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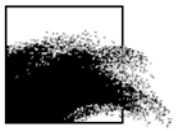

Seabed substrate coding on nautical charts in the Belgian part of the North Sea

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Prepared for Flemish Authorities, Flemish Hydrography

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Kint, L. & Van Lancker, V. 2021. Seabed substrate coding on nautical charts in the Belgian part of the North Sea. Scientific report. Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Brussels, 14 p.

Table of Contents

1. Introduction

Nautical charts contain information on seabed nature to (1) provide guidance on holding characteristics when anchoring; (2) assist in assessing the stability of shoals and in distinguishing rocks from unconsolidated material when navigating in shallow areas; (3) indicate where vessels can safely ground at low water in tidal areas; and (4) provide an indication of the nature of the seabed in deeper waters for fishermen and submariners. This report aims at updating sediment information on nautical charts in the Belgian part of the North Sea.

2. Nautical charts in the Belgian part of the North Sea

Flemish Hydrography produces national and international nautical charts of the Belgian part of the North Sea and adjacent areas (Fig. 1). Paper charts can be divided in separate large charts, chart sets and overview charts. Electronic Navigational Charts (ENCs) and Inland Electronic Navigational Charts (IENCs) are as well available. Several member states of the International Hydrographic Organization (IHO) publish INT-charts (international nautical paper charts). These separate large charts can be included in national series. A chart set consists of several loose overlapping smaller charts, collected in a folder. Overview maps cover large areas and are printed on single large map sheets. Nautical information is updated until the date mentioned, but the charts are not suitable for navigation. An overview of the nautical charts in the Belgian part of the North Sea can be found in the Catalogue of Hydrographic Publications (2020).

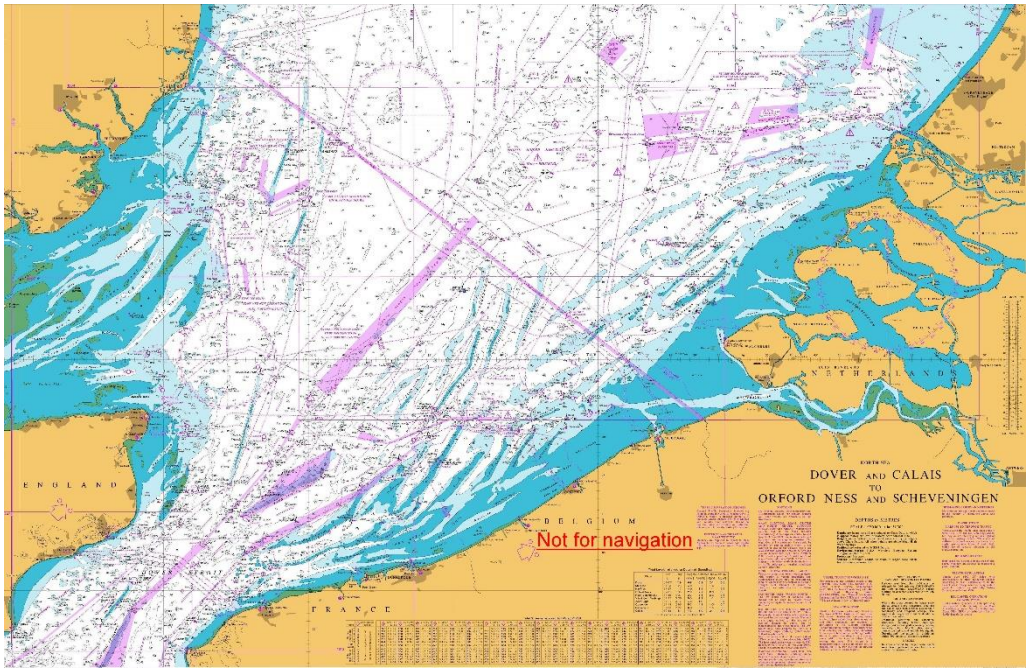

Figure 1. Example of a nautical overview chart of the southern part of the North Sea (1:250k scale).

