WP6 – Annex report:

eWater high-level harmonised legend for hydrogeological maps in Europe

(eWater WP6 2nd Phase (IGME, December 21st 2007)

1 Introduction

During the first phase of eWater project, a survey was done on current (hydro)geological maps and models available in the project partner countries. The survey yielded a database containing an overview of the maps and models available and their most important characteristics (format, content, scale, legend, projection, availability, etc.). The information was analysed and hydrogeological maps were selected to be published in the eWater system.

On the basis of this information, an attempt has been made to compare the map contents, namely the geological and hydrogeological classifications used by the partner countries and to define a high-level harmonised legend. The differences among hydrogeological and especially among litho- and chronostratigraphic classifications are huge. Notwithstanding this, the definition of a common legend has been attempted in order to explore and identify possible future steps for the harmonisation of these maps and models in the eWater project or in future hydrogeological cartographic initiatives in the Member States.

2 Framework and strategy

The approach followed to derive a high-level legend proposal for hydrogeological maps was to search for the lowest common denominator of the hydrogeological maps inventoried in the eWater project. This was considered a good way of assessing the present status of cartography in all the participating Geological Surveys, and a good way of maintaining a simple but robust enough standard legend that helps mediating between experts in hydrogeology and the general public. Other major international initiatives regarding harmonisation of hydrogeological maps referenced in the text recognise this mediating role as well.

Notwithstanding this, looking into the present and future needs of hydrogeological cartographic information, the requirements presently arising from the implementation of the Water Framework Directive (WFD, http://circa.europa.eu/Public/irc/env/wfd/library) and other related initiatives have been taken into account. The results of an inventory of international programmes and projects relevant to eWater, performed in the framework of this project and included in Asfirane and Balloffet (2007), provided a summarised view of these needs. The proposed legend has been conceived to provide the most basic hydrogeological information that may be complementary to the information to be compiled and made available through the Water Information System in Europe (WISE) for the WFD.

Other important demands for cartographic products are arising from ongoing European initiatives monitoring the environment, more specifically from those aimed at protecting the soil and assessing geological hazards. The potential consequences of these demands warrants further investigation, but do not lie within the scope of this project. In the following chapters some additional layers are mentioned that may be considered of interest to meet new demands. A deeper and systematic analysis of the implications of implementing the WFD and other regulatory initiatives is suggested in order to better define the future needs of cartographic developments and it could be considered as an objective in itself for a continuation of this project or a new proposal in this area of work.

Having these considerations in mind, the eWater legend is proposed to represent the hydrogeological and lithogeochemical characteristics of the outcropping geological formations (the container) whether aquifers or non-aquifers, but not the groundwater types or facies (the content). The main concepts to be represented in the hydrogeological maps to be published on the eWater portal, and to be captured in the high-level legend, are described in the following paragraphs.

3 Concepts to be represented in the high-level legend

3.1 Aquifer types

The “aquifer type” is the main concept used to classify geological formations according to the occurrence of groundwater and the groundwater flow regime in the proposed high-level legend, in the same way as proposed in Struckmeier and Margat (1995) and BGR (2007). Consequently, the following aquifer types are defined (their corresponding colours coincide with those used in BGR (2007)):

I: AQUIFERS IN WHICH FLOW IS MAINLY INTERGRANULAR (GENERALLY NON-CONSOLIDATED POROUS FORMATIONS)

I.a Extensive and highly productive aquifers

I.b Local or discontinuous productive aquifers, or extensive but only moderately productive aquifers

II: FISSURED AQUIFERS, INCLUDING KARST AQUIFERS (FISSURED AND COMPACTED FORMATIONS)

II.a Extensive and highly productive aquifers

II.b Local or discontinuous productive aquifers, or extensive but only moderately productive aquifers

III: MINOR AQUIFERS IN POROUS OR FISSURED FORMATIONS OR AREAS WITH NO GROUNDWATER RESOURCES

III.a Minor aquifers with local and limited groundwater resources

III.b Areas with essentially no groundwater resources

III.c Where there is an extensive aquifer immediately underlying a thin cover the appropriate aquifer colour should be used with vertical brown stripes (one mm wide and three mm apart)

The decision about whether flow is intergranular or fissured in an aquifer depends on which characteristic is dominant. For the purposes of eWater, representation of the main aquifer is suggested when two or more different aquifers overlap. Previous results of applying this legend to the International Hydrogeological Map of Europe (BGR, 2007) may help in taking these decisions as well as in assessing whether an aquifer is extensive or local.

Considering the small scale of work used in the eWater system (<1:200,000), thin cover layers could have been omitted. However, bearing in mind the purpose of the maps, it is advisable that thin low-permeability cover layers are represented in many cases where the occurrence of these layers is an important consideration in assessing the vulnerability of the underlying aquifers (e.g. in large areas in Denmark where sandy aquifers are covered by clayey tills). A similar consideration applies to alteration zones or Quaternary deposits in basement areas (e.g. in Sweden), where these formations may play an important role as main water bodies or they may constitute the aquifers most vulnerable to contamination in these areas

3.2 Lithogeochemical classification

A simple lithogeochemical classification is introduced into the eWater high-level legend in order to identify hydrogeological formations according to the main geochemical signature that they may have on the groundwater resources.

