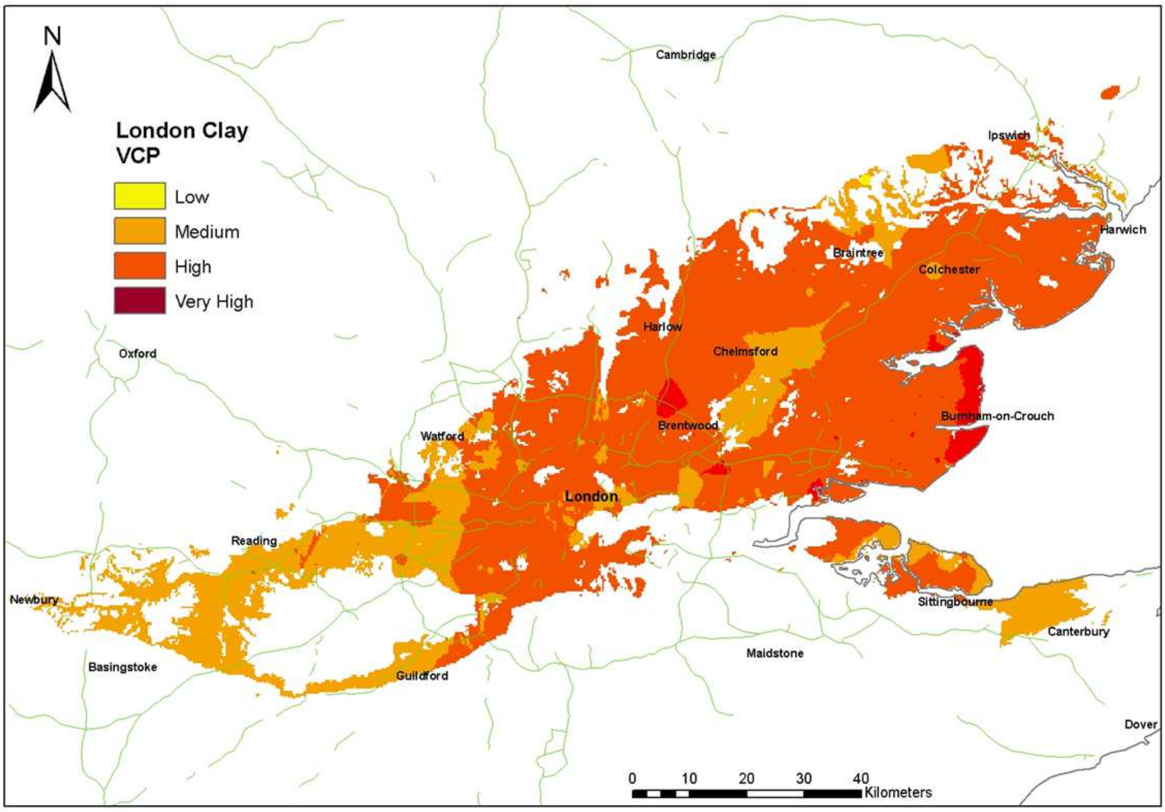


Figure 3: Volume change potential map of the London Clay, south-east United Kingdom

Spatially integrating higher resolution expert judgment, with domain-based statistical analyses of properties allows multiple users to build on a baseline dataset such as SubCoast

EGDI Option 2 subsidence methodology would develop similar techniques and data sources building on from SubCoast as and when data providers can create or identify relevant inforamtion. (e.g. geotechnical data) and/or other forms of measureable subsidence data (e.g. demographic data for insurance claims, public asset damage). Appropriate methods of data management and pan-European terminologies could allow EGDI to act as a hub for the localized spatial enhancements outlined above.

5.1.4 *Option 3 – High resolution regional-local enhancement*

SubCoast and Geosure demonstrate techniques for effectively modelling potential/sample-derived geological characteristics. Combinations of their data and techniques via EGDI would enable data providers/researchers to build on past studies to refine models as a set of multi-scale, multi-scope outputs. A further possible exemplar is demonstrated in the development of the PanGeo project. PanGeo takes the PSI methodologies (partially used in SubCoast), and the enhanced resolution and discriminant-domains used in Geosure, to deliver very high resolution (1:10000 scale) models of ground motion in multiple urban site across Europe. Effectively, PanGeo blends expert judgement, domain-based statistics and satellite-based observation into one output.

Within the EGDI, subsidence methodology option 3, SubCoast and PanGeo data could be effectively ‘merged’ (with additional processing and research effort) to create a new pan-European model of modelled-observed ground deformation. PanGeo focuses on all ground deformation (geogenic and anthropogenic sources of subsidence), localised expert judgement and higher resolution domain analysis at a scale suitable for PSI data could then be extrapolated to SubCoast-style domains of geology (and similar cadastral/urban coverage domain data). A Flow chart representing the methodology used for creating the final susceptibility map is shown in Figure 4.

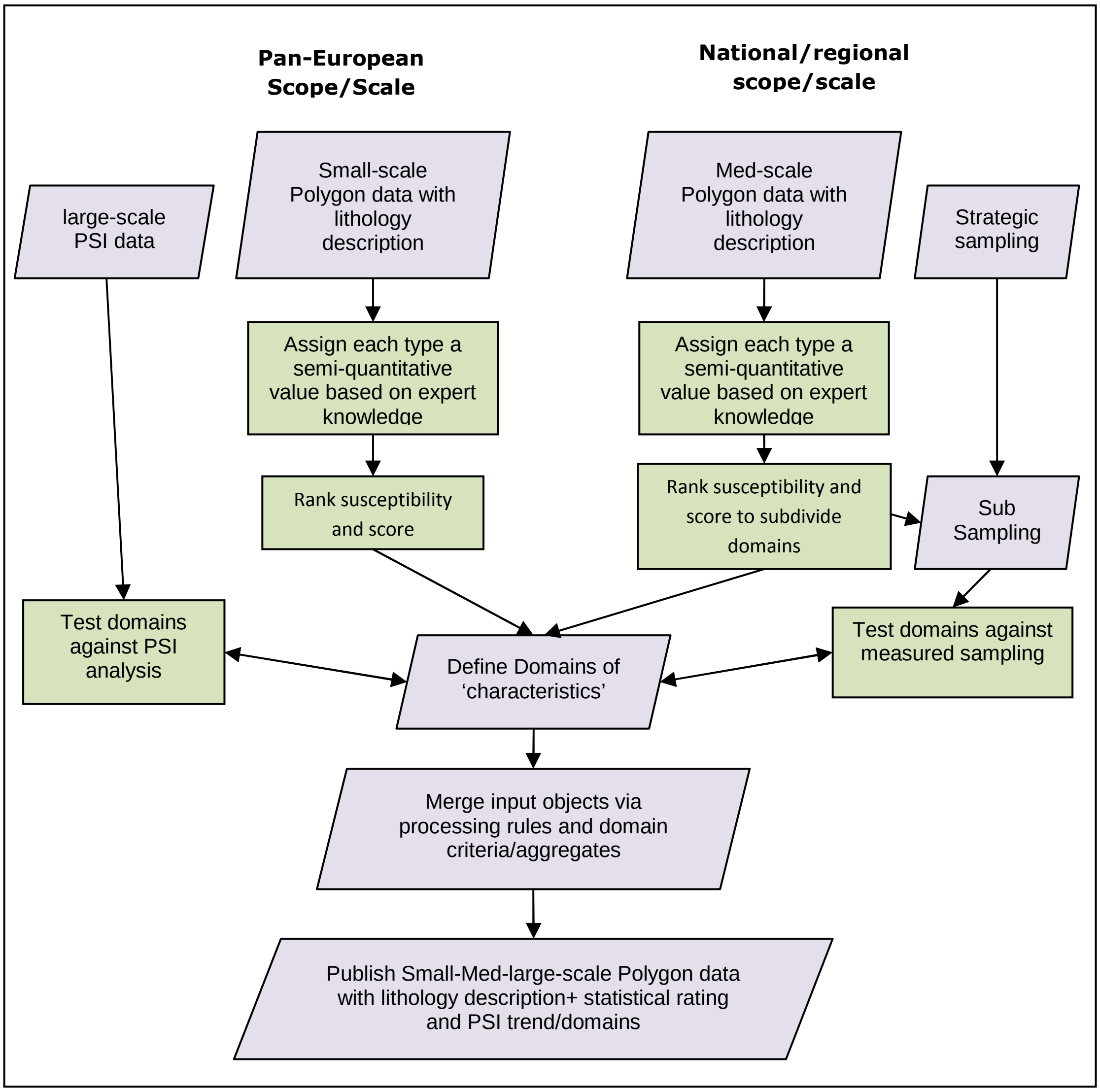


Figure 4: Selection criteria and work flow for using digital geological data to create a subsidence susceptibility dataset

Option 3 would benefit any data provider seeking to develop (over time) national-scope models of subsidence that progress from generic assumptions, through statistical methods to empirical forms of measureable subsidence data (e.g. PSI data).