3. Methodology

3.1. Sediment locations on nautical charts

Flemish Hydrography proposed a selection of 39 locations where information on the seabed substrate should be included on nautical charts in the Belgian part of the North Sea (Table 1). It concerns 37 locations that were already available on previous editions and two additional locations in the anchorage areas of the Oostdyck (location 39) and Westhinder (location 38).

Table 1. Locations selected for updated seabed substrate information on nautical charts in the Belgian part of the North Sea.

Location	Lat WGS84	Lon WGS84	Location	Lat WGS84	Lon WGS84
1	51,3983	2,4665	21	51,4627	3,0310
2	51,4257	3,0254	22	51,3695	2,9476
3	51,3752	2,5091	23	51,3670	3,0540
4	51,4205	3,0563	24	51,4491	2,9802
5	51,4827	2,8897	25	51,4237	3,2236
6	51,3944	3,2530	26	51,4198	2,9309
7	51,4528	3,0497	27	51,3791	2,6413
8	51,4180	3,1487	28	51,5026	2,7221
9	51,4381	2,8913	29	51,2779	2,8884
10	51,4352	2,9450	30	51,4185	3,0843
11	51,5257	3,1046	31	51,3793	2,5814
12	51,3555	2,7241	32	51,5267	2,9615
13	51,3535	2,9503	33	51,4286	2,6812
14	51,2723	2,9821	34	51,5078	3,0314
15	51,4518	3,2634	35	51,3962	3,0646
16	51,5030	2,9363	36	51,4095	3,2320
17	51,2568	2,8300	37	51,3487	2,9867
18	51,3030	2,8248	38	51,4167	2,6167
19	51,4605	2,6145	39	51,3333	2,5500
20	51,4589	3,0881			

3.2. Required classification of the seabed nature for nautical charts

On paper nautical charts (IHO S-4), abbreviations of the nature of the surface (NATSUR) and the nature quality (NATQUA) are used (Table 2).

On electronic nautical charts (IHO S-57), a marine region with a homogeneous bottom is required to be encoded using the seabed area object class (SBDARE) of the Object Catalogue for ENCs. It concerns the attributes *nature of the surface* (NATSUR) and *nature quality* (NATQUA) (Table 2). For mixed natures, the dominant nature of the seabed should be given first and qualifying terms, associated with the various natures of surface, must be listed in the same order as the nature of surface list. For example, "fine sand, mud and broken shells" is encoded to NATSUR = 4,1,17 and NATQUA = 1,,4. Or “fine sand and mud” is encoded to NATSUR = 4,1 and NATQUA = 1,. Underlying material should be encoded in the same way as mixed natures, replacing the comma (,) by a slash (/). The surface layer must be given first, followed by the underlying layers. For example, “fine sand and mud over rock” is encoded to NATSUR = 4,1/9 and NATQUA = 1,/.

Table 2. The most common combinations of the nature of the surface (NATSUR) and the nature quality (NATQUA) for the seabed area.

NATSUR[1]		NATQUA[2]									
		1	2	3	4	5	6	7	8	9	10
		Fine	Medium	Coarse	Broken	Sticky	Soft	Stiff	Volcanic	Calcareous	Hard
		f	m	c	bk	sy	so	sf	v	ca	h
1	Mud M										
2	Clay Cy										
3	Silt Si										
4	Sand S										
5	Stone St										
6	Gravel G										
7	Pebbles P										
8	Cobbles Cb										
9	Rock R										
11	Lava										
14	Coral Co										
17	Shells Sh										
18	Boulder Bo										

[1]NATSUR – Mud (< 0.0625 mm): soft, wet earth; Clay (< 0.002 mm): stiff, sticky earth that becomes hard when baked; Silt (0.002 - 0.0625 mm): when dried on hand will rub off easily; Sand (0.0625 - 2.0 mm): tiny grains of crushed or worn rock; Stone: a general term for rock fragments ranging in size from pebbles and gravel to boulders or a large rock mass; Gravel (2.0 - 4.0 mm): small stones with coarse sand; Pebbles (4.0 - 64.0 mm): small stones made smooth and round by being rolled in water; Cobbles (64.0 - 256.0 mm): stones worn round and smooth by water and used for paving; Rock: any formation of natural origin that constitutes an integral part of the lithosphere. The natural occurring material that forms firm, hard, and solid masses; Lava: the fluid or semi-fluid matter flowing from a volcano. The substance that results from the cooling of the molten rock. Part of the ocean bed is composed of lava;

Coral: hard calcareous skeletons of many tribes of marine polyps; Shells: exoskeletons of various water dwelling animals; Boulder (> 256.0 mm): a rounded rock.