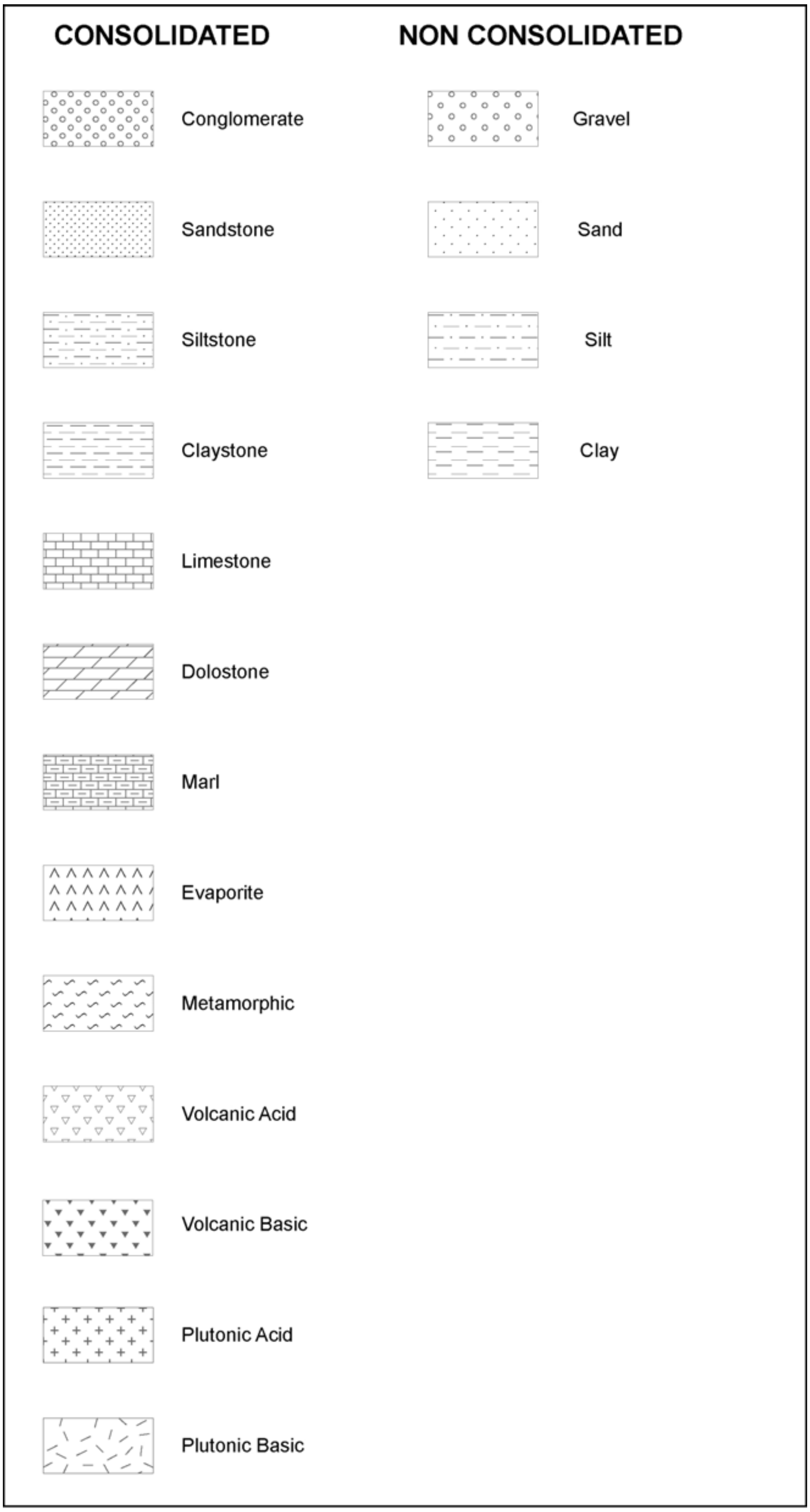
A review has been done of some important textbooks on hydro-geochemistry and how they treat the main environmental factors that need to be taken into account in the study and interpretation of groundwater chemical characteristics. “Rock type” is one of the most important environmental factors identified governing groundwater chemistry, together with climate, relief, and vegetation (Drever, 1982). Climate, “Geological Effects” and Biochemical Factors are the main factors controlling natural water composition listed by Hem (1985) as providing water and solid reactants, as well as influencing the main chemical reactions. Differences in the concentrations in unpolluted terrestrial waters are related to solubility of the minerals present in “parent rock”, and the rate of dissolution of these minerals (Appelo and Postma, 1994). The basic classifications of rock composition used in the references above were used to derive the proposed high-level legend.

The underlying idea of the proposed legend was to retain from the geological maps, which may serve as the basis for this cartography, only the information relevant to hydrogeology. A low number of ornaments are proposed to characterise and distinguish lithologies in Aquifer Groups I to III. Regarding Aquifer Group III, this classification describes the potential geochemical input from these formations to Aquifer Groups I and I that they may bind.

Only one fifth of the ornaments contained in the standard legend published by Struckmeier and Margat (1995) are used in the proposed legend. The legend proposed is also simpler than the one proposed by Pauwels et al. (2006) in the framework of the 6th Framework Programme of the European Commission Project “Background cRiteria for the IDentification of Groundwater thresholds” (BRIDGE). Some of the criteria used to reduce the number of ornaments contained in these two references were to avoid redundancy with regards to the geochemical signal that the rock types identified may have on groundwater and to avoid mixing lithological, chronostratigraphic and genetic criteria. The high-level legend does not contain information on chronostratigraphy because it is considered of secondary importance in hydrogeology. Harmonisation of this information would also be difficult and costly given the objectives and scope of the eWater project.

A distinction is made in the legend between consolidated and non-consolidated sediments because of the important implications of this concept in hydrogeology, as it influences the type of formation (porous or fissured), its vulnerability, or the type of drilling methods to be used in an area. A tighter and a less tight pattern are used for these two types of formations respectively.

Considering the scale of work of eWater, the representation of the different possible combinations of lithogeochemical classes that may be found in many cases in the field and in detailed cartographies (e.g. gravel and sand, sand and clay, clay and gypsum,…) will not be shown with different patterns. A decision will have to be taken about which is the main class to represent from all those present in each formation. The detailed information on the different classes can be included in the layer attributes. Any user will be able to obtain this information by just clicking on the corresponding polygons on the map. The layer attributes may also include more detailed terms like “marble”, “mica-schist”, etc. that are not used in the high-level legend. However, the number of terms to be translated into the languages of the eWater information system will be limited to those represented in the legend.



