Seismic interpretation at Triton, Offshore Sweden

Interpretation of Sub-Bottom-Profiler single and multi-channel seismic data

Geo Job no. 204305
Report 2, 2020-08-24

Revision:	Date:	Notes:
0	2020.08.24	Report 2

Maglebjergvej 1, DK-2800 Kgs. Lyngby
Tel.: +45 4588 4444
geo@geo.dk - www.geo.dk
CVR-No: 59781812

Prepared for:
OX2 AB
P.O. Box 2299
103 17 Stockholm, Sweden
Att: Henrik Sjöström
Email: henrik.sjostrom@ox2.com

Prepared by:
Kasper Henrik Lundvig, Geophysicist, M.Sc
Tel.: +45 3174 0203, KHL@geo.dk

Checked by:
Christoffer Smedmann Lausten, Geologist, M.Sc
Tel.: +45 3174 0285, CSL@geo.dk

Controlled / Approved by:
Thomas C. Larsen, Department Director
Tel.: +45 3174 0189, TCL@geo.dk

Contents

1 INTRODUCTION 3

2 GEOLOGICAL OVERVIEW 3

2.1 BATHYMETRY 3
2.2 QUATERNARY DEPOSITS 3
2.3 PRE-QUATERNARY DEPOSITS 3

3 SURVEY LINE OVERVIEW 3

3.1 SPARKER LINES 3
3.2 SLEEVEGUN LINES 3

4 PROCESSING SEQUENCE 4

5 SEISMIC HORIZONS 4

5.1 SEABED 4
5.2 HORIZON 1 4
5.3 HORIZON 2 4
5.4 HORIZON 3 5
5.5 HORIZON 4 5

6 GEOLOGICAL INTERPRETATION 5

6.1 QUATERNARY DEPOSITS 5
6.2 PRE-QUATERNARY DEPOSITS 5

7 CONCLUSION 6

LIST OF APPENDICES 7

LIST OF ANNEXES 7

1 Introduction

Prior to the potential development of a new Offshore Wind Farm (OWF) in the southern Baltic Sea named Triton, at request of OX2 AB (OX2), Geo has carried out a seismic interpretation. The aim of this study is to gain insight into the subsurface stratigraphy at the Triton site based on previously acquired seismic data. OX2 retrieved the seismic data from SGU (Geological Survey of Sweden) and passed it on to Geo. The seismic data consist of two datasets. The first is a single-channel dataset with a Sparker as a seismic source. The second is a multi-channel (i.e. 6-channels) dataset with a Sleevegun as a seismic source. According to the trace headers, all seismic lines were acquired during 1994. Due to time constraints, the multi-channel dataset was interpreted as a single-channel dataset.

2 Geological overview

The Triton site is located in the southern Baltic Ocean approximately 28 km south of the Swedish town of Ystad (Annex A.1, page 1). The Triton site is divided into two segments, a smaller eastern segment (corner coordinates C, D, E, F) and a larger western segment (corner coordinates A, B, G, H, I, J, K, L).

2.1 Bathymetry

The water depth at Triton ranges from (43 – 48) m bsl deepening towards SE based on multibeam data. The seabed is quite flat and appears without any significant features (Geo project 204136, report 1, Appendix A.1, page 14).

2.2 Quaternary Deposits

The seabed soils consist mainly of mud to muddy sand (Geo project 204136, report 1, Enclosure 1.2). Due to the lack of proximate BH data, the Quaternary deposits are not well known in this area. The closest available BH according to GEUS (DGU 551430.3) is located approximately 19 km SE of the eastern segment of Triton. Here, the Quaternary deposits are 15 m thick and consists of sandy calcareous clay.

2.3 Pre-Quaternary deposits

The expected Pre-Quaternary deposits at the Triton site are Paleocene Limestone (Geo project 204136, report 1, Enclosure 1.3).

3 Survey line overview

3.1 Sparker lines

A survey line overview for the Sparker lines are shown in Appendix A.1, page 1. Nineteen (19) Sparker lines where used for interpretation, nine (9) trending north-south and ten (10) trending east-west. Please note that lines sp_01D_0013, sp_01D_0014 and sp_01D_0015 have been divided into two separate line segments by SGU. The second part of the line segment is followed by a "_2" in the filename.

3.2 Sleevegun lines

A survey line overview for the Sleevegun lines are shown in Appendix A.1, page 2. Seventeen (17) Sleevegun lines where used for interpretation, eight (8) trending north-south and nine (9) trending east-west. Please note that lines 01D_0013, 01D_0014 and 01D_0015 have been divided into two separate line segments by SGU. The second part of the line segment is followed by a "_2" in the filename.

4 Processing sequence

The received seismic lines were pre-processed and ready for interpretation. However, in order to enhance the reflectors of interest a standardized processing sequence was established. The processing sequence was as follows:

1. Normalizer
2. Median filter
3. Trace equalizer
4. Trace mixer

5 Seismic horizons

The Seabed Horizon and four (4) separate sub-seabed Horizons were identified on all the Sparker and Sleevegun lines. The Seabed Horizon and Horizons 1-3 were interpreted mainly on the Sparker lines. Horizon 4 was predominantly interpreted on the Sleevegun lines where it was more pronounced. An example of an interpreted Sparker line (sp_D01_0013_2) is shown in appendix A.1, page 3, along with a marking of the seismic Horizons. An example of an interpreted Sleevegun line (D01_0013_2) is shown in appendix A.1, page 4, along with markings of seismic Horizon 4.

5.1 Seabed

The Seabed Horizon was interpreted on all Sparker lines in Two-Way Time. A conversion v_p of 1500 m/s was used in the water column, due to the lack of a vertical velocity profile, to derive the depth below sea-level in meters. A contour map is shown in Appendix B.1, page 1, showing the interpolated depth to Seabed below sea level, produced from Seabed interpretations on all Sparker lines. The seabed appears relatively featureless and flat, dipping slightly downwards towards SE (approximately 43 (NW) to 46 (SE) m bsl). The converted depth below Seabed in meters is generally in accordance with the values derived from the high-resolution multibeam bathymetric surveys previously performed in the area (Geo project 204136, report 1, Appendix A.1, page 14).

5.2 Horizon 1

Horizon 1 was interpreted on all Sparker lines. Horizon 1 is characterized by a pronounced change in reflectivity. High amplitude plan parallel reflections are observed above Horizon 1 and low amplitude complex diffuse to mounded discontinuous reflections are observed below Horizon 1 (Appendix A.1, page 3). Seismic Layer 1 is bounded by the Seabed at the top and Horizon 1 at the base. Horizon 1 was interpreted on all Sparker lines in Two-Way time. A fixed conversion v_p of 1600 m/s was for Seismic Layer 1, due to the lack of a vertical velocity profile, to derive the total depth below sea-level in meters. A contour map showing the interpolated depth below sea level in meters to Horizon 1 is shown in Appendix B.1, page 2 that ranges from 43 to 54 m bsl.

5.3 Horizon 2

Horizon 2 was interpreted on all Sparker lines. Horizon 2 is characterized by an isolated zone of high amplitude more continuous semi to sub parallel reflectors (Appendix A.1, page 3). Seismic Layer 2 is bounded by Horizon 1 at the top and Horizon 2 at the base. Horizon 2 was interpreted on all Sparker lines in Two-Way time. A fixed conversion v_p of 1600 m/s was used in Seismic Layer 2, due to the lack of a vertical velocity

profile, to derive the total depth below sea-level in meters. A contour map showing the interpolated depth below sea level in meters to Horizon 2 is shown in Appendix B.1, page 3 that ranges from 46 to 66 m bsl.

5.4 Horizon 3

Horizon 3 was interpreted on all Sparker lines. Horizon 3 is characterized by an isolated zone of high amplitude more continuous semi to sub parallel reflectors, similar to Horizon 2 (Appendix A.1, page 3). Seismic Layer 3 is bounded by Horizon 2 at the top and Horizon 3 at the base. Horizon 3 was interpreted on all Sparker lines in Two-Way time. A fixed conversion v_p of 1600 m/s was used in Seismic Layer 3, due to the lack of a vertical velocity profile, to derive the total depth below sea-level in meters. A contour map showing the interpolated depth below sea level in meters to Horizon 3 is shown in Appendix B.1, page 4 that ranges from 45 to 73 m bsl.