5.1.5 *Recommendations*

Option 1 Shows the development of a pan-European subsidence-potential layer (selected subsidence styles). This development is dependent on the OneGeology 'urn_litho' codes being correct across all nations and relies heavily on expert judgment, local knowledge and user understanding of scope/scale issues.

Option 2 shows how regional-scale models utilising lithostratigraphy and quantitative data interpretation, can improve stakeholder experience of scale and scope (generally as clearer domains of properties, clearer definitions of uncertainties) as well as bring more relevant research techniques into play (for example consideration of extrapolation of quantified values withn similar lithologies/facies across Europe).

Option 3 Shows how a pan-European multiscale, multiscope series of subsidence models based on lithology (qualitative and where possible quantitative) could be merged with European PSI data. Having coupled 'baseline' outputs (OneGeology-Europe) and 'developing' data outputs (PSI), there is considerable scope for longer-term, continuous development of increasingly refined subsidence modelling, which in turn can act as a focus for assessment of other impacts (flooding, cadastral liabilities, infrastructure resilience etc)

5.2 Mineral resources: Scaleable Identification of Superficial Sand and gravel resources

Sand and gravels deposits are sediments laid down during the last two million years as a result of fluvial, glacial, marine and Aeolian sedimentary processes. A set of key criteria can be used for initial identification and categorisation of sand and gravel resources:

- Age –recent or quaternary deposits
- Geology –mostly superficial material
- Depositional environment - fluvial, glacial, marine, aeolian
- Economic factors - distance to market, links to transport network
- End use - construction, industrial

All of these criteria can be set within a pan-European context and given an harmonised vocabulary or definition. The methodology outlined below considers the first three criteria (as these are most relevant to pan European-scope), but does not consider the economic or end use criteria (which are generally regional/local in scope and operate within a context of time/market behaviour).

The methodology is divided into three options illustrating the use of digital geological data at different scales and scope to generate a spatial extent of sand and gravel resources. **Error! Reference source not found.** provides an overview of the process.

Option 1 Pan-European Resource Map indicating the presence or absence of gross sand and gravel resource, based on age and geology using geological data mapped at small (1:1 million) scale (see Option 1 section).

Option 2 Pan-European (or trans-national) Specific-Resource map: As option 1 but offering a greater level of detail based on medium scale mapping and increased data attribution, based on age and geology using geological data mapped at 1:100 000 scale or less (see Option 2 section).

Option 3 National-Regional Resource/reserve Map: Presence of sand and gravel from small (1:50 000 or less) scale data supplemented with information on thickness, quality and composition derived from integration of other complimentary data sources e.g. grain size analysis, borehole logs (see Option 3 section), produces more detailed data that allows generalised volumetric estimates (ie potential 'reserve' and net resource mapping).

An example of each option is provided, based on currently available geological data.

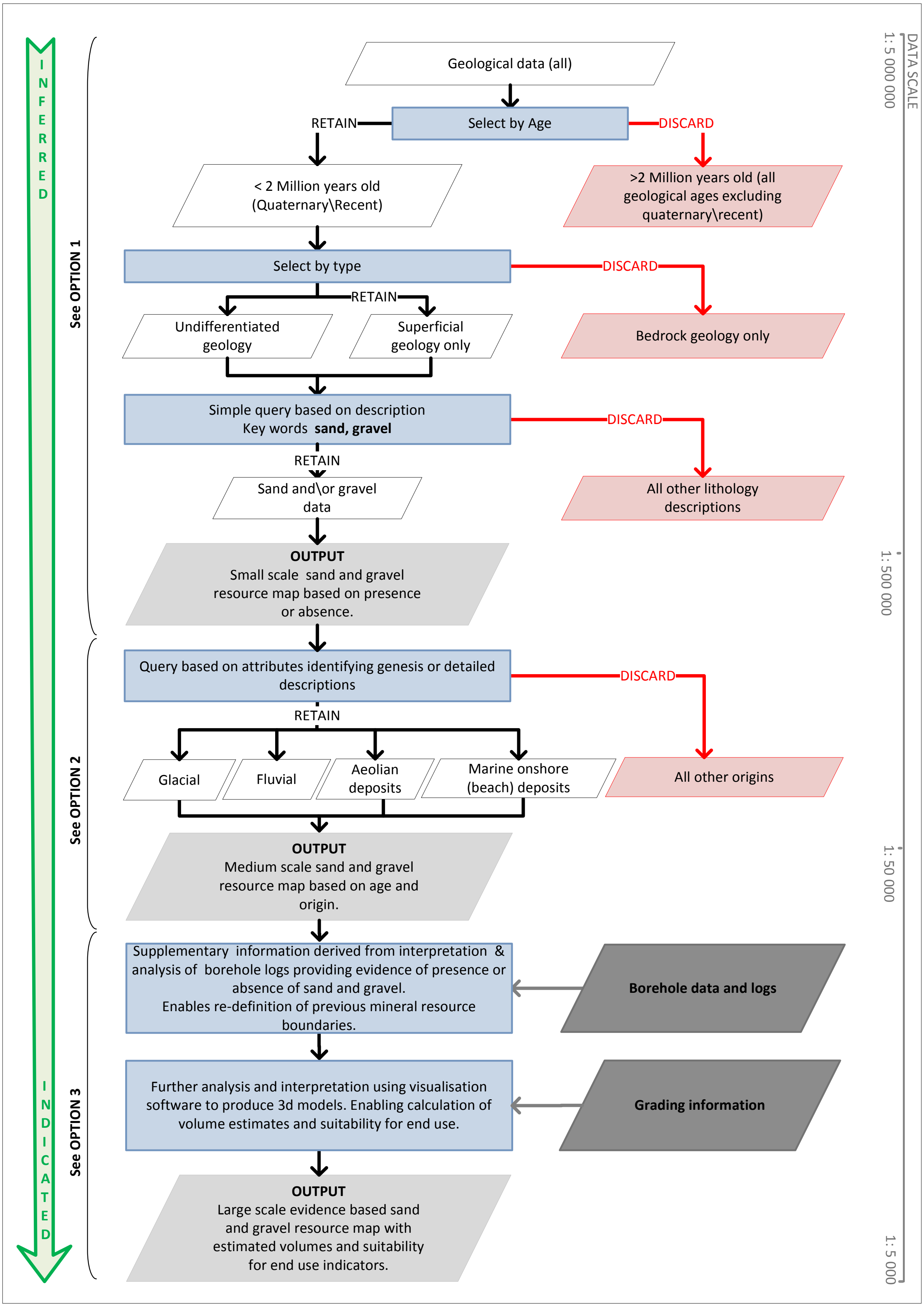


Figure 5: Selection criteria for identification of superficial sand and gravel resources

5.1.6 *Definitions*

5.1.6.1 Sand and gravel

Sand and gravel are based on particle size as opposed to composition. Currently the term 'gravel' (or coarse aggregate) is used to describe material coarser than 4mm, with a maximum size of 80mm. 'Sand' (or fine aggregate) describes material finer than 4mm but coarser than 0.063 mm. Material with a particle size of less than 0.063mm (i.e. clay and silt) is classed as 'fines'. The percentage of sand, gravel and clay is used to determine the suitability of material as a resource. Figure 6 shows the relationship between the sand, gravel and clay content.Note that the areas coloured in blue represent the 'optimum' economic resource.