Lithogeochemical classification symbols

3.3 Depositional environment

Several eWater project partner countries have thought that identifying genetic aspects of the hydrogeological formation is important. In the framework of the project, and considering the needs of these partners, the concept of “depositional environment” has been introduced. The concept is only meant to be applied to the detrital formations. In addition to the data views that will be generated for the aquifer types and lithogeochemical classes, a different view is proposed so that the depositional environments can be represented on the maps. Different colours are proposed that will be applied to the legend patterns to differentiate six main depositional environments: marine, glacial, fluvial, lacustrine, aeolian and gravitational. This data view is optional, as it may be just of interest for several countries.

3.4 Boundaries between aquifers: line and point symbols

Considering the eWater objectives and the partner countries’ hydrogeological map inventory results, the only lines proposed to be represented on the maps are the boundaries between different aquifer types. Point representation has not been considered in this proposal as far as they will be represented in a different layer, whose format will be specified in the WP5 results.

4 Other layers of interest to be considered in future hydrogeological cartographic initiatives

A wide variety of area information, in addition to the type of aquifer, rock composition, and depositional environment, is normally provided by the hydrogeological maps and models available in Europe. Rock texture, porosity, and degree of fissuring are important geological factors that control the chemical characteristics of groundwater under natural conditions for any given lithology. Regional structure is an important part of the hydrogeological model. Knowledge of the chronostratigraphy may help recognise the geological structure. Many geological and hydrogeological maps produced in the partner countries show part of this information at different formats and scales. However, strong limitations arise for a harmonised representation of these detailed geological and hydrogeological data. Consequently, these additional layers have not been included in the high-level legend.

The other most important layers identified in eWater for the future implementation of the WFD, in addition to the layer representing aquifer types and main lithogeochemical classes, are those representing: 1) recharge, 2) soil properties, 3) unsaturated zone characteristics, 4) aquifer vulnerability, 5) drinking water protection areas, 6) potentiometric maps, and 7) hydrochemical element distribution. Again, some of the hydrogeological maps produced in the partner countries, and particularly some of the 3-D representations (models) available in the Netherlands and Denmark, show parts of this information although in different formats and scales. Some considerations on vulnerability are given in the following paragraphs: contour maps of the potentiometric surface and hydrochemical element distribution. The delimitation of drinking water protection areas requires scales of work much larger than the ones dealt with in the eWater project.

4.1 Vulnerability maps

"Vulnerability is an intrinsic property of a groundwater system that depends on the sensitivity of that system to human and/or natural impacts" (Vurba and Zaporozec, 1994). This concept of vulnerability is based on the assumption that the physical environment may provide some degree of protection to groundwater against natural and human impacts, especially with regard to contaminants entering the subsurface environment.

The high-level legend proposed represents the extremes of flow regimes within the aquifers (intergranular and fissured) which, combined with the proposed lithogeochemical classification, gives in many cases an idea of the potential of the contaminant spreading within the aquifer system and helps assess vulnerability. However, the principal attributes used in assessing intrinsic groundwater vulnerability are recharge, soil properties (percolation rate and attenuation potential), and characteristics (nature and thickness) of the unsaturated zone. The characteristics (potential for contaminant spreading) of the groundwater system, topography and groundwater/surface water relation are considered attributes of secondary importance (Vurba and Zaporozec, 1994). A model legend for groundwater vulnerability maps, included in Vurba and Zaporozec (1994), constitutes a good reference for further developments in this field.

4.2 Potentiometric maps and hydrochemical element distribution

Considering the small scale of work used in the eWater system (<1:200,000), this type of representations do not lie within the objective and scope of the project. However, it must be stressed that mapping the distribution of contaminants and some major and minor associated elements will need to be made at an appropriate scale in the research of contamination problems and risk assessments resulting from implementing WFD in the next decade. This information may be included as additional layers to the background information provided by the cartography proposed in eWater.

5 Work methodology

The GIS methodology for implementing the hydrogeological high-level legend is defined in this Chapter.

Information Source

A layer depicting the hydrogeological formations in vector format must be selected for each country (geological formations can be used if it is the only digital map available covering the whole country). This layer is the one that must be adapted to comply with the proposed legend. It is best to use a layer with several attributes (if not all of them) like:

- *Aquifer type*
- *Lithology*
- *Permeability*
- *Chronostratigraphy*

High-level legend file name

The recommended file name for the selected layer is given in Table 1 for each country. The first row in Table 1 describes the concepts represented and geographical area (country) of the layer. A prefix and suffix are used for each recommended file name. The prefix is taken from the first letter of the main concepts represented in the layer. The suffix is related to the country to which the layer belongs.

Main concepts represented: **A**quifer types, **L**itho**G**eo**Ch**emical classification (5 characters of the prefix are used) and Depositional Environment.
Recommended file name: **ALGCh_aa** (the 2 suffix characters indicate the country)

Layer	Recommended file name
Aquifer types and Lithogeochemical classification of Austria	ALGCh_at
Aquifer types and Lithogeochemical classification of Czech	ALGCh_cz
Aquifer types and Lithogeochemical classification of Denmark	ALGCh_dk
Aquifer types and Lithogeochemical classification of France	ALGCh_fr
Aquifer types and Lithogeochemical classification of Hungary	ALGCh_hu
Aquifer types and Lithogeochemical classification of Lithuania	ALGCh_it
Aquifer types and Lithogeochemical classification of Italy	ALGCh_lt
Aquifer types and Lithogeochemical classification of the Netherlands	ALGCh_ne
Aquifer types and Lithogeochemical classification of Slovakia	ALGCh_sk
Aquifer types and Lithogeochemical classification of Slovenia	ALGCh_si
Aquifer types and Lithogeochemical classification of Spain	ALGCh_es
Aquifer types and Lithogeochemical classification of Sweden	ALGCh_se

Table 1. Recommended layer file names

Layer content

Table 2 lists the attributes of interest for eWater to be defined in the project layer, irrespective of the items present in the original layer/s.