[2]NATQUA – Fine (0.625 - 0.250 mm): falls within the smallest size continuum for a particular nature of surface term; Medium (0.250 - 0.500 mm): falls within the moderate size continuum for a particular nature of surface term; Coarse (0.500 - 2.0 mm): falls within the largest size continuum for a particular nature of surface term; Broken: fractured or in pieces; Sticky: having an adhesive or glue like property; Soft: not hard or firm; Stiff: not pliant; thick, resistant to flow. Volcanic: composed of or containing material ejected from a volcano; Calcareous: composed of or containing calcium or calcium carbonate; Hard: firm; usually refers to an area of the sea floor not covered by unconsolidated sediment.

3.3. Seabed substrate information

Given the required classification of seabed nature for the purpose of providing an additional layer to nautical charts, the most detailed information was evaluated. Typically, this would be available from lithological descriptions of neighbouring cores and grab samples. The Royal Belgian Institute of Natural Sciences hosts such a descriptive dataset, i.e. SediLITHO@SEA dataset (Fig. 2; Kint & Van Lancker 2020). Where information is missing or scarce, other supportive datasets and mapping products were consulted. The SediCURVE@SEA dataset (Van Lancker 2009; update in progress) contains the full-spectra of grain-size data, while the compilation of the SediSURF@SEA dataset (Van Lancker 2007) was limited to already parameterised grain-size information (e.g., median grain size and silt-clay percentage only). Derived maps of seabed substrates (Fig. 3) and models of the subsurface (Fig. 4) were used to validate the seabed coding for this study. In complement, seabed sediment nature was also verified from potential occurrence areas of coarse sand, gravel and shells (Fig. 5), and from the Flemish Hydrography's latest 20-m bathymetry digital terrain model. Information of the seabed substrate for each sediment location was limited to 1 m in depth with a surrounding buffer of 1000 m.