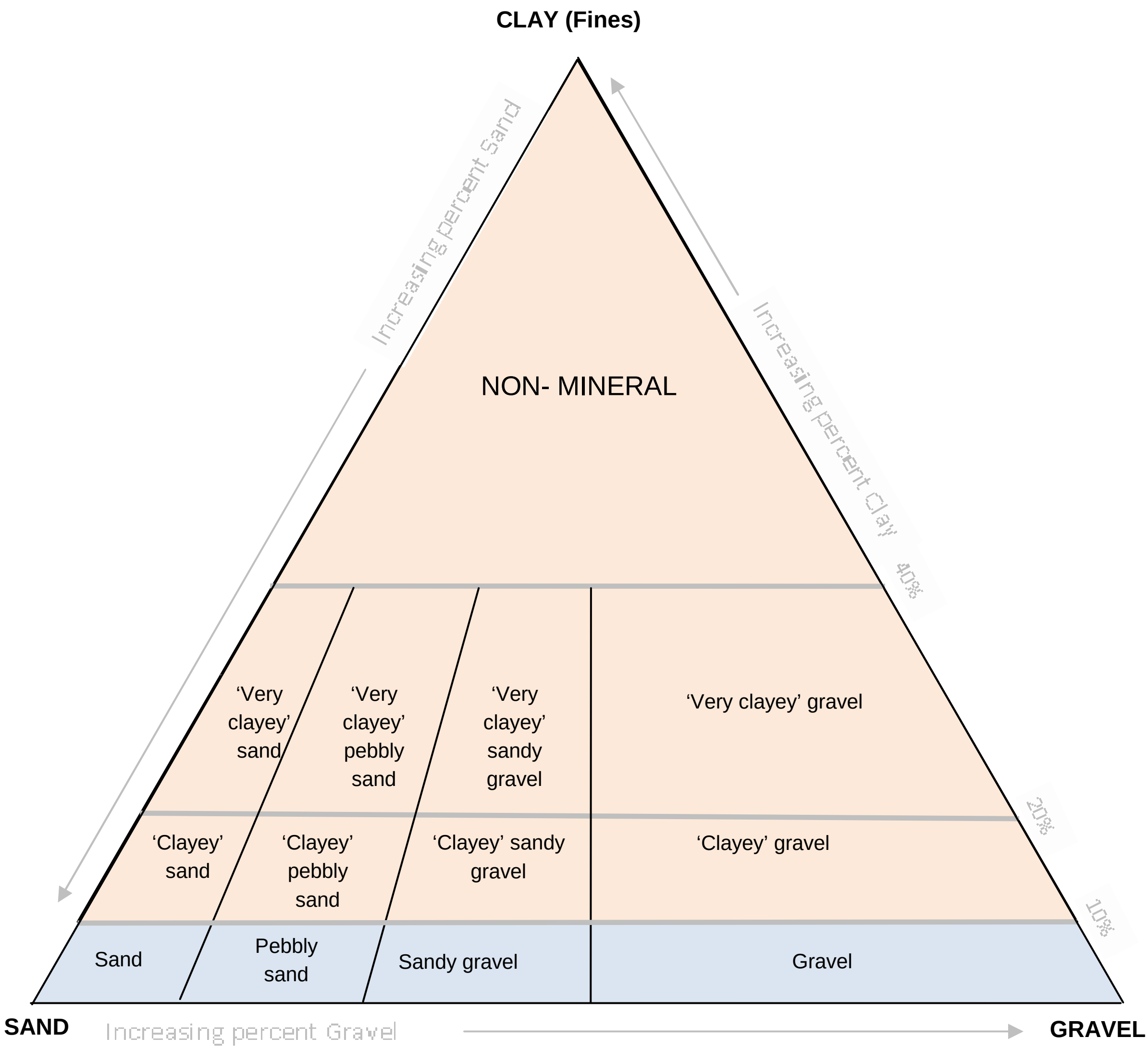
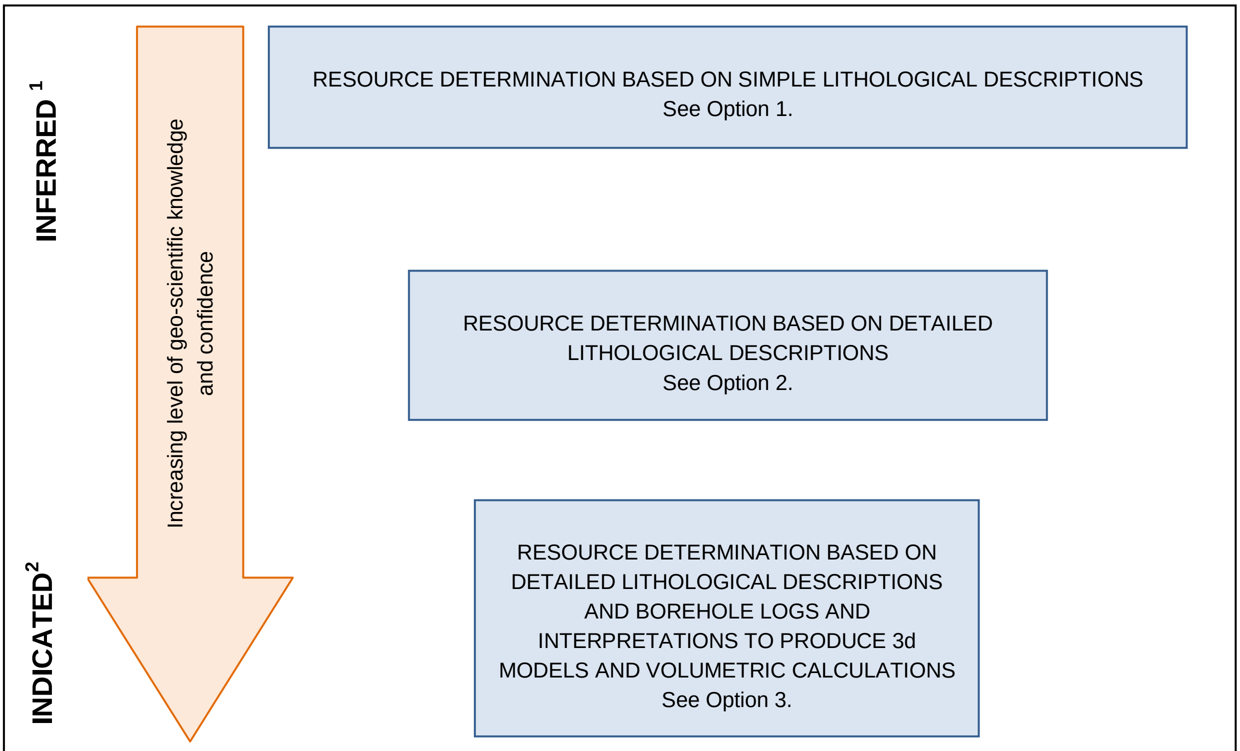


Figure 6: Mineral resources based on % sand, gravel & clay (fines or contaminants).

5.1.6.2 Mineral resource

A 'Mineral Resource' is defined as a concentration or occurrence of material of economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction.

The location, quantity, grade, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are subdivided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories (See Figure 7).



[1] **Inferred Mineral Resource** is that part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which is limited or of uncertain quality and reliability.

[2] **Indicated Mineral Resource** is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed.

Definitions are extracts from the Pan-European code for reporting of exploration results, mineral resources and reserves ('The PERC reporting code'), 2008. The full document is available at http://www.vmine.net/percreserves/documents/PERC_REPORTING_CODE_jan2009.pdf

Figure 7: Relationship between inferred and indicated mineral resources.

5.1.7 *OPTION 1: Identification of sand and gravel resources using small scale data.*

DATA SCALE 1:5 000 000 to 1:500 000

DESCRIPTIONS* Generalised classes based on lithology at its simplest level defining only generic 'sand and gravel' (ie no differentiation of origin or composition)
Minimal use in the identification only of general classes of resources, no indication of suitability of material for specific end uses.

*Standardised definitions have been established as part of the One Geology GeoSciML portrayal, see Table 1.

Table 2: One Geology definitions for sand and gravel for implementation of data.

PREFERRED LABEL	DEFINITION	URL
GRAVEL	Clastic sediment containing greater than 30 percent gravel-size particles (greater than 2.0mm diameter). Gravel in which more than half of the particles are of epiclastic origin.	http://resource.geosciml.org/classifier/cgi/lithology/gravel
GRAVEL SIZED SEDIMENT	Sediment containing greater than 30 percent gravel-size particles (greater than 2.0mm diameter). Composition or genesis of clasts not specified.	http://resource.geosciml.org/classifier/cgi/lithology/gravel_size_sediment
SAND	Clastic sediment in which less than 30 percent of particles are gravel (greater than 2mm in diameter) and the sand to mud ratio is at least 1. More than half of the particles are of epiclastic origin.	http://resource.geosciml.org/classifier/cgi/lithology/sand
SAND SIZED SEDIMENT	Sediment in which less than 30 percent of particles are gravel (greater than 2mm in diameter) and the sand to mud ratio is at least 1. Composition or genesis of clasts not specified.	http://resource.geosciml.org/classifier/cgi/lithology/sand_size_sediment

Taken from http://onegeology.org/docs/technical/GeoSciMLPortrayalTemplate.xlsx

5.1.8 *Option 1 Methodology*

This is a simple method for broad delineation of sand and gravel resources based on lithology. Superficial (surface) sand gravel resources are of quaternary (recent) age, as a result the methodology focuses on lithology as the key element in resource identification.