Short field name	Long field name	Content description
AqTyC	AquiferTypeCode	Aquifer Type Code classification proposed in BGR (2007)
AqTyD	AquiferTypeDesc	Aquifer Type Description classification proposed in BGR (2007)
LiGeoCh	LithoGeoChemClass	Simplified LithoGeochemical Description Classification according to the main geochemical signature
DepEnv	DepositionalEnvironment	Depositional environment description of the geological formations
LiEnvSym	LithoEnvSymbol	Depositional environment and the associated lithology symbols
Descript	Description	Detailed description of the unit including lithological information in addition to LIGEOCH, presence of organic matter,…

Table 2. ALGCh_aa basic items

The hydrogeological formations represented in the ALGCh layer will be characterised by the mandatory assignment of two codes: one for the aquifer type and another for the lithogeochemical classification. A third optional classification is considered to identify the depositional environment of the geological formations.

Data Dictionary

The aquifer type codes, lithogeochemical classes, and depositional environments of the hydrogeological formations in the original layer should be done according to the terms described in Sections 3.1 to 3.3 of this document and in Tables 3 to 5.

AquiferTypeCode	AquiferTypeDesc
Ia	Extensive and highly productive aquifers
Ib	Local or discontinuous productive aquifers, or extensive but only moderately productive aquifers
IIa	Extensive and highly productive aquifers
IIb	Local or discontinuous productive aquifers, or extensive but only moderately productive aquifers
IIIa	Minor aquifers with local and limited groundwater resources
IIIb	Areas with essentially no groundwater resources
IIIc	Where there is an extensive aquifer immediately underlying a thin cover the appropriate aquifer colour should be used with vertical brown stripes (one mm wide and three mm apart)

Table 3. Aquifer Types

LithoGeoChemClass
Conglomerate
Gravel
Sandstone
Sand
Siltstone
Silt
Claystone
Clay
Limestone
Dolostone
Marl
Evaporite
Metamorphic
Volcanic acid
Volcanic basic
Plutonic acid
Plutonic basic

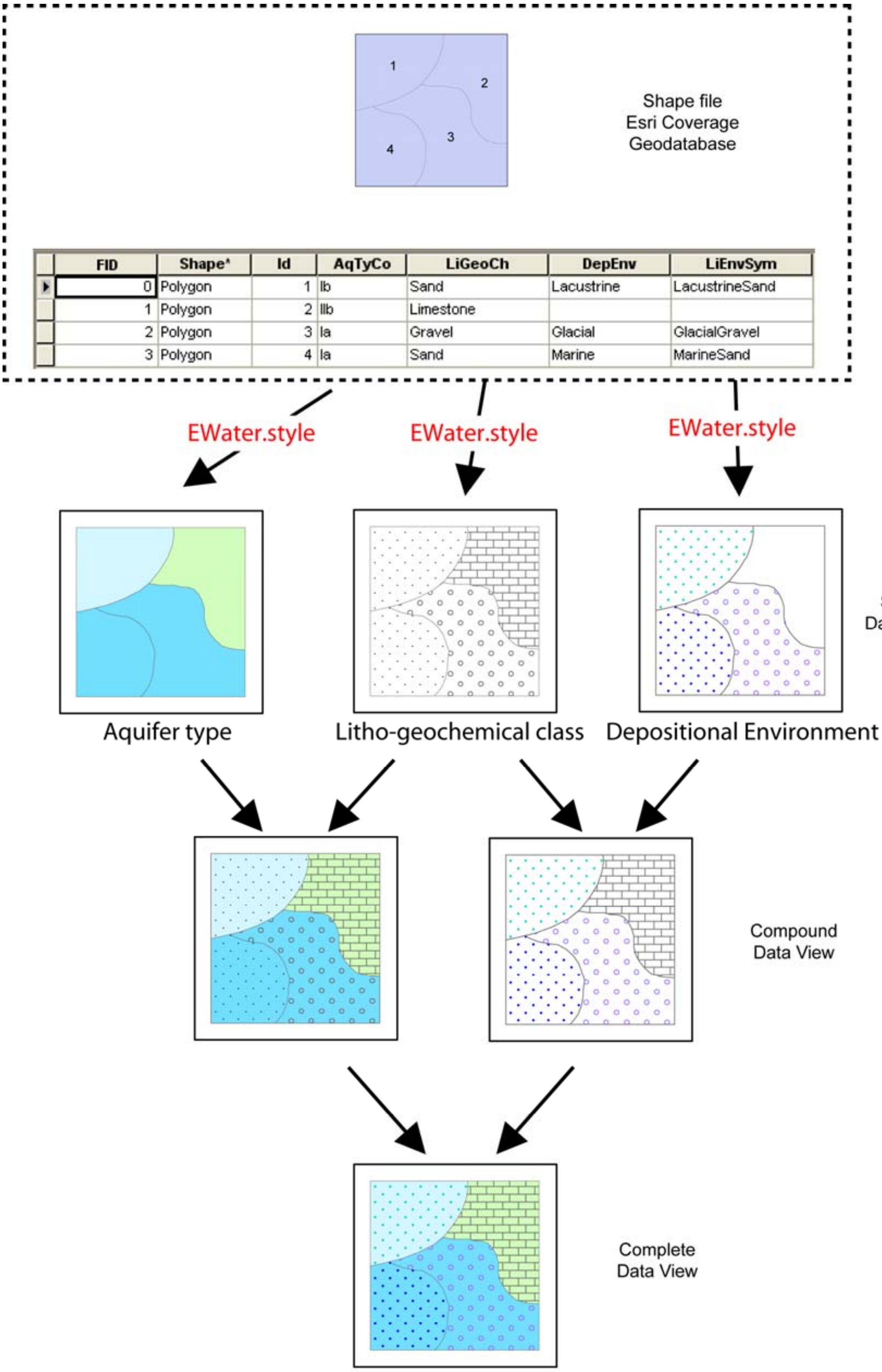
Table 4. LithoGeochemical Classification