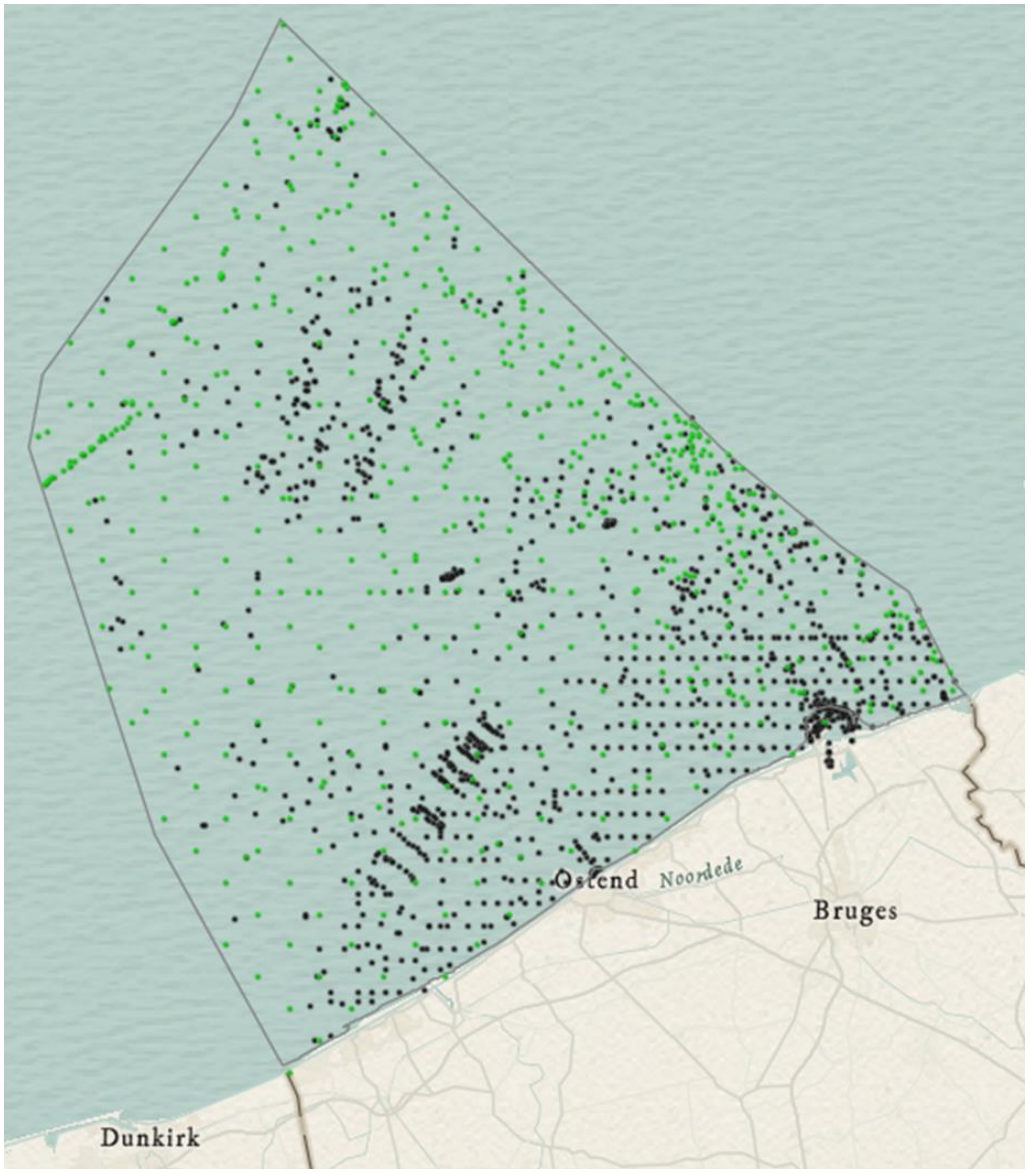

Figure 2. Locations with lithological descriptions from cores (in black) and grab samples (in green) in the Belgian part of the North Sea (SediLITHO@SEA dataset; Kint & Van Lancker 2020). Source: RBINS GeoNetwork