At a scale of 1:1 million the attribution level is limited; if source data is divided into superficial (or Quaternary) and bedrock; the bedrock data should be discarded, however if there is no split then the entire geological dataset should be retained (See **Error! Reference source not found.**).

Figure 8 shows data for Poland from the One Geology portal (http://portal.onegeology.org/). The legend illustrates the limited level of detail available.

Currently the data for the One Geology portal held is in raster format and cannot be queried to select individual elements. However, future development of the One Geology portal is to develop querying functionality (see recommendations).

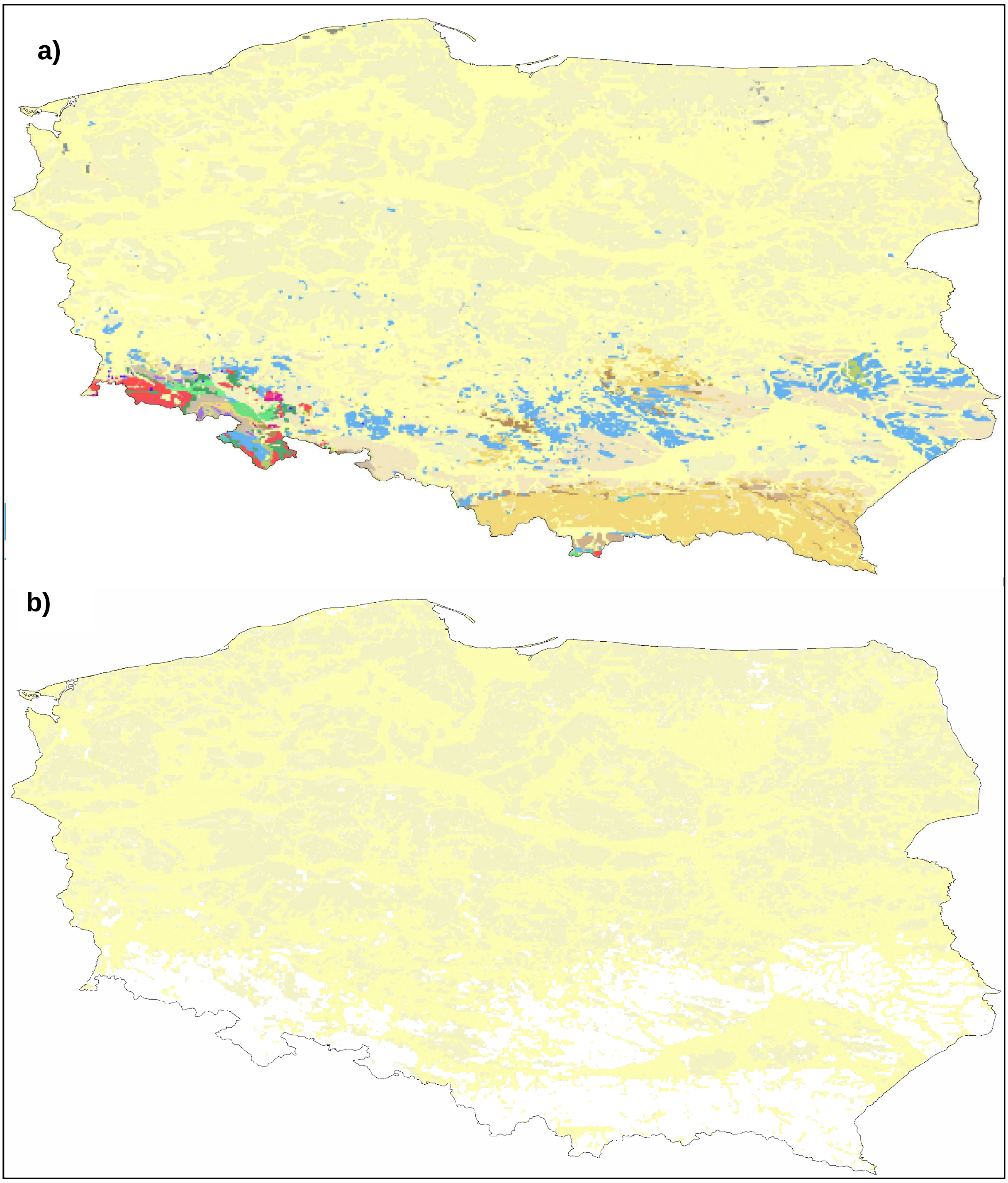


Figure 8: a) Poland Geology including bedrock and superficial and b) Poland Superficial sand and gravel resulting from query 1.
Source: Polish Geological Institute National Research Institute (from One Geology portal).

The source data for this 1:1 million geological dataset is vector data which contains attributes which can be queried. Identification of sand and gravel resources can be carried out using a ‘Select by attributes query’. The selection criteria should include the terms sand and gravel.

Option 1 Query

"LEX_D" LIKE '%SAND%' OR "LEX_D" LIKE '%GRAVEL%'

An example query is shown in Figure 9 (example uses Quantum GIS 1.8.—Lisboa free Open Source Geographic Information System software [available from: http://www.qgis.org/]).

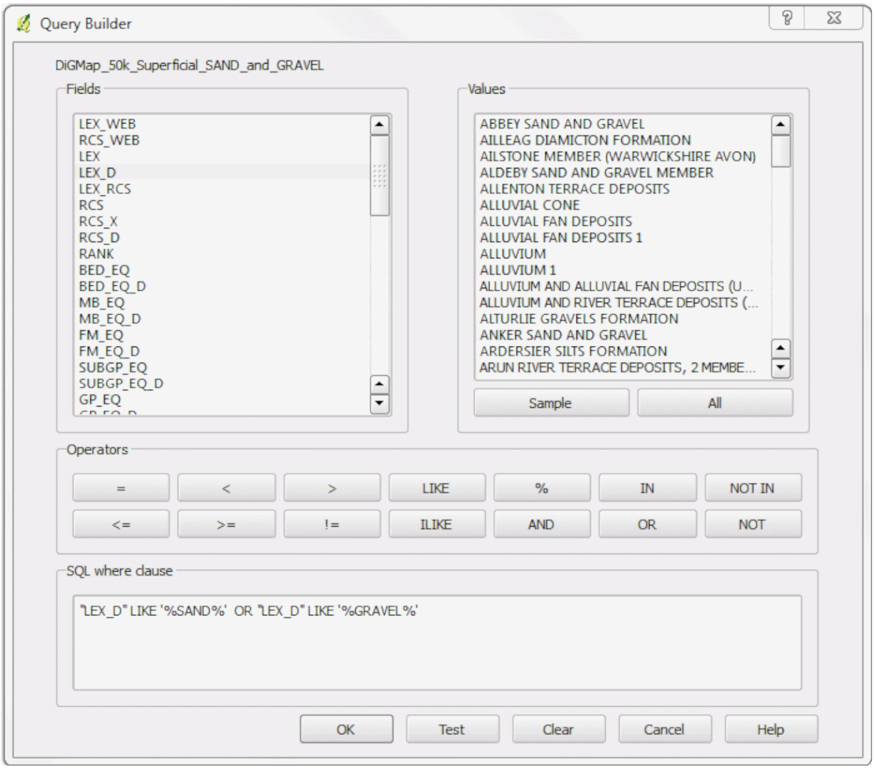


Figure 9: Query Builder using the search terms sand and gravel to identify sand and gravel resources.

The results identified by this query can be exported to a new file and provide rudimentary sand and gravel resource map (see Figure 8b).

5.1.9 *OPTION 2: Identification of sand and gravel resources using medium scale data.*

DATA SCALE	1:50 000 to 1:10 000
DESCRIPTIONS	Further filtering of query results required to remove non resource formations e.g. tidal flat deposits which are usually of mixed composition including significant clay or silt content. General classification based on sand and gravel descriptors. Origin or genesis using fluvial, glacial and marine (beach) deposits may contain sub-divisions within main classes.