Fluvial gravel	----	----	Marine gravel	Glacial gravel	Gravitational gravel
Fluvial sand	Lacustrine sand	Aeolian sand	Marine sand	Glacial sand	Gravitational sand
Fluvial silt	Lacustrine silt	Aeolian silt	Marine silt	Glacial silt	Gravitational silt
Fluvial clay	Lacustrine clay	Aeolian clay	Marine clay	Glacial clay	Gravitational clay

Table 5. LiEnvSym attribute codes

Data views

Three views of the data will be generated from the high-level legend spatial file: 1) aquifer type, 2) lithogeochemical classes, and 3) depositional environment.



FID	Shape*	Id	AqTyCo	LiGeoCh	DepEnv	LiEnvSym
0	Polygon	1	Ib	Sand	Lacustrine	LacustrineSand
1	Polygon	2	IIb	Limestone		
2	Polygon	3	Ia	Gravel	Glacial	GlacialGravel
3	Polygon	4	Ia	Sand	Marine	MarineSand

Chart showing the generation of the different views of the data

Symbols

Colours and symbols that will represent aquifer types, lithogeochemical classes and depositional environment graphically have been assembled in the ewater.style library (version 9.1 ArcGis). To simplify the layer symbols, the library symbols match the AquiferTypeCode LithoGeoChemClass and LiEnvSym. attribute codes. Therefore, the AquiferType, LithoGeoChemClassification and DepositionalEnvironmenT layer symbols can be done in ArcGIS with a Match to symbol in a Style using ewater.style and selecting the attribute for each of these three layers' symbols in the Value field. Figures 1 to 3 show the aquifer type, lithogeochemical classification and depositional environment symbol definition in the ewater.style library.

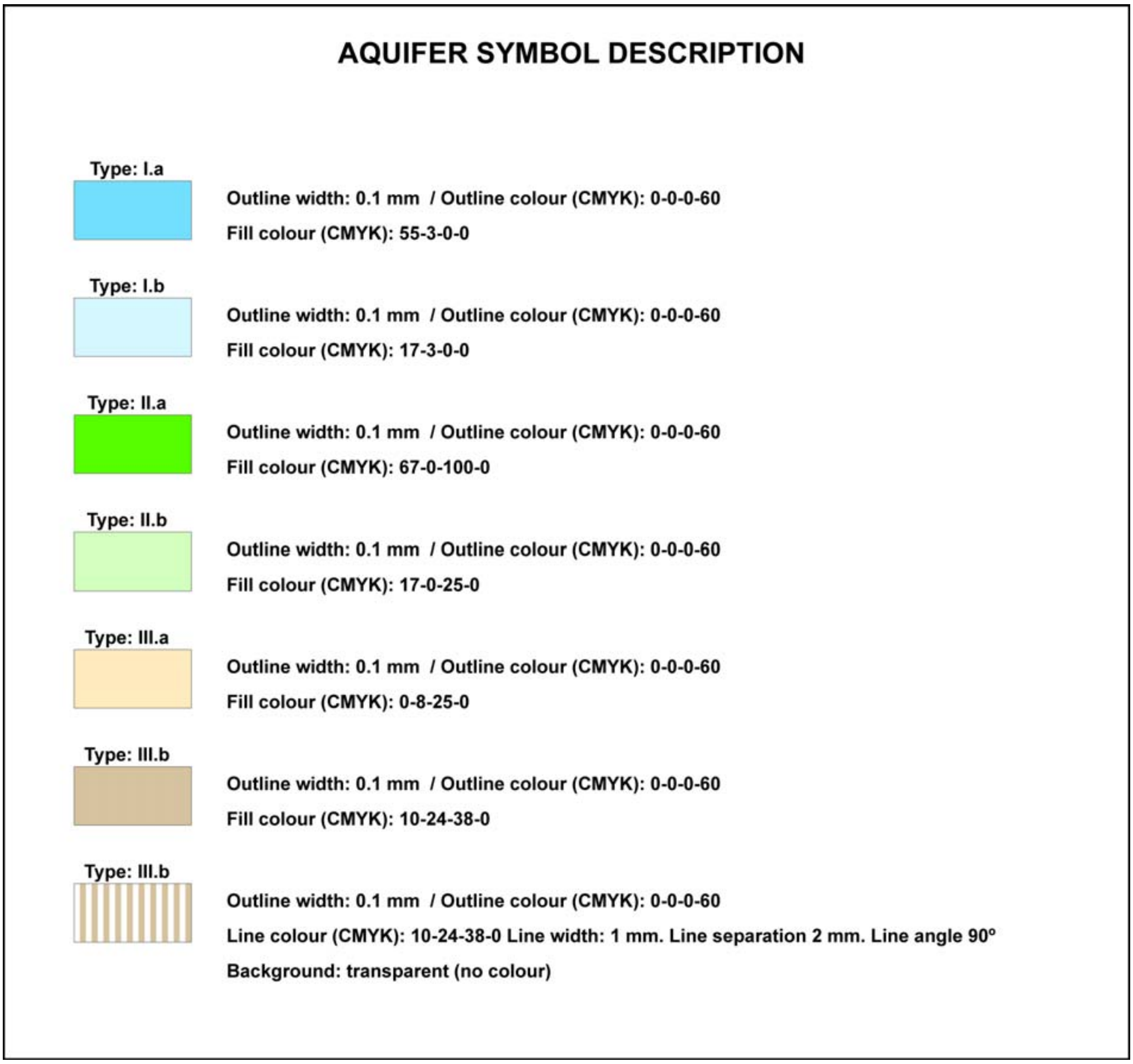


Figure 1. Aquifer Type symbol description (ewater.style)