5.5 Horizon 4

Horizon 4 was interpreted on most Sparker lines and all Sleevegun lines. Horizon 4 is characterized by an isolated zone of high amplitude more continuous semi to sub parallel reflectors followed by high amplitude continuous plan-parallel reflectors (Appendix A.1, page 4). Seismic Layer 4 is bounded by Horizon 3 at the top and Horizon 4 at the base. Horizon 4 was interpreted on all Sleevegun lines in Two-Way time. A fixed conversion v_p of 1600 m/s was used in Seismic Layer 4, due to the lack of a vertical velocity profile, to derive the total depth below sea-level in meters. A contour map showing the interpolated depth below sea level in meters to Horizon 4 is shown in Appendix B.1, page 5 that ranges from 46 to 82 m bsl.

6 Geological interpretation

Due to the lack of proximate borehole data, the geological interpretation of the seismic data is based solely on a priori information and on the Desk Study Report 1 from Geo project 204136.

6.1 Quaternary deposits

Seismic Layer 1 (between Seabed and Horizon 1) is interpreted to be consisting of Mud to Muddy Sand based on the known seabed soils in the area (Geo project 204136, report 1). Seismic Layers 2, 3 and 4 is interpreted to be sequences consisting of Quaternary deposits with varying compositions. Horizons 2 and 3 are interpreted to be internal reflectors within the Quaternary deposits.

6.2 Pre-Quaternary deposits

Horizon 4 is interpreted to be the base of the Quaternary sequence. This horizon truncates the plan-parallel reflectors dipping downwards towards east that is expected to be consisting of Paleocene Limestone. The interpreted Limestone is observed until the first seafloor multiple at approximately 122 ms or 98 m bsl. The thickness of the complete Quaternary unit (i.e. seismic layers 1, 2, 3 and 4) is shown as an interpolated contour map in Appendix C.1, page 1. The thickness of the Quaternary deposits show great variability ranging from 2 to 40 m across the Triton site. The Quaternary deposits are thickest towards the northern and eastern parts of the Triton area and thinnest towards the west. In the central part of the Triton area, the Quaternary deposits are around 16 m thick. Also shown in Appendix C.1, page 2, are a geological profile showing the interpreted Horizons and the related geological interpretation along lines D01_0014 and D01_0014_2.

7 Conclusion

A total of nineteen (19) Sparker lines and seventeen (17) Sleevegun lines where used to identify the Seabed Horizon and four (4) sub-seabed seismic Horizons at the Triton site. A site overview is given in Appendix A.1, pages 1-2. Examples complete with Horizon interpretations are given in Appendix A.1, pages 3-4. The depth below sea level in meters to all the four seismic Horizons are shown on interpolated contour maps in Appendix B.1, pages 1-5.

The top 1 to 3 meters below seabed is expected to be Mud to Muddy sand based on a priori seabed soil information from the area. Below the Muddy Sand, a sequence of Quaternary deposits varying greatly in thickness is present. The combined thickness of the Quaternary deposits and the Muddy Sand is shown in Appendix C.1, page 1. The average thickness of the Quaternary deposits is around 16 m. However, in the northern and eastern parts of the Triton site it can be as thick as 40 m. The presence of Paleozoic Limestone is interpreted to be below the Quaternary deposits. The top of the Paleozoic Limestone is correlating with Horizon 4. The depth below sea level in meters to the top of the Paleozoic Limestone (i.e. Horizon 4) is shown in Appendix B.1, page 5.

The Sparker lines where mainly used to identify the Seabed Horizon and Horizons 1-3. The Sleevegun lines (with a lower relative frequency content than the Sparker lines), where used to identify Horizon 4 due to its greater vertical penetration. The typical sub-seabed penetration for Sparker lines is 30 – 35 m below seabed. For Sleevegun lines the deepest reflections were observable until the first seafloor multiple at approximately 50 m below seabed. With more advanced processing and the use of multi-channel data, reflectors residing even deeper will be resolvable on the Sleevegun lines. However, this is outside the scope of this report.

List of Appendices

Appendix A.1

P. 1/4 Sparker Line Overview
P. 2/4 Sleevegun Line Overview
P. 3/4 Sparker line example 13_2 (sp_D01_0013_2)
P. 4/4 Sleevegun line example 13_2 (D01_0013_2)

Appendix B.1

P. 1/5 Depth to Seabed - Interpolated
P. 2/5 Depth to Horizon 1 - Interpolated
P. 3/5 Depth to Horizon 2 - Interpolated
P. 4/5 Depth to Horizon 3 - Interpolated
P. 5/5 Depth to Horizon 4 - Interpolated

Appendix C.1

P. 1/2 Thickness of Quaternary deposits - Interpolated
P. 2/2 Geological Profile D01_0014 and D01_0014_2

List of Annexes

A.1 Triton site overview with corner coordinates as provided by OX2

Appendix A.1

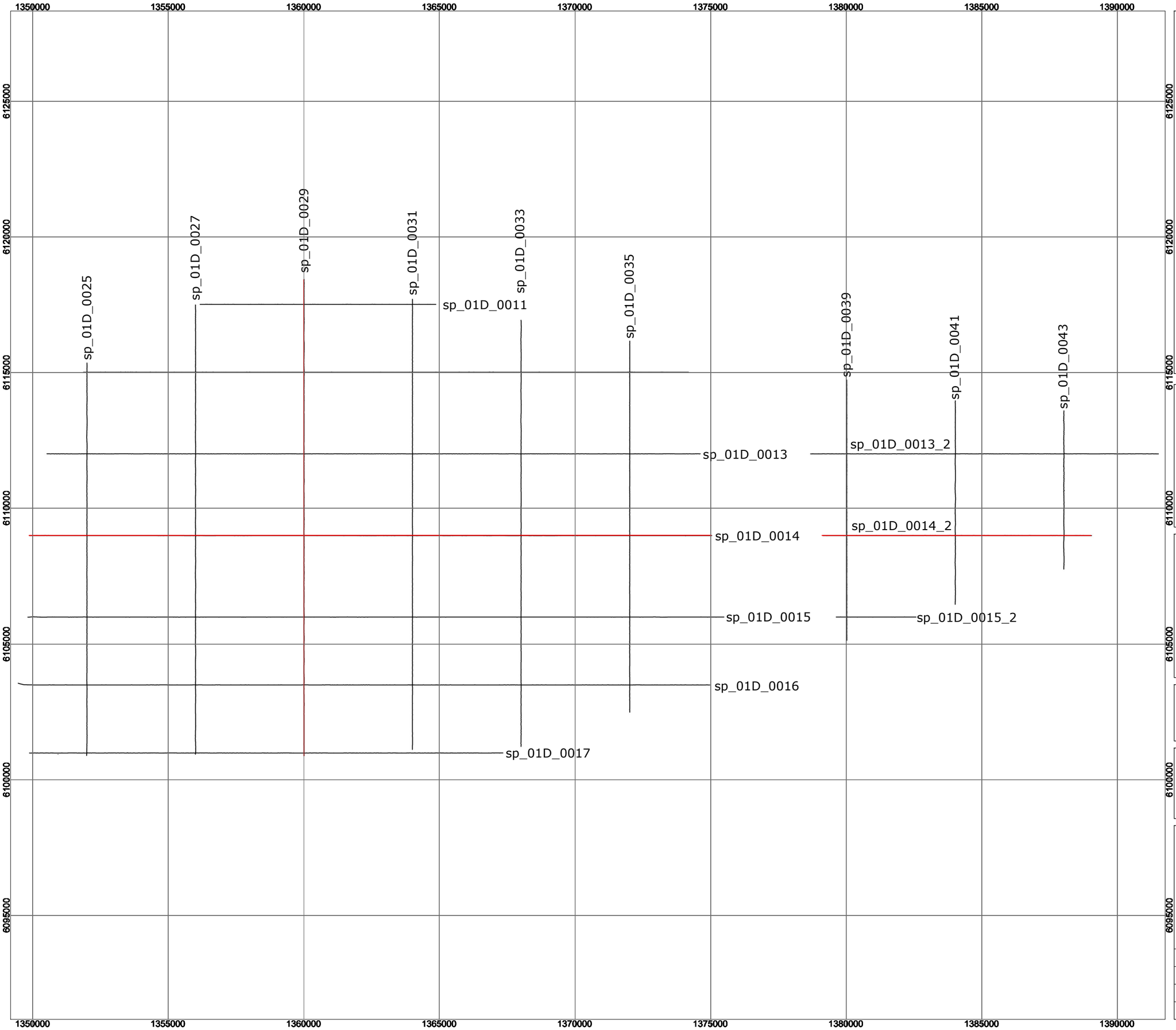
P. 1/4 Sparker Line Overview

P. 2/4 Sleevegun Line Overview

P. 3/4 Sparker line example 13_2 (sp_D01_0013_2)

P. 4/4 Sleevegun line example 13_2 (D01_0013_2)

4 Pages



LEGEND:

Sparker Lines

Geological Profiles

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT: GEO SUBSURFACE EXPERTISE

CLIENT: OX2

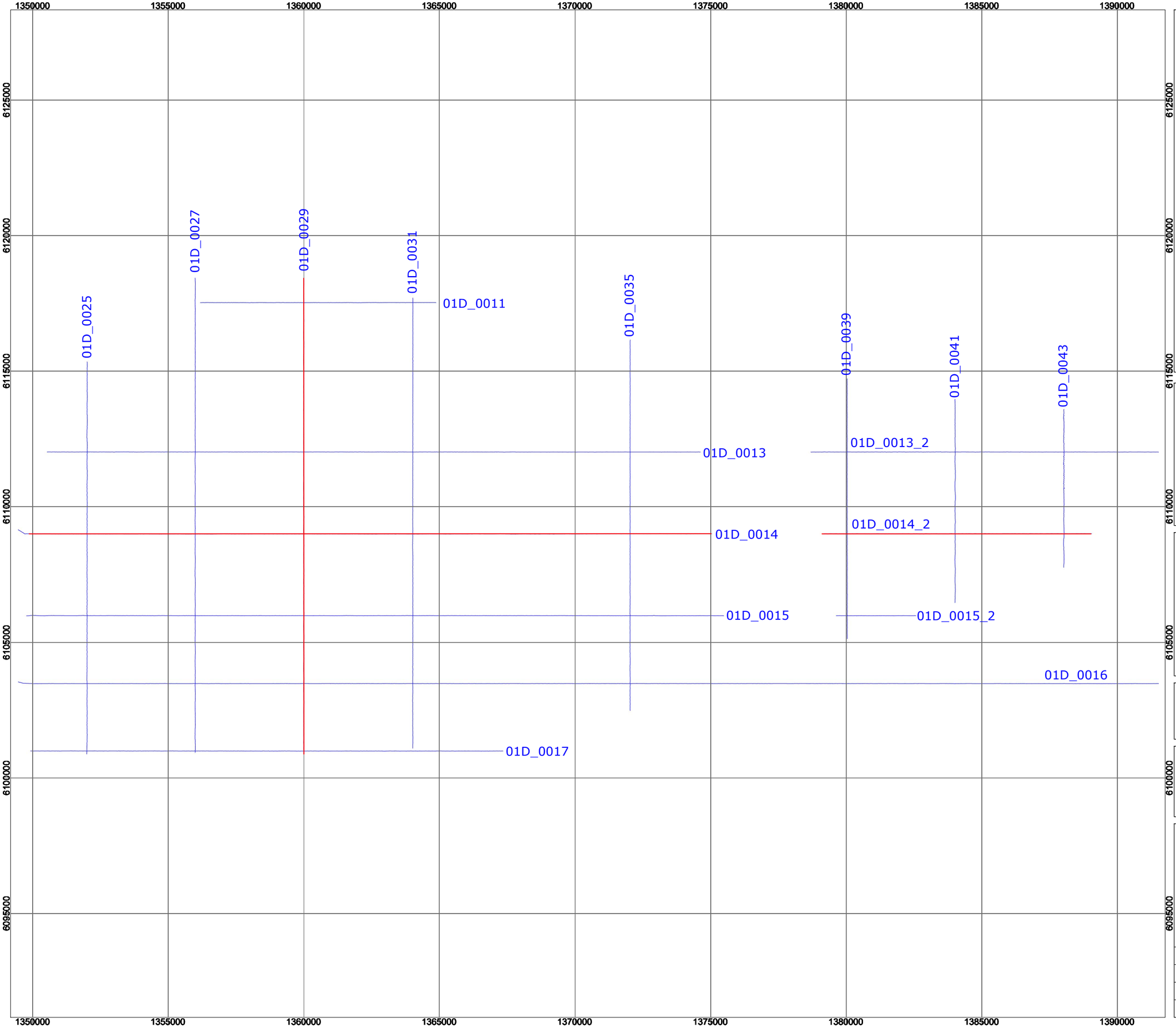
PROJECT:

OX2 - Triton

Sparker Line Overview

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Sparker Line Overview - Triton	KHL	CSL	TCL

GEO Project No. 204305 | Appendix No. A.1 (page 1/4)



LEGEND:

- Sleevegun Lines
- Geological Profiles

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT: GEO SUBSURFACE EXPERTISE

CLIENT: OX2

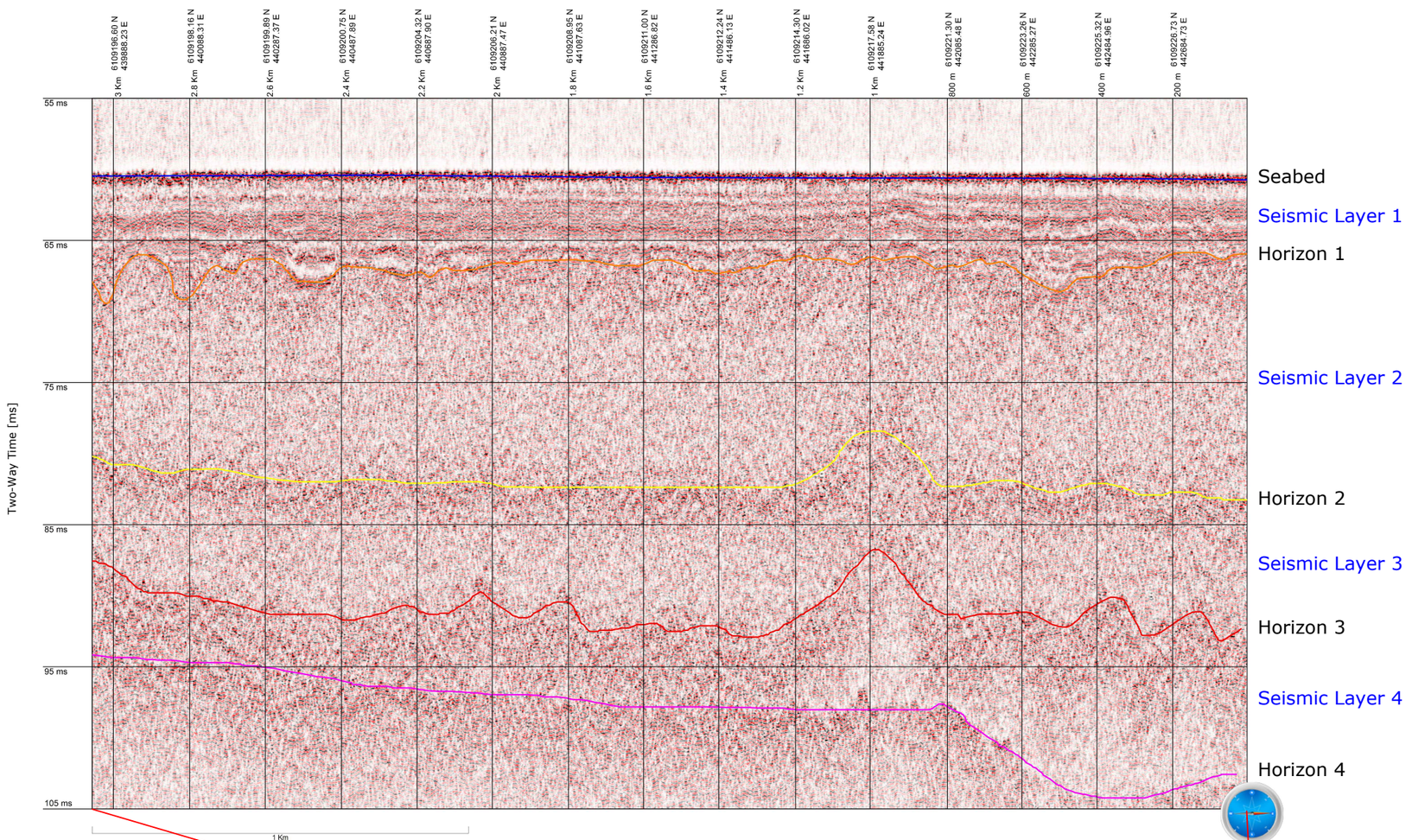
PROJECT:

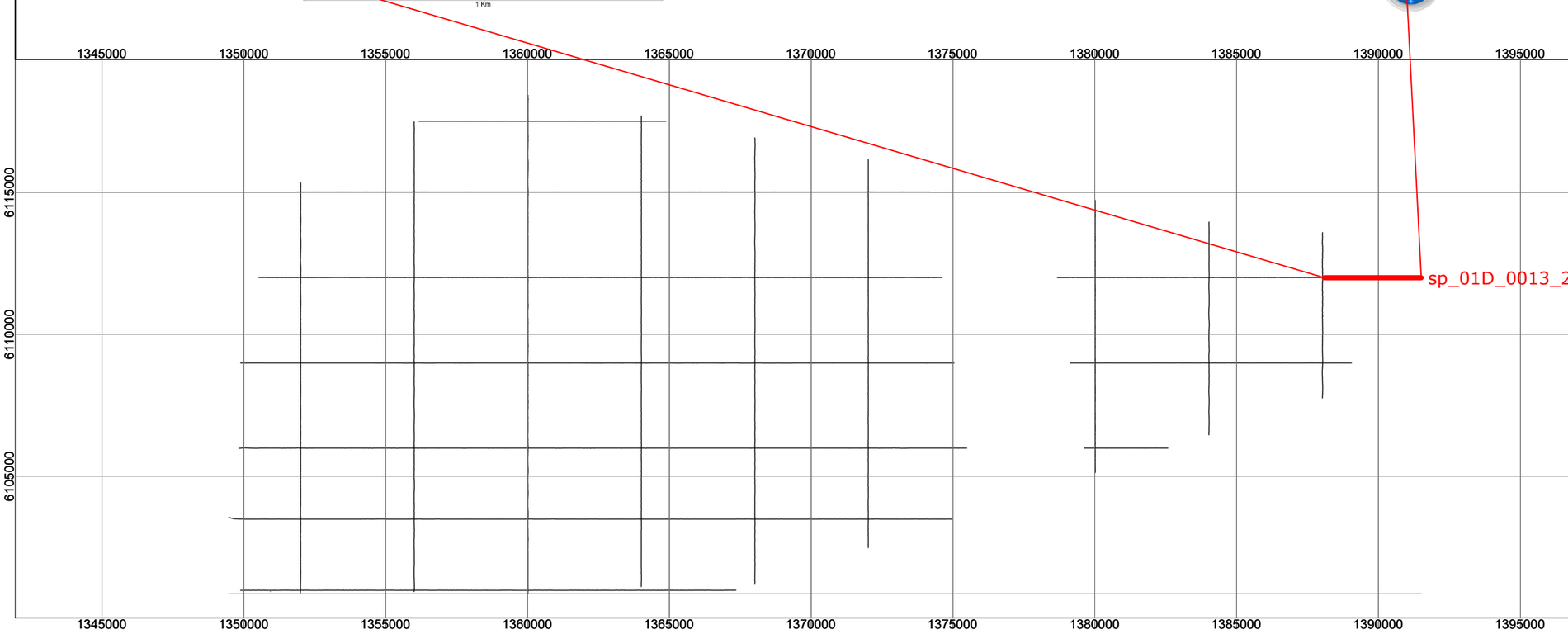
OX2 - Triton

Sleevegun Line Overview

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Sleevegun Line Overview - Triton	KHL	CSL	TCL

GEO Project No.	Appendix No.
204305	A.1 (page 2/4)





LEGEND:

Sparker Lines

Sparker Example

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT:

CLIENT:

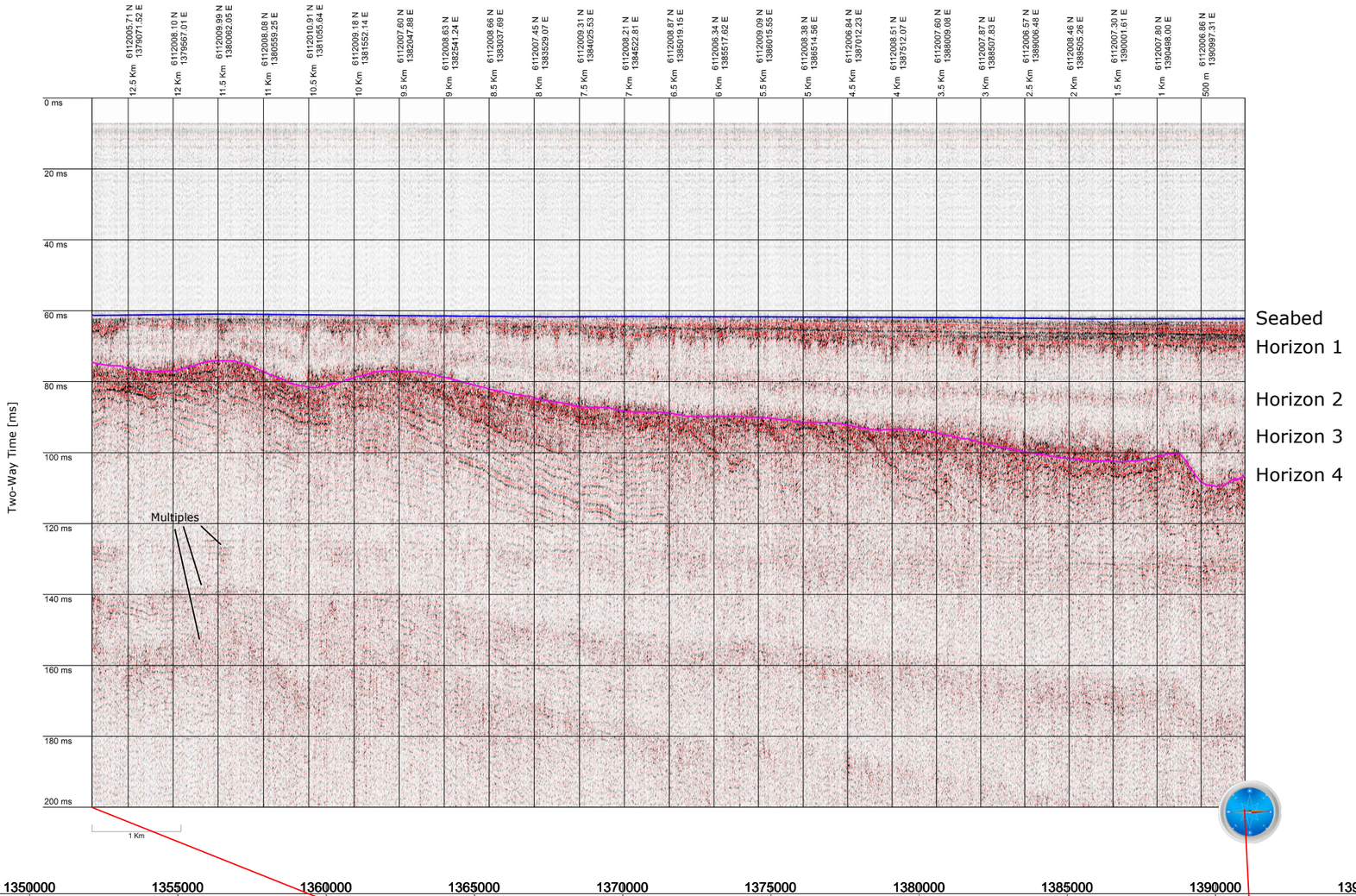
PROJECT:

OX2 - Triton

Sparker line example 13_2
sp_D01_0013_2 (segment)

Rev.	Date	Remarks	Drawn	Checked	Approved
Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Sparker line example 13_2 - Triton	KHL	CSL	TCL

GEO Project No.	Appendix No.
204305	A.1 (page 3/4)



LEGEND:

Sleevegun Lines

Sleevegun Example

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT:

CLIENT:

PROJECT:

OX2 - Triton

Sleevegun line example 13_2
D01_0013_2

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Sleevegun line example 13_2 - Triton	KHL	CSL	TCL

GEO Project No. 204305 | Appendix No. A.1 (page 4/4)