5.1.10 *Option 2 Methodology*

The source geological data may be divided into bedrock and superficial; if so the initial step is to discard the bedrock data. If however the source data is not separated into bedrock and superficial run the query on the combined geology layer (see **Error! Reference source not found.**).

Building on the 'Select by attributes' query created in Option 1 all formations containing sand and gravel as any part of their description can be identified. A second query shown below can then be run on the extracted sand and gravel results to identify and allow removal of formations whose descriptions include clay, silts and silt (see Figure 6).

Option 2 Query
"LEX_D" LIKE '%SILTS%' OR "LEX_D" LIKE '%SILT%' OR "LEX_D" LIKE '%CLAY%'

Figure 9 shows both the superficial deposits and those remaining after the two queries have been used to identify sand and gravel areas and exclude silt and clay, in essence a map of sand and gravel resources. From this point expert knowledge can be applied to identify formations which are not resources. For example descriptions of 'head' and 'moraine' are likely to represent mixed deposits which are unsuitable for development as sand and gravel resources. Care must be taken to ensure that viable deposits are not removed at this time; examples exist e.g. in the USA where glacial outwash produces stratified deposits which are worked for boulders and gravel resources; this is not the case in Great Britain where the majority of outwash material is poorly sorted and generally unsuitable as a resource.

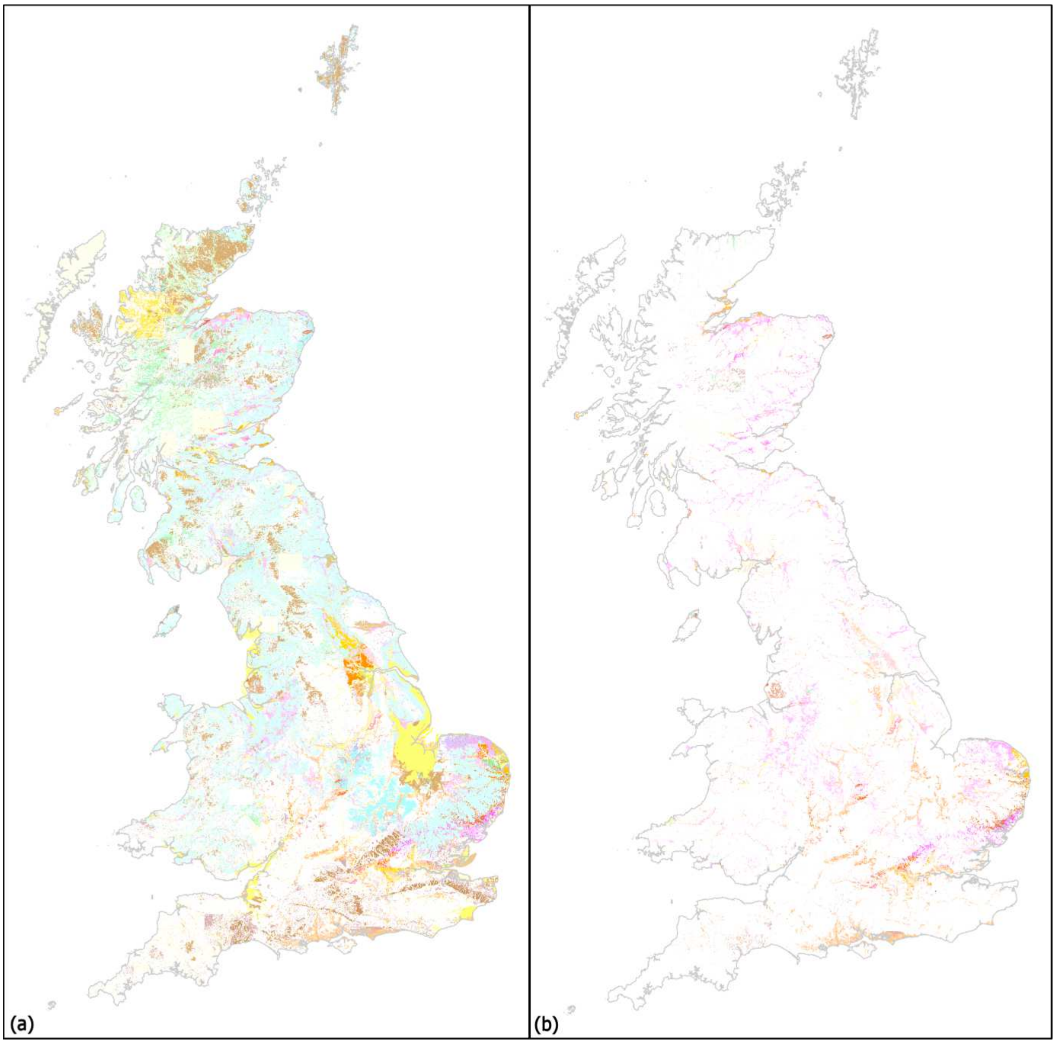


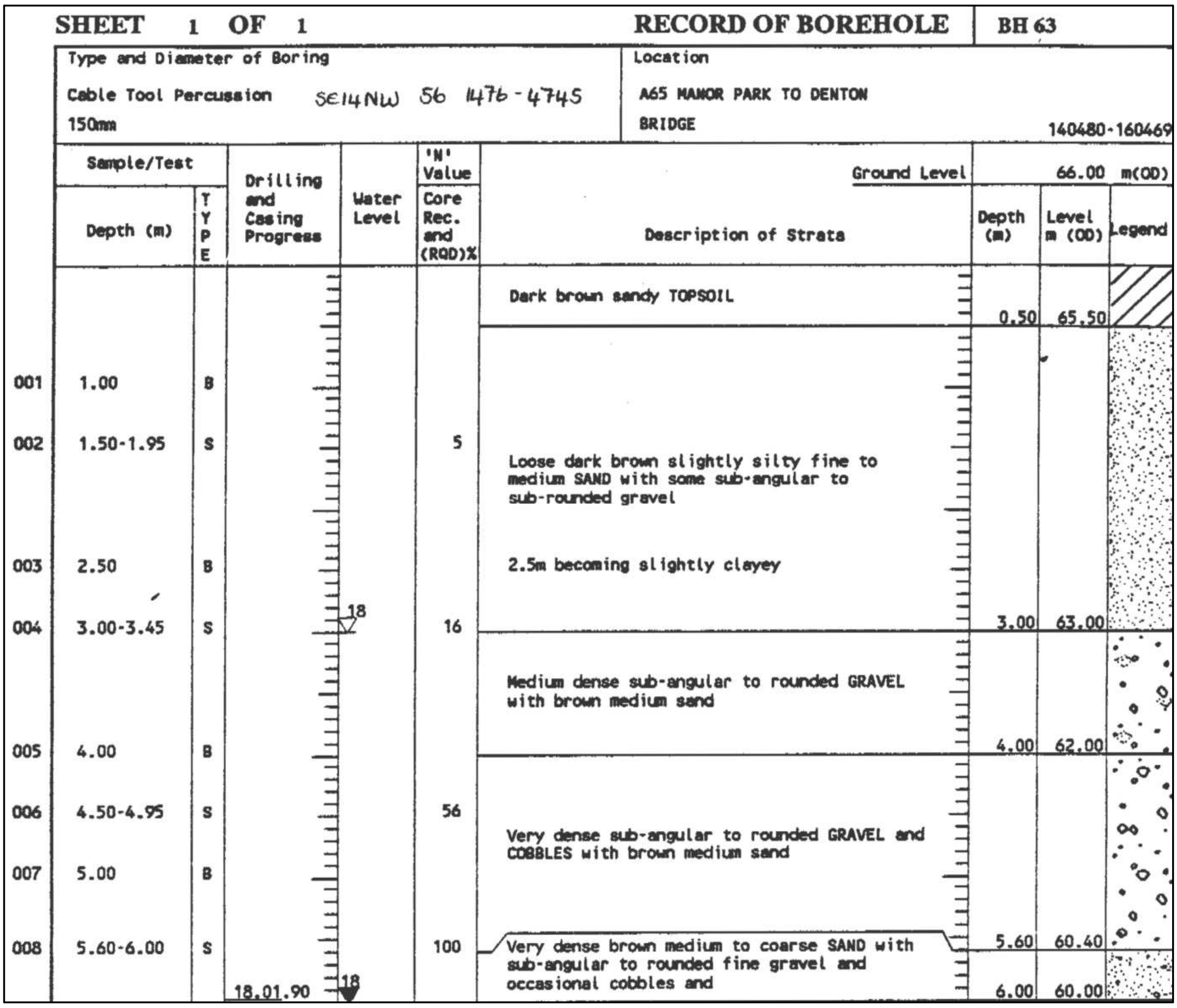
Figure 10: (a) Input Great Britain superficial deposits. (b) Output Great Britain superficial deposits queried to identify sand and gravel resources
Source: British Geological Survey 1:50 000 scale DiGMap data

5.1.11 *OPTION 3: Identification of sand and gravel resources using medium scale data and supplementary subsurface information.*

DATA SCALE	1:50 000 to 1:10 000
DESCRIPTION	Use the results of Option 2 queries as basis of sand and gravel resources but refine further via available subsurface data.