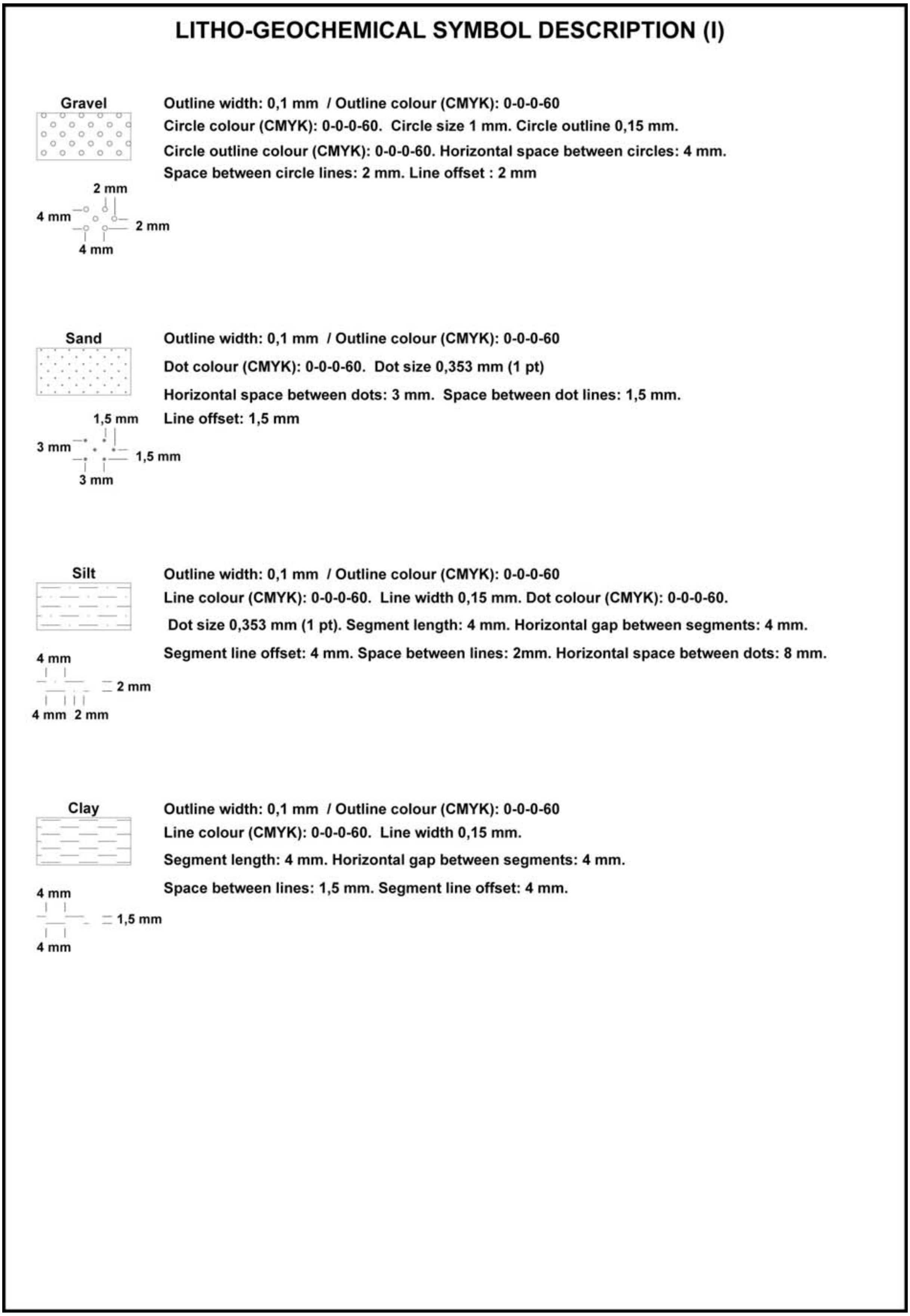


Figure 2. LithoGeochemical symbol description (ewater.style)