Appendix B.1

P. 1/5 Depth to Seabed - Interpolated

P. 2/5 Depth to Horizon 1 - Interpolated

P. 3/5 Depth to Horizon 2 - Interpolated

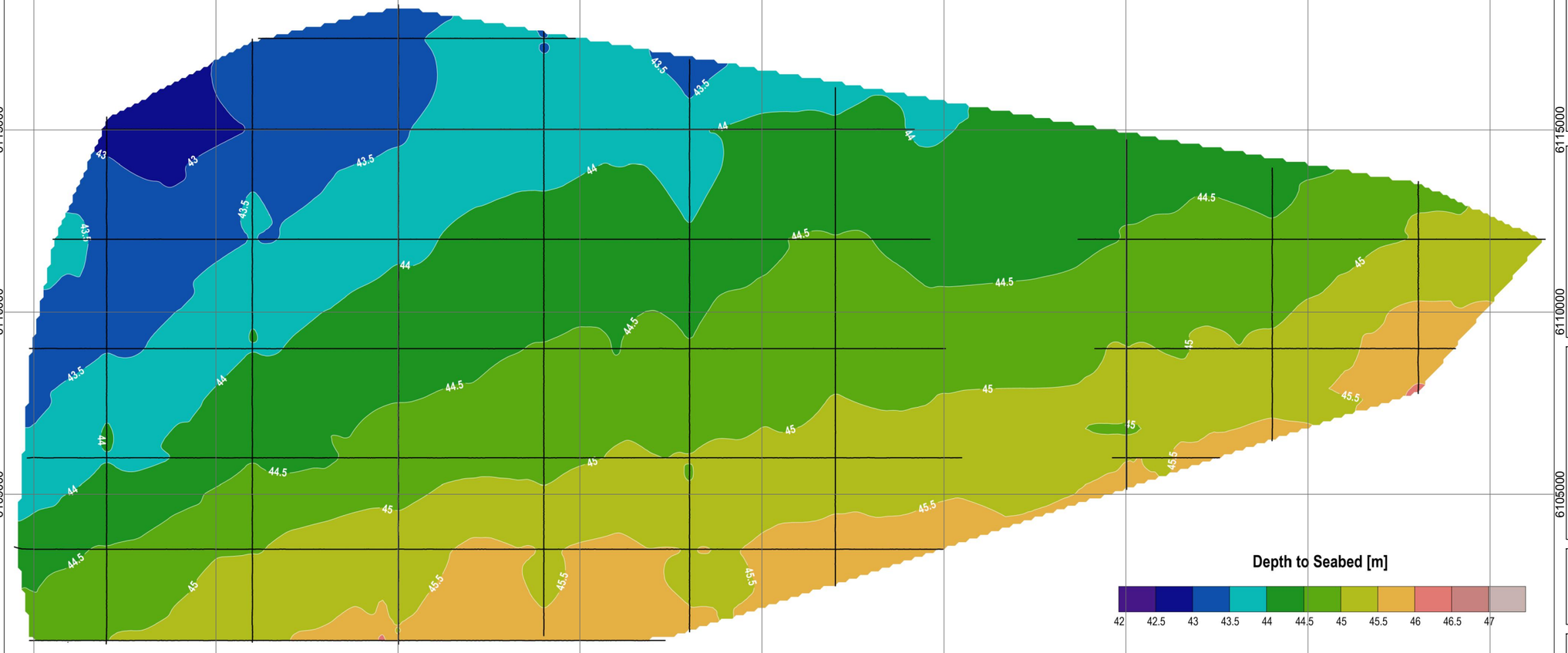
P. 4/5 Depth to Horizon 3 – Interpolated

P. 5/5 Depth to Horizon 4 - Interpolated

5 Pages

1350000 1355000 1360000 1365000 1370000 1375000 1380000 1385000 1390000

6125000 6120000 6115000 6110000 6105000 6100000 6095000



1350000 1355000 1360000 1365000 1370000 1375000 1380000 1385000 1390000

LEGEND:

Sparker Lines

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT: GEO SUBSURFACE EXPERTISE

CLIENT: OX2

PROJECT:

OX2 - Triton

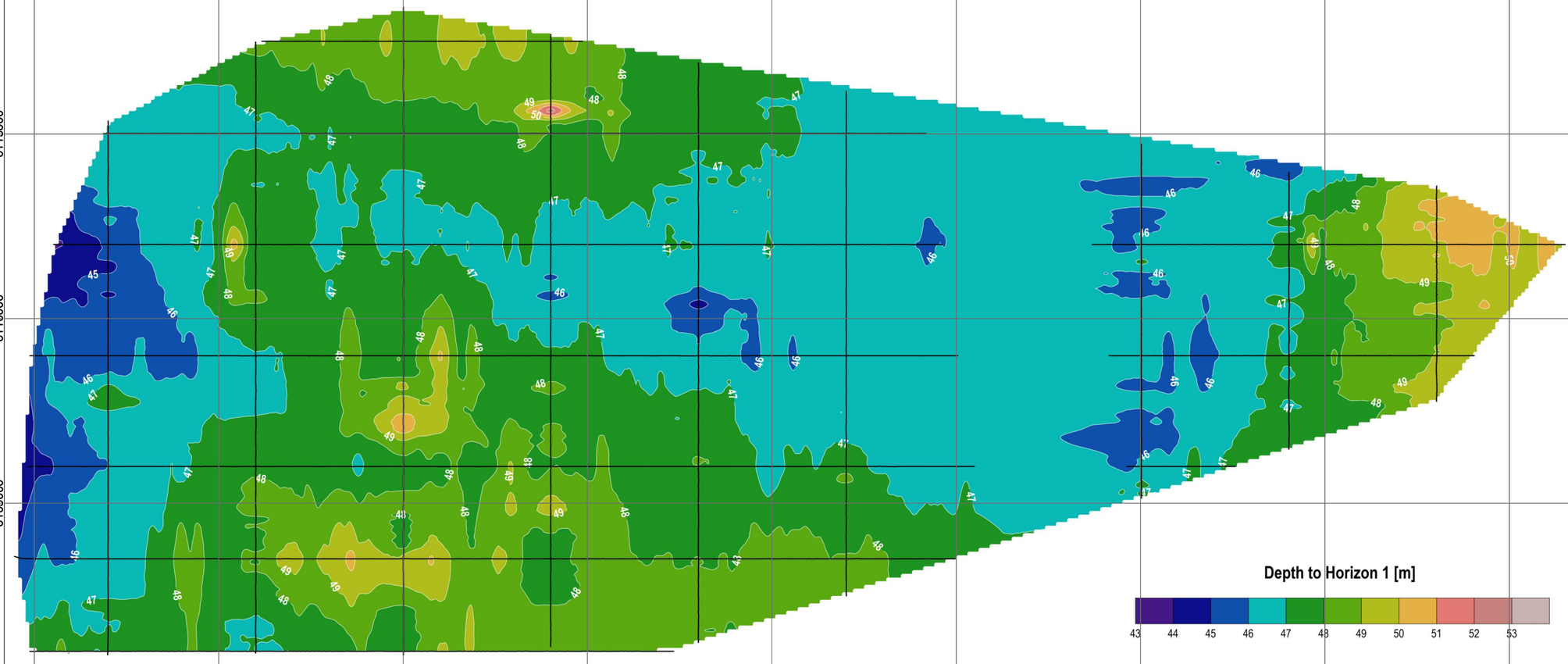
Depth to Seabed [m]
Interpolated

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Depth to Seabed - Triton	KHL	CSL	TCL

GEO Project No.	Appendix No.
204305	B.1 (page 1/5)

1350000 1355000 1360000 1365000 1370000 1375000 1380000 1385000 1390000

6125000 6120000 6115000 6110000 6105000 6100000 6095000



LEGEND:

Sparker Lines

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT: GEO SUBSURFACE EXPERTISE

CLIENT: OX2

PROJECT:

OX2 - Triton

Depth to Horizon 1 [m]
Interpolated

Rev.	Date	Remarks	Drawn	Checked	Approved
Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Depth to Horizon 1 - Triton	KHL	CSL	TCL

GEO Project No.	Appendix No.
204305	B.1 (page 2/5)

1350000 1355000 1360000 1365000 1370000 1375000 1380000 1385000 1390000

6125000 6120000 6115000 6110000 6105000 6100000 6095000

Depth to Horizon 2 [m]

46 48 50 52 54 56 58 60 62 64

LEGEND:

Sparker Lines

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT:

CLIENT:

PROJECT:

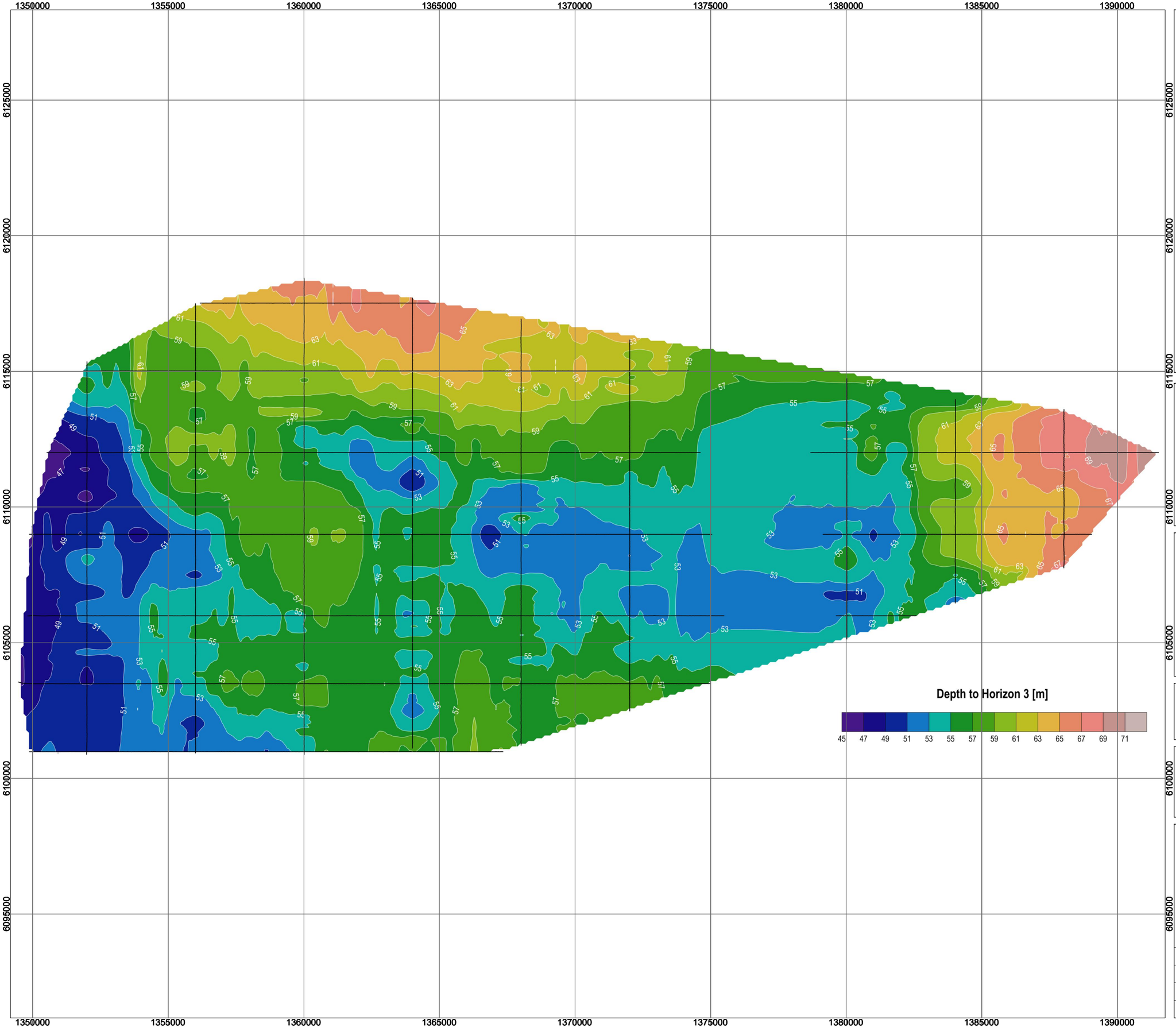
OX2 - Triton

Depth to Horizon 2 [m]
Interpolated

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Depth to Horizon 2 - Triton	KHL	CSL	TCL

GEO Project No. 204305

Appendix No. B.1 (page 3/5)



LEGEND:

Sparker Lines

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT: GEO SUBSURFACE EXPERTISE

CLIENT: OX2

PROJECT:

OX2 - Triton

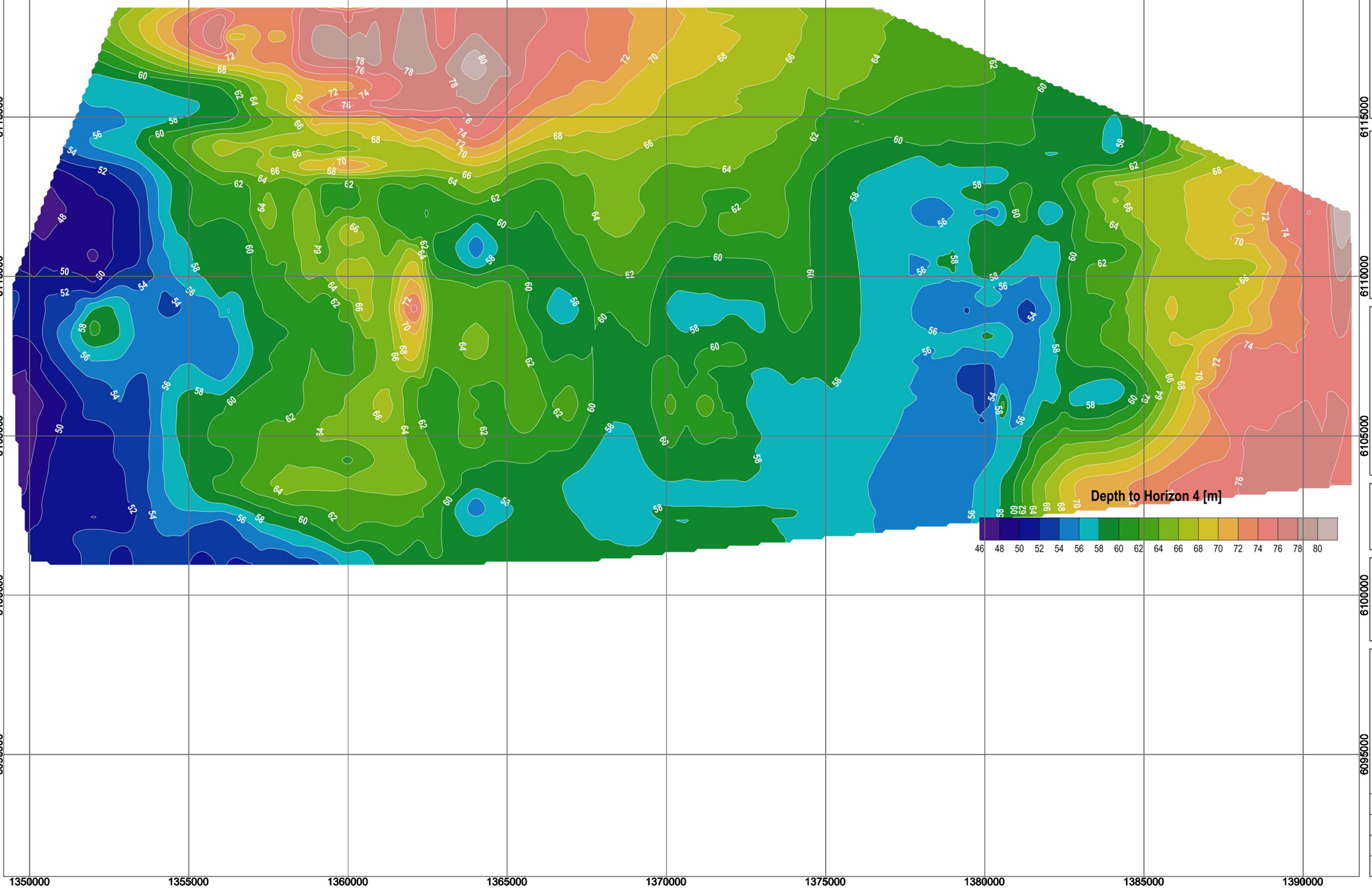
Depth to Horizon 3 [m]
Interpolated

Rev.	Date	Remarks	Drawn	Checked	Approved
Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Depth to Horizon 3 - Triton	KHL	CSL	TCL