5.1.12 *Option 3 Methodology*

This option builds on the results of Option 2 and using additional subsurface data derived from borehole logs (see **Error! Reference source not found.**). This supplementary information provides an evidence base to support the presence or absence of sand and gravel resources. An example borehole log is shown in Figure 11. From analysing these logs the thickness of each horizon can be established and in some cases information on the composition may be included.


SHEET 1 OF 1 — RECORD OF BOREHOLE — BH 63

Type and Diameter of Boring: Cable Tool Percussion 150mm — SE14NW 56 1476-4745

Location: A65 MANOR PARK TO DENTON BRIDGE — 140480-160469

Ground Level 66.00 m(OD)

	Sample/Test Depth (m)	TYPE	Drilling and Casing Progress	Water Level	'N' Value Core Rec. and (RQD)%	Description of Strata	Depth (m)	Level m (OD)
						Dark brown sandy TOPSOIL	0.50	65.50
001	1.00	B						
002	1.50-1.95	S			5	Loose dark brown slightly silty fine to medium SAND with some sub-angular to sub-rounded gravel		
003	2.50	B				2.5m becoming slightly clayey		
004	3.00-3.45	S		18	16		3.00	63.00
						Medium dense sub-angular to rounded GRAVEL with brown medium sand		
005	4.00	B					4.00	62.00
006	4.50-4.95	S			56	Very dense sub-angular to rounded GRAVEL and COBBLES with brown medium sand		
007	5.00	B						
008	5.60-6.00	S			100		5.60	60.40
			18.01.90	18		Very dense brown medium to coarse SAND with sub-angular to rounded fine gravel and occasional cobbles and	6.00	60.00

Figure 11: Example of borehole log illustrating thickness and composition of individual horizons.

Where boreholes show no evidence of sand and gravel or it is mixed with too much clay\fines (see Figure 6) they can be used with expert knowledge to redefine the extent of the resource areas through the exclusion of areas not recognised as a resource. Figure 12a) illustrates the area selected based exclusively on geological description; whilst Figure 12b) indicates the revisions made to the extent of the resource based on the evidence gained from the borehole logs.

A further development of this option would be the use of the borehole information to model individual horizons from the borehole data. This is a migration from a simple two dimensional representation of the data to two and a half or simple three dimensional interpretations of the data. This would allow simple volumetric calculations to be carried out using surface area and thickness of resource derived from the borehole log data.

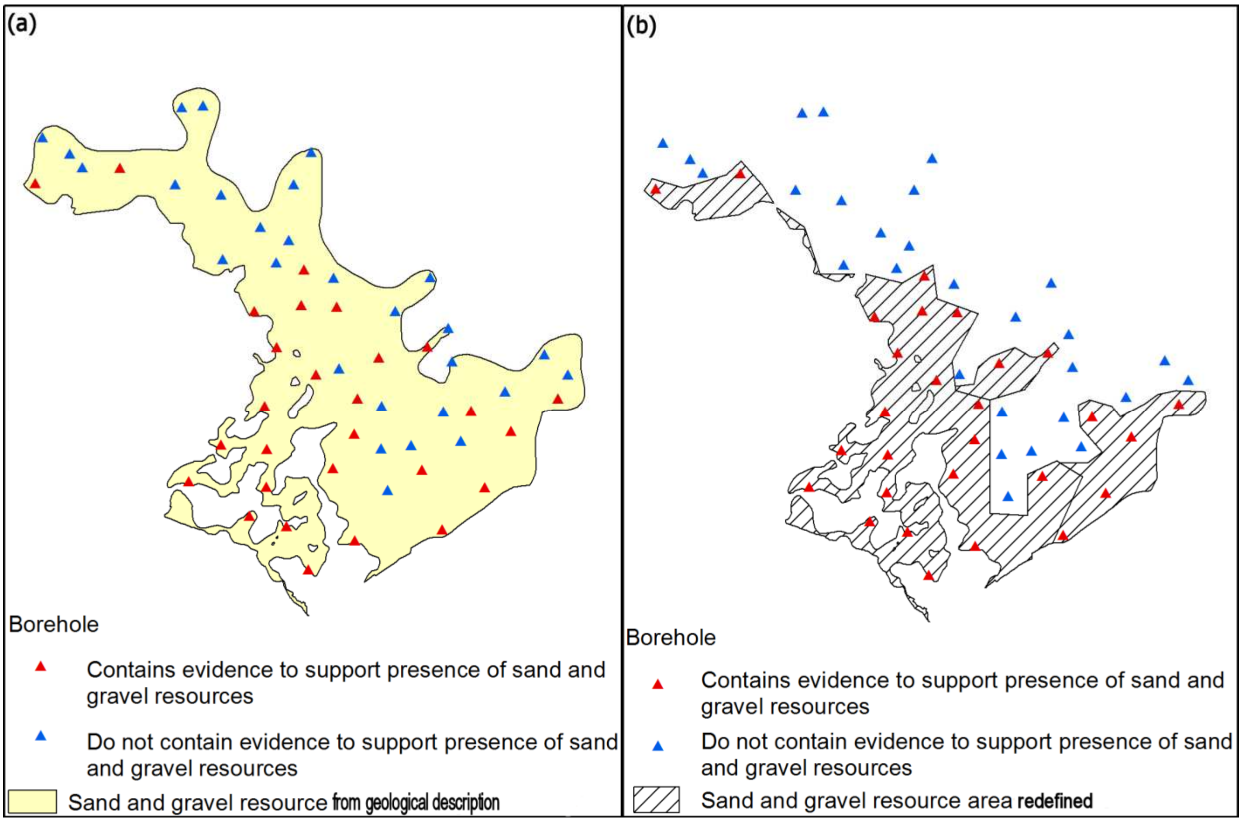


Figure 12: Rationalisation of sand and gravel resources from borehole information.

Although Option 3 is unlikely to be suitable for a cross Europe approach, it has been successfully applied at a national scale in the Netherlands as illustrated in Figure 13. The maps and website (http://www.delfstoffenonline.nl/delfstof/zandgrindviewer.htm) provide an indication of thickness and extent estimates of sand and gravel by both total quantity and extractable volume based on detailed borehole and grading information.

The methodology requires a significant amount of detailed borehole data and knowledge on how to interpret the data to generate realistic volume calculations. This option is more appropriate at a more local scale.

Further details of the application and development of 3D models is described in Task 3.4 Technical requirements for 3D.