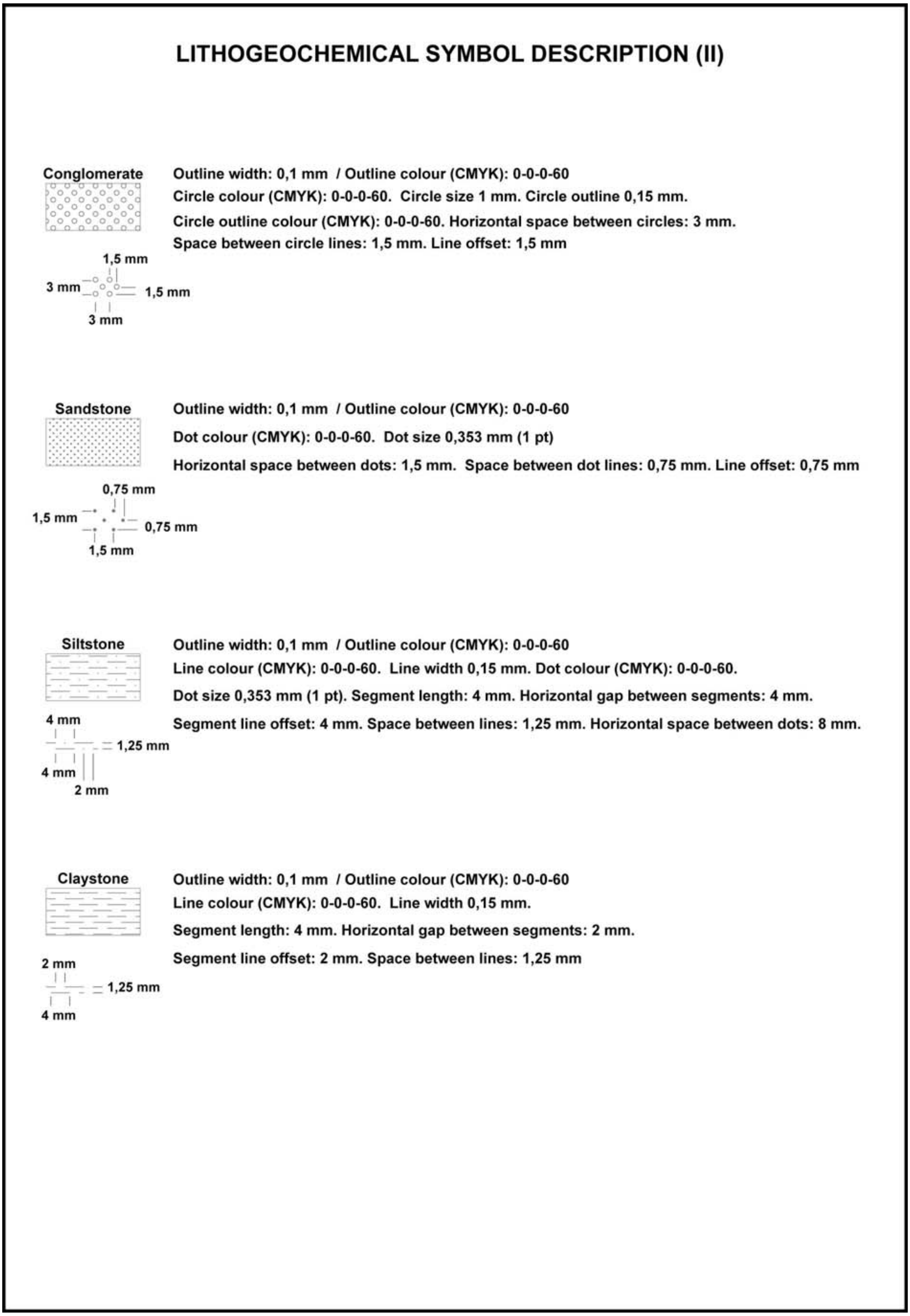


Figure 2 contd. 1. LithoGeochemical symbol description (ewater.style)

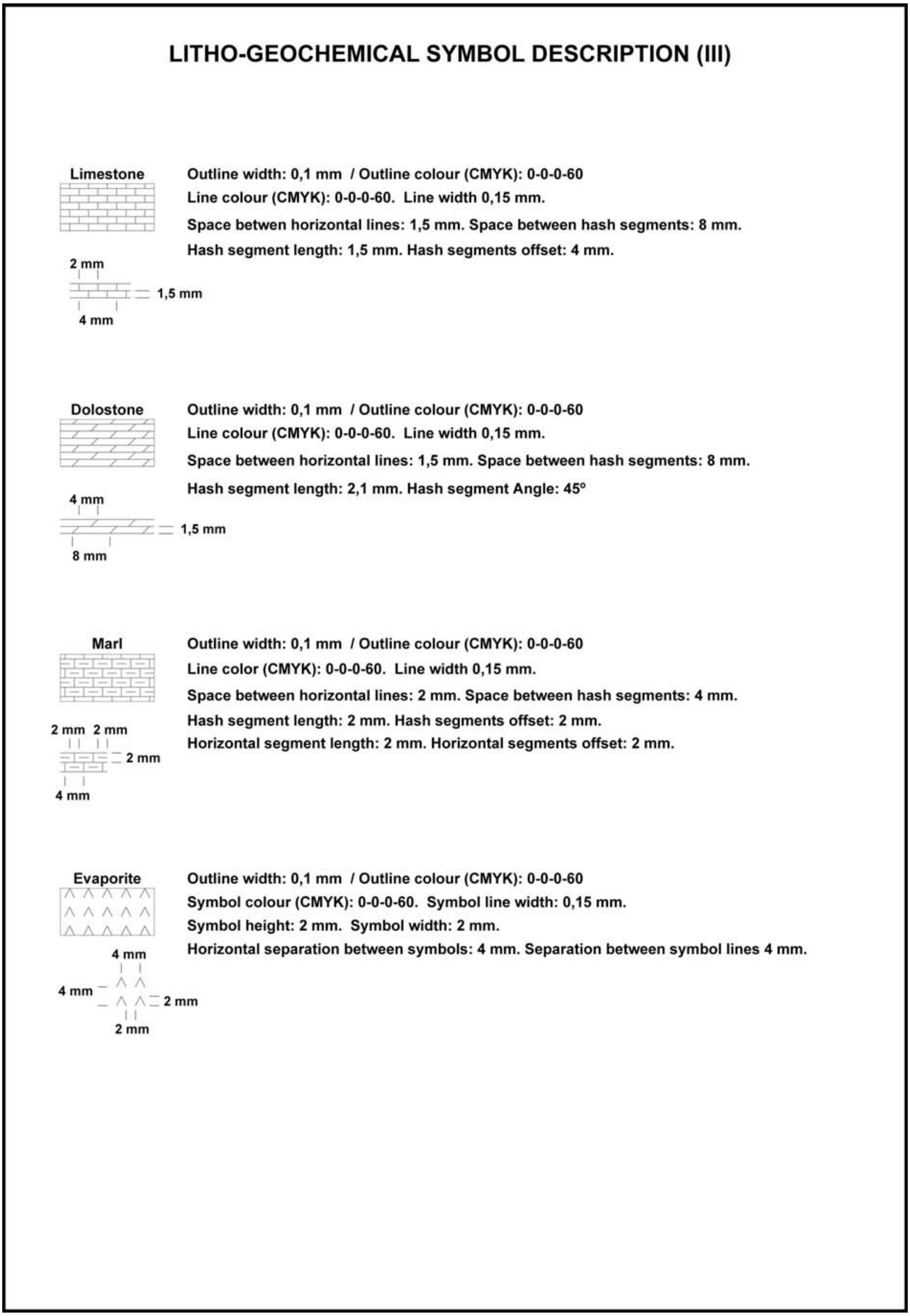


Figure 2 contd. 2. LithoGeochemical symbol description (ewater.style)