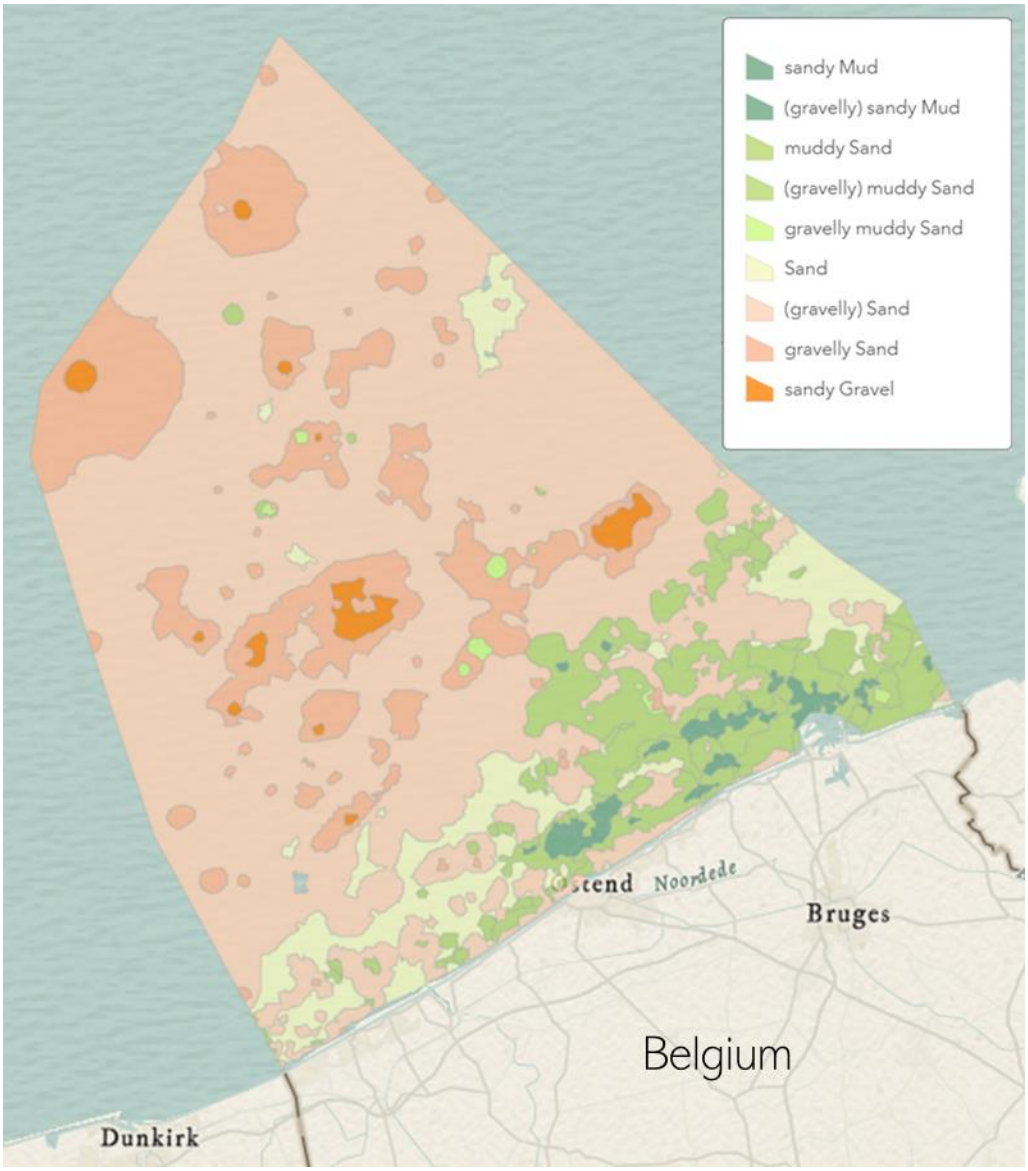

Figure 3. Seabed substrate map (1:250k scale) representing 16 modified Folk (1954) classes (EMODnet Geology Consortium 2020; Kaskela et al. 2019). For the Belgian part of the North Sea a maximum of 9 classes are present based on a interpolation of percentage clay-silt, sand and gravel (SediCURVE@SEA dataset; Van Lancker 2009, v2016). Source: EMODnet Geology data portal (revision is ongoing)