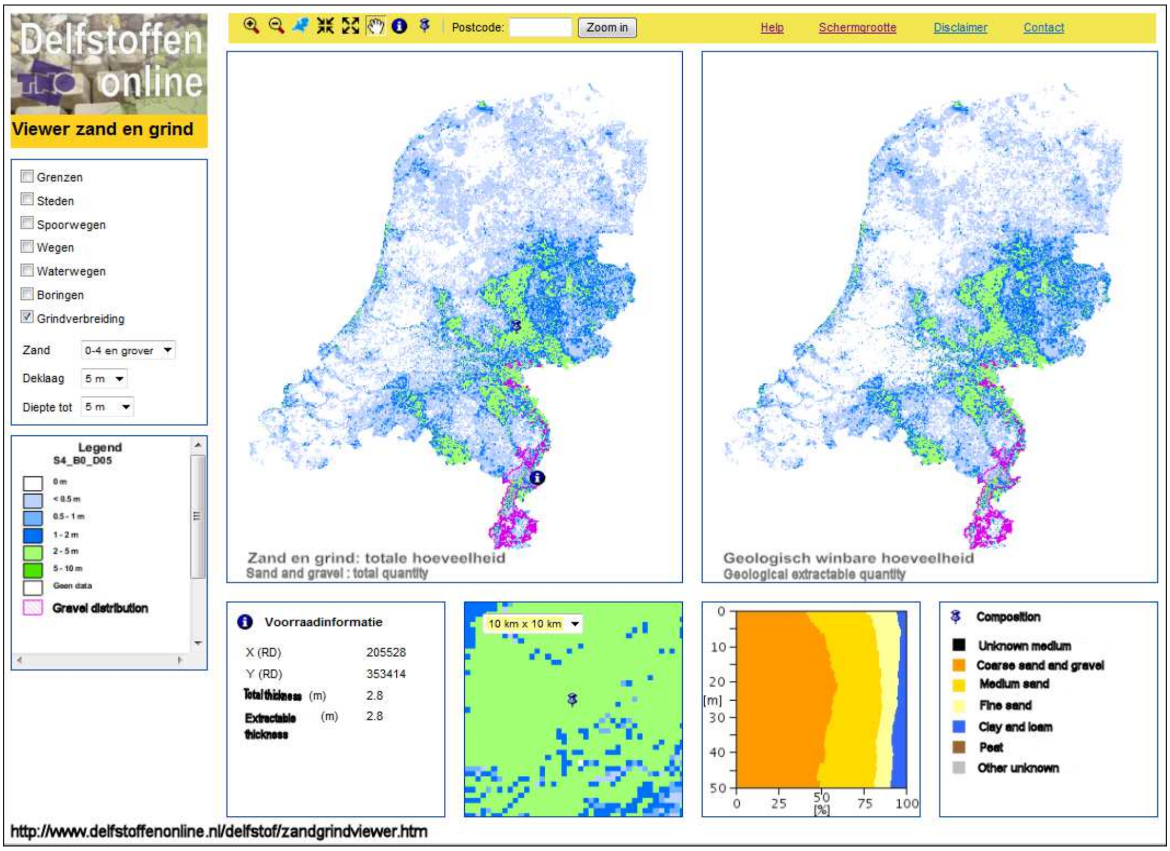


Figure 13: Sand and Gravel resource maps and thickness estimations for the Netherlands.

5.2 Sustainability

Extraction of sand and gravel makes an important contribution to European development. The extraction process has a marked influence both positive and negative, through economic development, social progress, and its environmental footprint. Sand and gravel extraction may result in permanent or temporary changes to the landscape and environment.

Sustainable development can be described as '*meeting the needs of the present without compromising the needs of the future*'.

Sustainable development seeks to create a balance between economic development, environmental protection, community benefits and government responsibilities. The key being that the developmental benefits are maximised whilst negative human and environmental impacts are minimised. Unsustainable development is driven by commercial benefit with reckless regard for societal and environmental destruction.

The methodologies outlined here do not consider even the most basic sustainability issues. However, through the implementation Options 2 or 3 the foundation for the development of a multi criteria analysis could be established. Figure 14 illustrates some of the key areas for investigation to ensure identification of suitable sustainable sites for future development.

Whilst the main focus of the EU Raw Materials initiative is metals, it recognises the importance of sustainability in the extractive industry. Included in this is the impact of the extraction of construction materials such as sand and gravel. It suggests that the currently the EU is self sufficient in construction minerals, in particular aggregates (2011 figures). In developing sustainable supply the EU policy proposes that 'lower value materials', notably construction materials are managed through land use planning legislation.

It is recommended that the issue of sustainability is explored as a separate issue within the EGDI project.

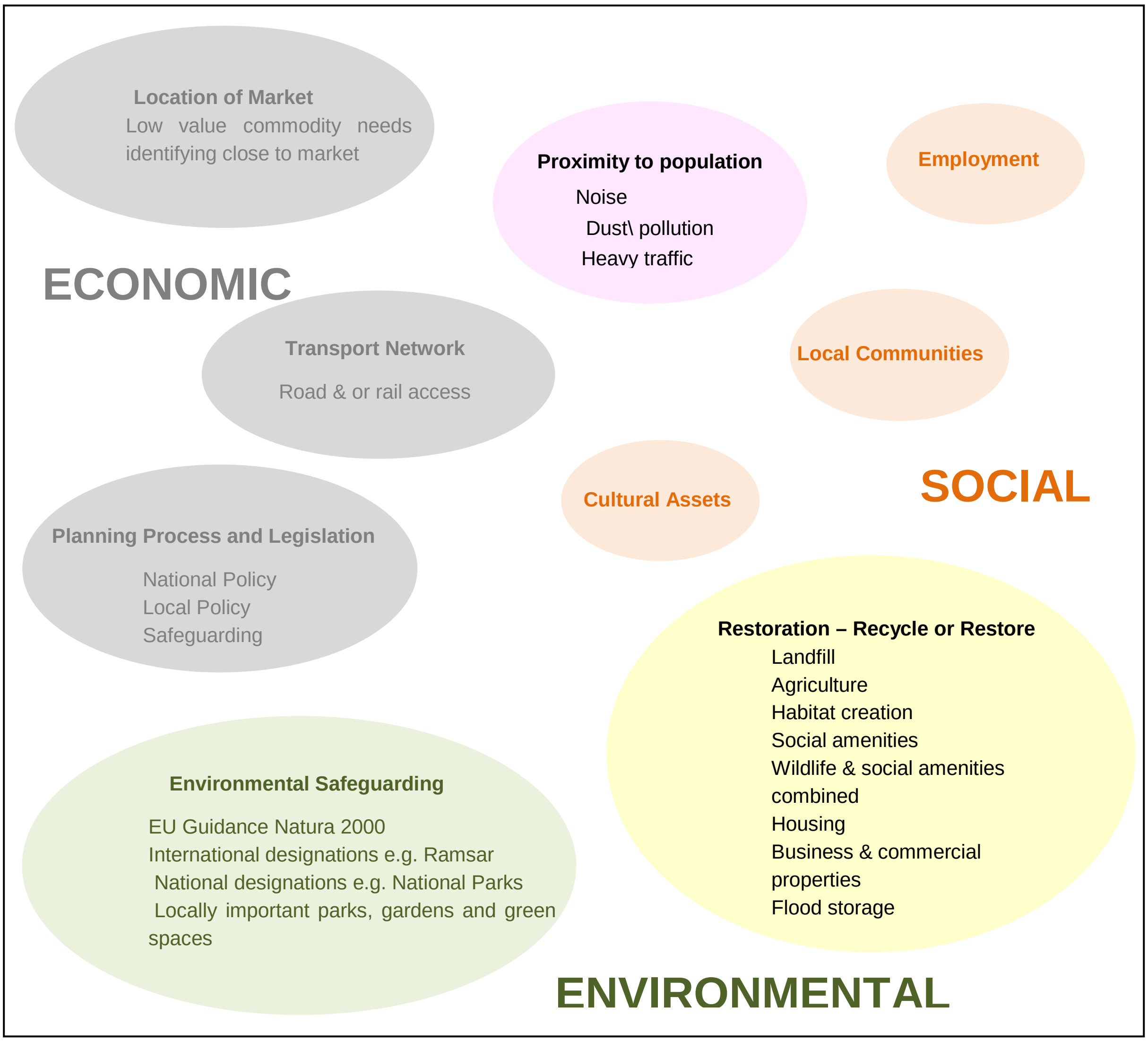


Figure 14: Criteria for sustainable development of superficial sand and gravel resources.

5.2.1 *Limitations of methodology for consideration*

- Paucity of data.
- Geological consistency and similarity across areas is assumed but not proven.
- Coverage at a trans-national scale would be required to produce a European map.
- Source data needs to be vector not raster (see Option 1).
- No consideration has been given to the topology or character of the landscape only the surface geology.
- The methods outlined below have been developed using data at specific scales and it is inappropriate and inaccurate to use the data at larger scales.
- Volumetric analysis results are estimates.
- Fitness for purpose, maps produced are for information purposes and strategic spatial planning not site specific evaluation.
- Methodology does not consider areas sterilised by urbanisation or environmental designations.
- Cost analysis of transport to market has not been carried out.
- Economic factors including value of commodity have not been considered.
- End use criteria have not been applied.