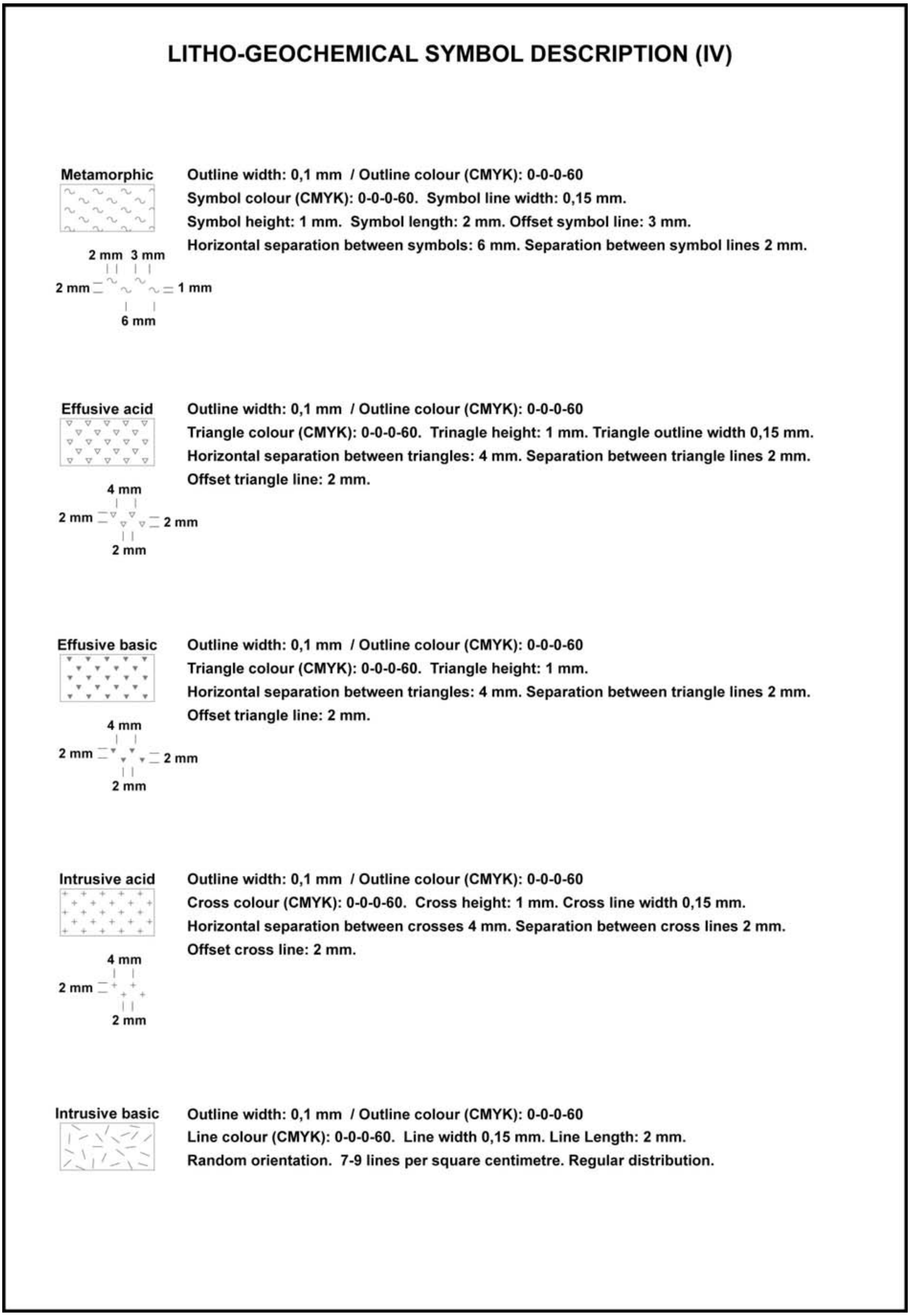


Figure 2 contd. 3. LithoGeochemical symbol description (ewater.style)

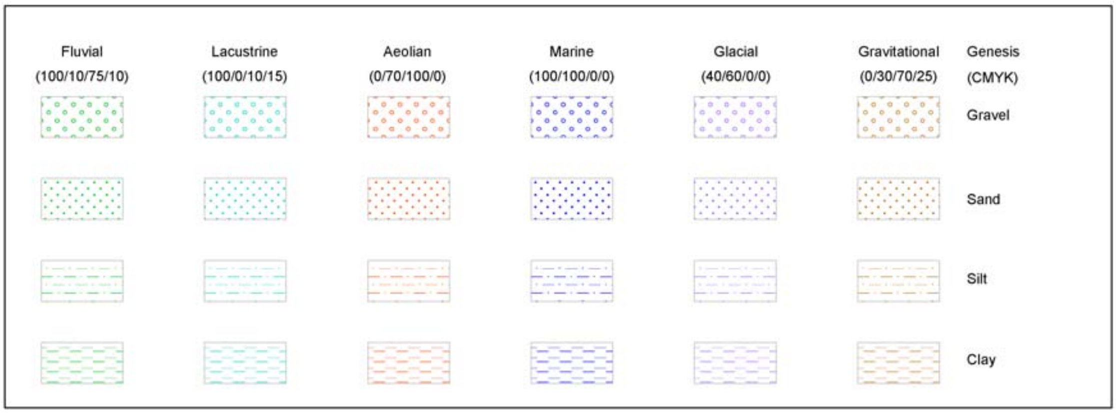


Figure 3. Depositional Environment symbol description (ewater.style)

8. References

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