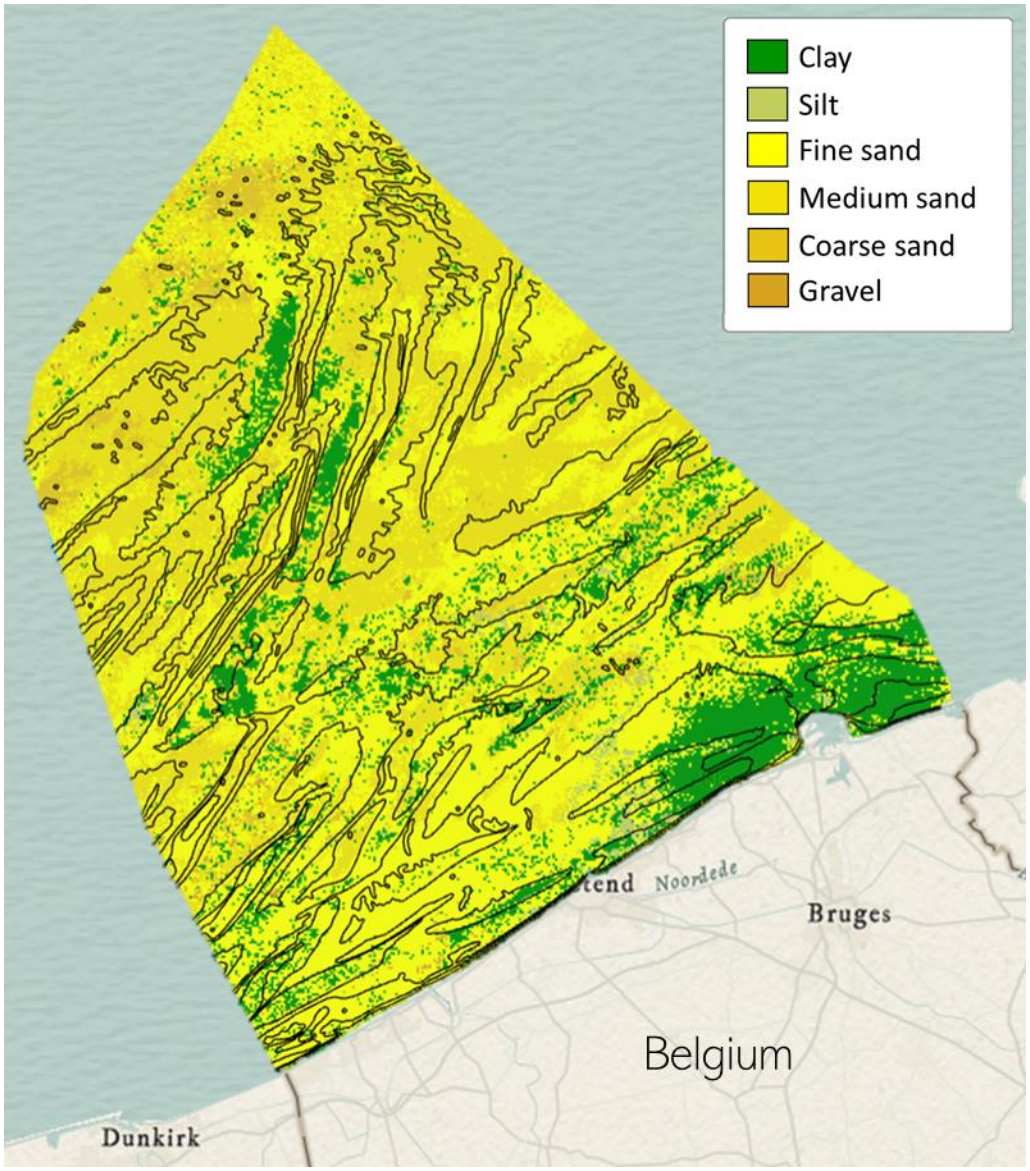

Figure 4. Plan view of a 3D subsurface model (1:400k scale) representing 6 Wentworth (1922) classes (TILES Consortium 2018a; Hademenos et al. 2018). Encoded information of clay, silt, fine-medium-coarse sand and gravel (SediLITHO@SEA dataset; Kint & Van Lancker 2020) was combined with seismic data, so interpolation was possible within the major lithostratigraphic units of the Quaternary (Pleistocene, Lower and Upper Holocene). Here, the main seabed sediments of the upper 1 m are shown. This 3D subsurface model does not yet contain detailed surface characteristics, and was tuned mostly for sand qualities, not for gravel and shells. Given their patchy nature, modelled information of these coarse sediment fractions are prone to large uncertainties. Source: TILES Decision Support System (TILES Consortium 2018b)

Figure 5. Spatial distribution of coarse sand and gravel potential occurrences (GIS@SEA dataset; Van Lancker et al. 2007, v2012) based on a combination of Quaternary sediment thickness maps, analyses of bathymetric data (single beam; multibeam where available), seabed samples (SediSURF@SEA dataset, Van Lancker 2007), and visual observations from video drop frames and diving information (mostly from the Belgian Navy). The gravel has varying sizes, contains shell material as well and may be buried under a sand layer. The map has been updated in 2009 and 2012 for nature management purpose. A complete revisiting is ongoing.

4. Results

Based on the above mentioned information, Table 3 synthesizes the seabed sediment information for all 39 locations with respective abbreviations and encoding of the nature of the surface (NATSUR) and the nature quality (NATQUA).