5.2.2 *Recommendations*

Option 1 would allow development of single European sand and gravel layer. However its development would be dependent on progress within One Geology using GeoSciML portrayal to release WFS (Web Feature Service) deploying the scheme described in table 1. It will then be possible to run a query to extract all superficial sand and gravel data. When available this option should be tested as it has potential to provide general coverage for Europe.

Option 2 will produce superficial sand and gravel resource layer but would require more careful data management and some knowledge of sand and gravel resources to ensure that like features are matched across international boundaries.

The methodology employed should be selected based on three key criteria

- Availability of consistent source data
- Level of attribution associated source data
- End use of the derived data product

Maintenance of any European wide superficial sand and gravel dataset would be key to its application and use for informed decision making. The update process should be timely to retain the comprehensive nature of the superficial sand and gravel data but should not represent to onerous a burden for data reprocessing. A sustainable update policy with defined threshold values should be implemented. For example if 20% of the countries have updated their source data **or** a five year period has elapsed then the data should be reprocessed to integrate all changes and updates to the superficial sand and gravel dataset.

Application of these methodologies would result in the creation of spatial datasets for delivery through a GIS. Release of spatially enabled data aligns with the proposed EGDI infrastructure described in Work package 4 where GIS is identified as one of the main thematic delivery tools. In the concluding comments it is emphasised that dataset delivery is a key criteria in the development of the EGDI system architecture.

5.3 Incorporation of existing technologies

Throughout the EGDI-scope project, references have been made to multiple existing projects, such as InGeoClouds, eENVplus, and Minerals4EU that are providing a range of technological and processing tools to format and provide data. These projects have specific objectives and focuses as well as individual funding mechanisms. However, as discussed in the case of scientific research projects, the funding is usually for a limited amount of time, with no long-term sustainability plan. There are two main possibilities, firstly further funding is obtained or they are funded directly by the commitment of individual or a group of organisations/surveys, or secondly, the technologies and outputs are moved into the scope of the EGDI implementation. These tools and expertise are recognised as important to consider for potential incorporation into the EGDI developments. Below is a brief overview of three example projects that are currently in development and of specific relevance to the EGDI, of course there will be others.

5.3.1 *Current projects developing technologies*

5.3.1.1.1 InGeoClouds

InGeoCloudS is an immediate and cost-efficient solution for self-service deployment of data and services on the Internet. Data providers keep full control on their data and on their operation costs and data is delivered through the cloud. The InGeoCLOUDS project aims at demonstrating the feasibility of employing a cloud-based infrastructure coupled with the necessary services to provide seamless access to geospatial public sector information, especially targeting the geological, geophysical and other geoscientific information. Further details can be found at http://www.ingeoclouds.eu/

5.3.1.1.2 eENVplus

The eENVplus Infrastructure focuses on providing applications for the integration of data services. It supports the implementation of INPIRE through a phased approach. eENVplus uses common services which it processes uses tools to create risk-based products. The project so far has a series of pilot studies to trial these. These tools are potentially something that could be implemented within the EGDI. Further details can be found at http://www.eenvplus.eu/

5.3.1.1.3 Minerals4EU

The Minerals4EU project will establish a network intelligence structure and deliver, via a web portal, relevant mineral-specific data and a European Minerals Yearbook to support decision making on policy and adaptation strategies throughout the EU. It is built around INSPIRE, allowing information to be shared. Minerals4EU is in close collaboration with the EGDI-scope project and as a newly initiated project, will aim to feed mineral-specific information into the broader scope of the EGDI as a pilot study. Again, the methodologies regarding technology transfer and lessons-learned will be an important input to the future EGDI implementation. Further details can be found at http://www.eurogeosurveys.org/minerals4eu/

6 Conclusions

The EGDI project needs to deliver an implementation plan for a stable pan-European Geological Data Infrastructure. The Infrastructure is to enable European geological surveys to serve and maintain INSPIRE-compliant, interoperable geological data and information reflecting our understanding of the subsurface. Key to that infrastructure is an understanding of extant data and methodologies that have already delivered value added outputs under public funding. Work packages 2-5 have built an overview of data and methods from recent projects.
From the scoping work completed to date there are some key conclusions to draw:

- Inspire compliance is a fundamental requirement for data to be useful to future users
- Further clarification may be needed to be provided in scope of INSPIRE data (for which EGDI could play a role, particularly in managing metadata for proxy or analogous datasets from across the INSPIRE annexes)
- Significant Pan-European datasets exist (Offering quick wins for establishing baseline data around which to build the EGDI infrastructure)
- Significant EGS-member data exist (again offering EGDI a fundamental role in coordinating integration of national data into a pan European context, ensuring sustainability)
- Methodologies for Pan-European products exist, but are subject to issues of availability and documentation as project budgets recede (EGDI can act as a host and repository for these methods and products)
- Methodologies and tools for services and data provision (e.g. via cloud-based computing) exist and could potentially be incorporated into the EGDI
- EGDI infrastructure can provide support for four key areas:
    1. Preservation and clarification of current/recent/past methods
    2. Options for harmonisation of disparate scale/scope data
    3. Options for structured vocabularies to integrate methods/data
    4. Options for cross-research to incorporate geological data with other spatial themes to develop new products relating geo-science impacts with societal, environmental, statutory, commercial and educational agendas

5. Options for the use of, and further development of appropriate ‘tools’.

- EGDI will stimulate cross-topic collaboration encouraging expert groups to engage with public, policy-makers and wider stakeholder communities.

The secondary objective of an EGDI is to create a framework to sustain results from past, on-going and future European projects (e.g. OneGeology Europe, EuroGeosource, PanGeo, eMODNet, etc.). The data-scoping workpackages have identified the following:

- There is a clear need for preservation (and metadata management/clarification) of current/recent/past Pan European data
- Significant Pan-European datasets exist
    - Some should be incorporated into EGDI as a priority (see listing below)
    - Some are harmonised and aligned to impact, or strategic agendas (and popular as baseline data)
    - Some are variable in scale, scope and context (requiring thought on future completion/inclusion, re-purposing)
    - Some are current (offering evolving content and completeness)
    - others are legacy/frozen (offering options for re-use, baseline/temporal benchmarking)
- Significant EGS-member data exist
    - EGDI would be an ideal mechanism to coordinate trans-national harmonisation
    - EGDI could develop mechanisms of integration to build national data into pan-european datasets
    - EGDI offers additional support for campaigns to complete, harmonise, re-purpose national datasets
    - EGDI offers an opportunity to host legacy (european-focussed) data as a distributed, centralised or cloud concept.

Immediate implementation of data	Primary activity if adopted
OneGeologyEurope 1: 1 million surface geology - Part Europe coverage	1. Assess options for completeness* 2. Assess companion datasets for spatial stratification/upscaling 3. Assess options cross referencing with demographic/asset/environment datasets
EMODnet-Geology 1:1 million substrate map - Northern European seas coverage	1. Assess options for completeness* 2. Assess companion datasets for spatial stratification/upscaling 3. Assess options cross referencing with demographic/asset/environment datasets
Promine datasets **EuroGeoSource datasets** - archives	1. Assess options for completeness/integration
International Hydrogeological Map of Europe	1. Assess options for completeness 2. Assess companion datasets for spatial stratification/upscaling 3. Assess options cross referencing with demographic/asset/environment datasets

Terrafirma, PanGeo and **SubCoast**	1. Assess companion datasets for spatial stratification/upscaling * 2. Assess options cross referencing with demographic/asset/environment datasets 3. Assess underlying methods for re-use at differing scales

*see quick wins below

6.1 Quick-win development potential

Quick-win development and implementation (within c.1 year)
OneGeologyEurope 1: 1 million surface geology Increased coverage to 85-90% coverage
EMODnet-Geology 1:250 000 substrate map - All European waters
NEW methodologies: **aggregate resources – sand and gravel**
NEW Subsidence data combining information from **PanGeo** and **SubCoast**

6.2 Longer-term recommendations

Geogenic geochemical background values (incorporating GEMAS into OneGeology-Europe)
NEW Permeability data attributes added to the OneGeology-Europe base map
Land-use datasets compilations for multi-users
Other hazard data methodologies e.g. landslides, flood.
Borehole data
3D data models?

References

Cartwright, C. E. et al., 2013. *D 3.2 Review of relevant datasets available within Europe,* s.l.: EGDI-Scope.

Lee, K. A. & Armstrong, R. W., 2012. *D 3.1 Review of previous and ongoing projects,* s.l.: EGDI-Scope.