Table 3. Classification of the nature of the surface (NATSUR) and the nature quality (NATQUA) for the 39 proposed locations.

	NATSUR_DESCR	NATQUA_DESCR	NATSUR_ABBR	NATQUA_ABBR	NATSUR_CODE	NATQUA_CODE
1	sand,shells	fine-medium,broken	S,Sh	f-m,bk	4,17	1-2,4
2	sand	fine	S	f	4	1
3	sand,shells,clay	fine-medium,broken,	S,Sh,Cy	f-m,bk,	4,17,2	1-2,4,
4	sand	fine	S	f	4	1
5	sand,gravel,shells,clay	fine-medium,,broken,	S,G,Sh,Cy	f-m,,bk,	4,6,17,2	1-2,,4,
6	clay,sand	,fine	Cy,S	,f	2,4	,1
7	sand,clay,shells,silt	fine-medium,,broken,	S,Cy,Sh,Si	f-m,,bk,	4,2,17,3	1-2,,4,
8	sand,clay	fine,	S,Cy	f,	4,2	1,
9	sand,gravel,shells,silt	fine-coarse,,broken,	S,G,Sh,Si	f-c,,bk,	4,6,17,3	1-3,,4,
10	sand	fine-medium	S	f-m	4	1-2
11	sand,gravel	fine-medium,	S,G	f-m,	4,6	1-2,
12	sand	medium	S	m	4	2
13	sand,silt	fine,	S,Si	f,	4,3	1,
14	silt,sand,clay	,fine,	Si,S,Cy	,f,	3,4,2	,1,
15	sand	fine	S	f	4	1
16	sand,gravel,shells,mud	medium-coarse,,broken,	S,G,Sh,M	m-c,,bk,	4,6,17,1	2-3,,4,
17	sand,clay	fine,	S,Cy	f,	4,2	1,
18	sand,shells,silt	fine,broken,	S,Sh,Si	f,bk,	4,17,3	1,4,
19	sand,gravel,clay	medium,,	S,G,Cy	m,,	4,6,2	2,,
20	sand,clay,shells,silt	fine-medium,,broken,	S,Cy,Sh,Si	f-m,,bk,	4,2,17,3	1-2,,4,
21	sand,silt,clay	fine,,	S,Si,Cy	f,,	4,3,2	1,,
22	sand,shells,silt	fine-coarse,broken,	S,Sh,Si	f-c,bk,	4,17,3	1-3,4,
23	clay,shells,silt	,broken,	Cy,Sh,Si	,bk,	2,17,3	,4,
24	sand	fine-medium	S	f-m	4	1-2
25	sand,clay	fine,	S,Cy	f,	4,2	1,
26	sand,shells,silt	fine,broken,	S,Sh,Si	f,bk,	4,17,3	1,4,
27	sand,gravel,cobbles,shells,clay	fine,,,broken,	S,G,Cb,Sh,Cy	f,,,bk,	4,6,8,17,2	1,,,4,
28	sand	medium	S	m	4	2
29	sand,silt,clay	fine,,	S,Si,Cy	f,,	4,3,2	1,,
30	sand,clay	fine,	S,Cy	f,	4,2	1,
31	sand,gravel,cobbles,shells,clay	fine-medium,,,broken,	S,G,Cb,Sh,Cy	f-m,,,bk,	4,6,8,17,2	1-2,,,4,
32	sand	fine-medium	S	f-m	4	1-2
33	sand,shells,silt	fine-medium,broken,	S,Sh,Si	f-m,bk,	4,17,3	1-2,4,
34	sand	medium	S	m	4	2
35	sand,clay	fine,	S,Cy	f,	4,2	1,
36	clay,sand	,fine	Cy,S	,f	2,4	,1
37	sand	fine	S	f	4	1
38	sand,shells	medium,broken	S,Sh	m,bk	4,17	2,4
39	sand,shells	medium,broken	S,Sh	m,bk	4,17	2,4

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This report was issued by Operational Directorate Natural Environment in May 2021

The reference code is FH/2/LK/2021/EN/SR01.

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