GEO Project No.	Appendix No.
204305	B.1 (page 4/5)

1350000 1355000 1360000 1365000 1370000 1375000 1380000 1385000 1390000

6125000 6120000 6115000 6110000 6105000 6100000 6095000



1350000 1355000 1360000 1365000 1370000 1375000 1380000 1385000 1390000

LEGEND:

Sleeve gun lines

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT: GEO SUBSURFACE EXPERTISE

CLIENT: OX2

PROJECT:

OX2 - Triton

Depth to Horizon 4 [m]
Interpolated

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Depth to Horizon 4 - Triton	KHL	CSL	TCL

GEO Project No.	Appendix No.
204305	B.1 (page 5/5)

Appendix C.1

P. 1/2 Thickness of Quaternary deposits - Interpolated

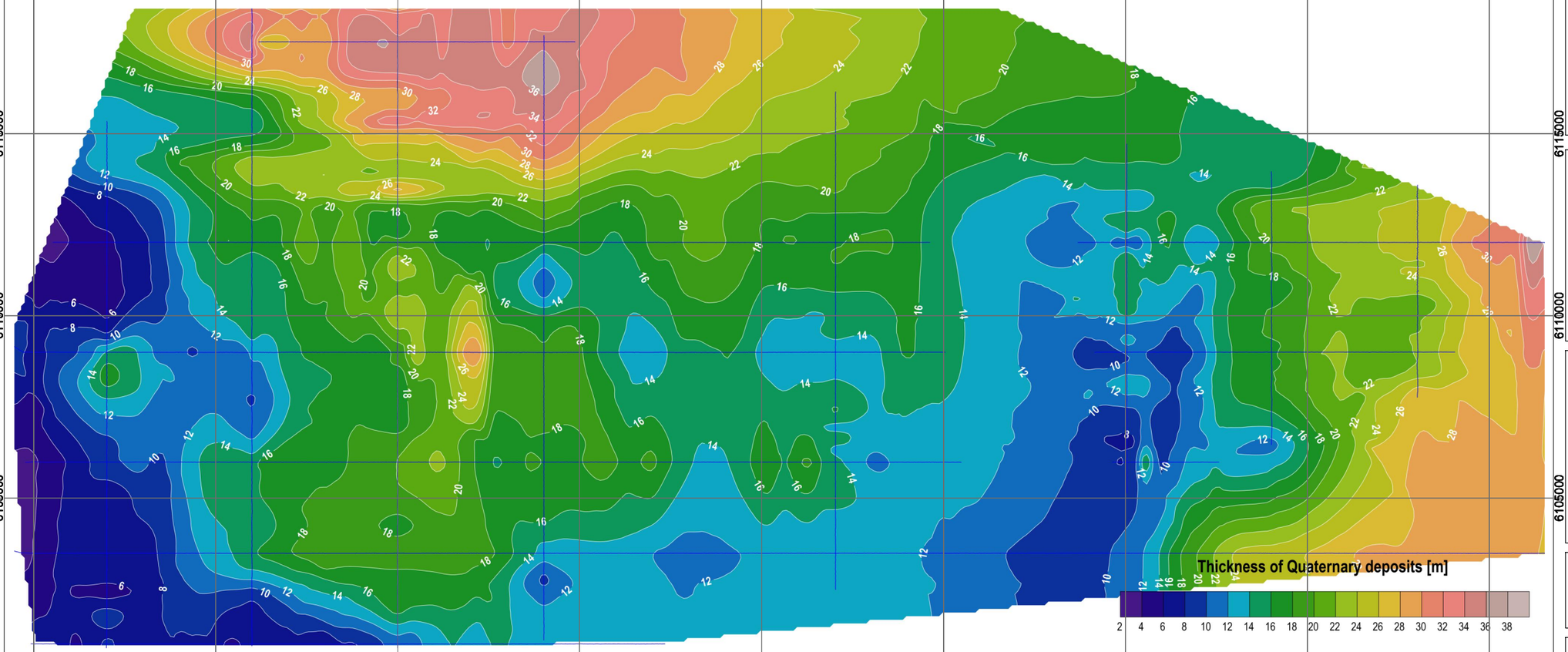
P. 2/2 Geological Profile D01_0014 and D01_0014_2

2 Pages

Your ref.: OX2 – Seismic interpretation at Triton, Offshore SE
Geo Job no. 204305
Report no. 2

1350000 1355000 1360000 1365000 1370000 1375000 1380000 1385000 1390000

6125000 6120000 6115000 6110000 6105000 6100000 6095000



LEGEND:

Sleeve gun lines

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT:

CLIENT:

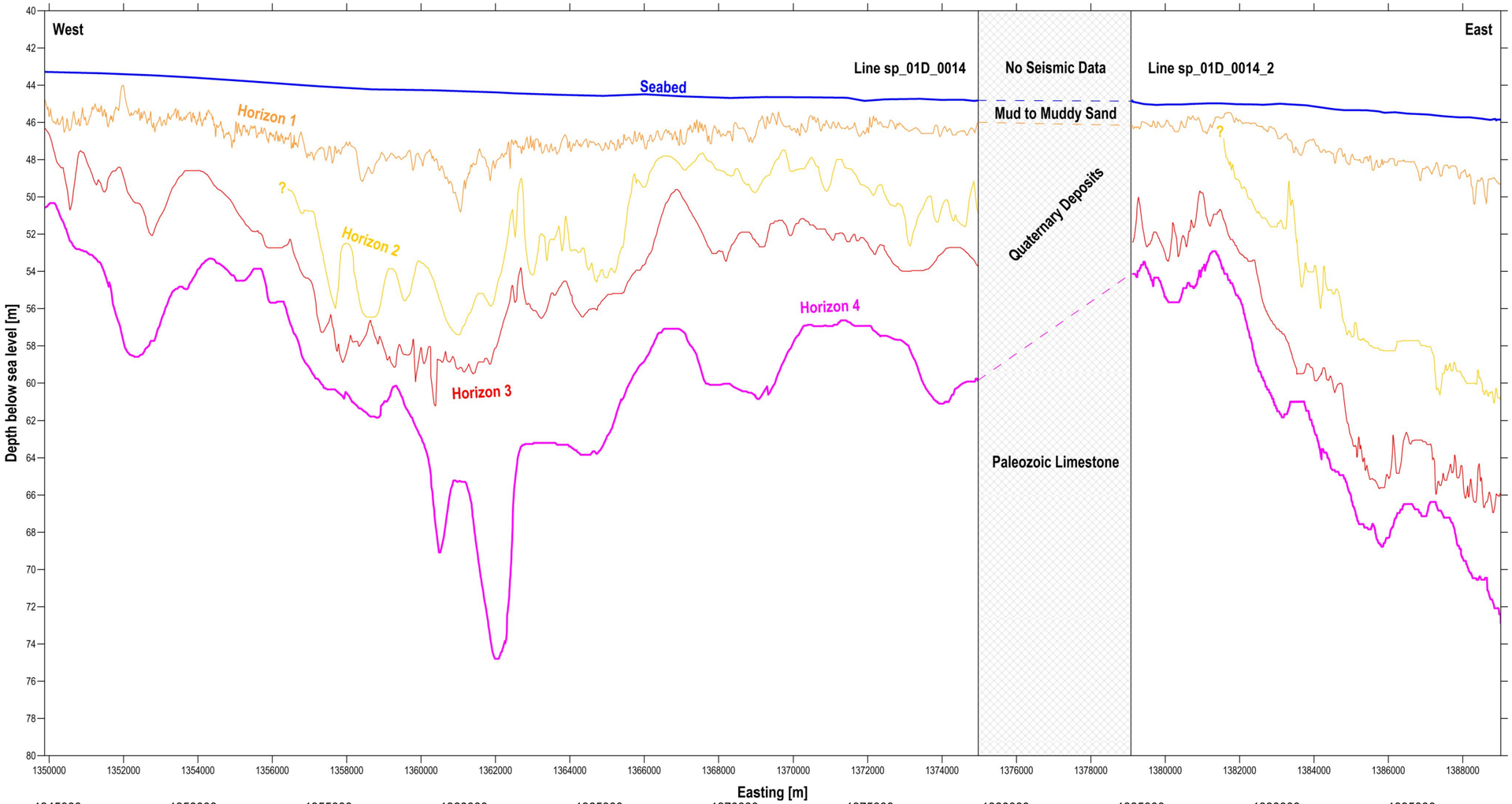
PROJECT:

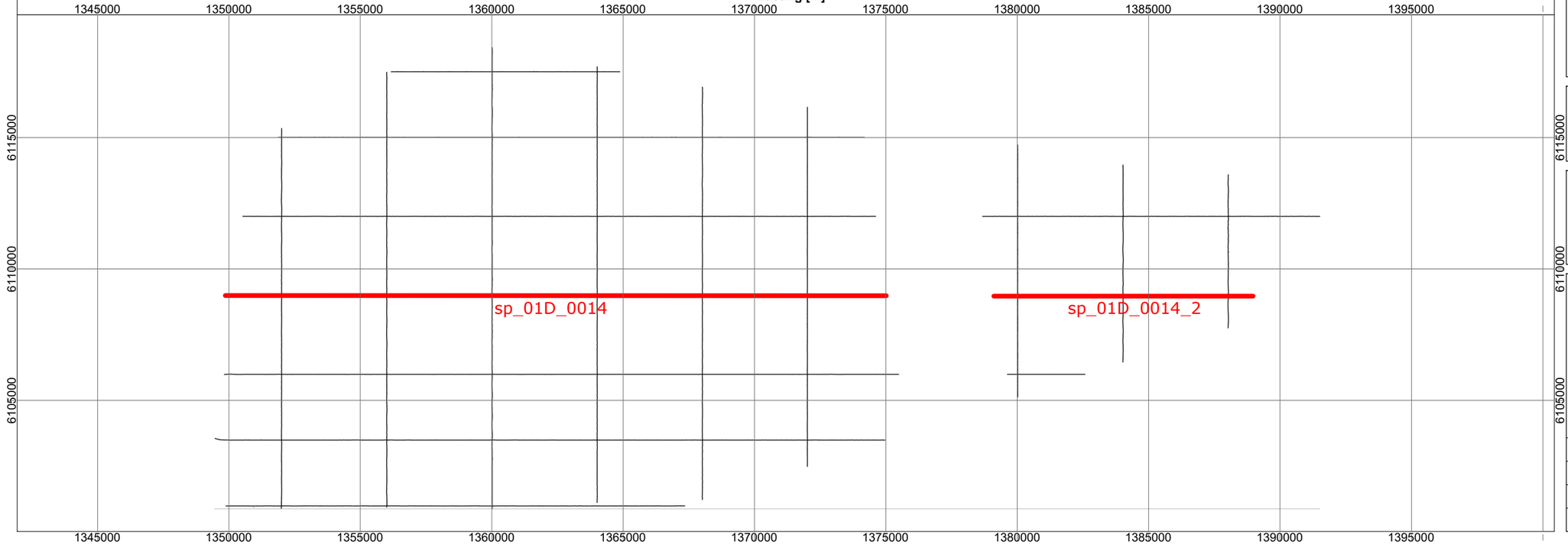
OX2 - Triton

Thickness of Quaternary deposits [m]
Interpolated

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Quaternary deposits - Triton	KHL	CSL	TCL

GEO Project No.	Appendix No.
204305	C.1 (page 1/2)





LEGEND:

Sparker lines

Geological Profiles

GEODETIC PARAMETERS:

Ellipsoid: GRS 1980
Datum: SWEREF99
Remarks: RT90 2.5 gon v

NOTES:

REFERENCES:

CONSULTANT:

CLIENT:

PROJECT:

OX2 - Triton

Geological Profile 14

Rev.	Date	Remarks	Drawn	Checked	Approved
0	2020-08-24	Geological Profile 14 - Triton	KHL	CSL	TCL

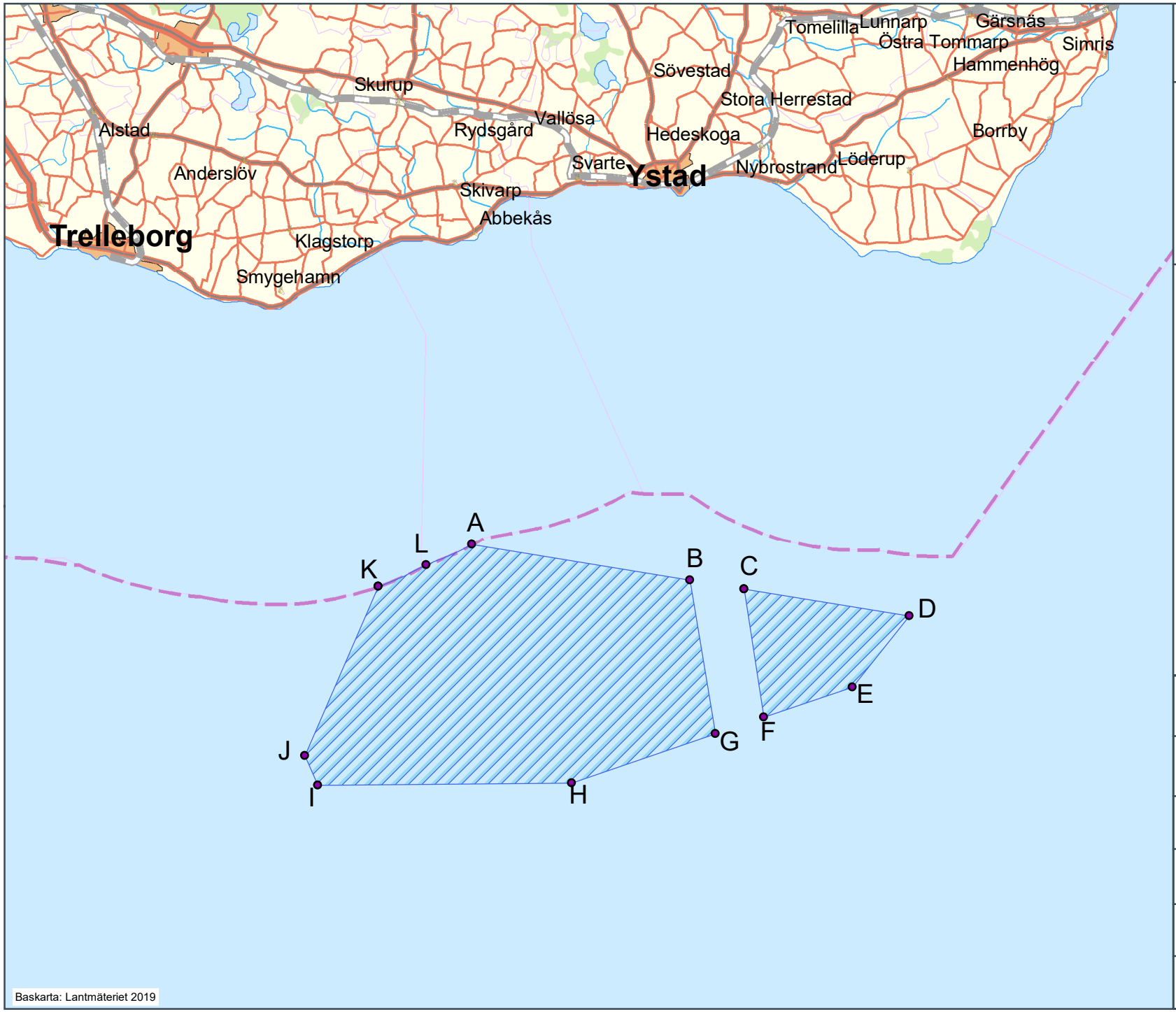
GEO Project No. 204305

Appendix No. C.1 (page 2/2)

Annex A.1

P. 1/1 Triton site overview with corner coordinates as provided by OX2

1 Page



0 2 4 km

Skala (A4):1:400 000

Teckenförklaring

Triton

Hörnkoordinater (WGS84)

A: 55°10.85′N, 13°35.85′E
B: 55°09.56′N, 13°51.44′E
C: 55°09.23′N, 13°55.32′E
D: 55°08.22′N, 14°07.09′E
E: 55°05.29′N, 13°03.12′E
F: 55°04.00′N, 13°56.85′E
G: 55°03.30′N, 13°53.44′E
H: 55°01.20′N, 13°43.30′E
I: 55°00.90′N, 13°25.29′E
J: 55°02.08′N, 13°24.30′E
K: 55°09.05′N, 13°29.26′E
L: 55°09.98′N, 13°32.63′E

Karttitel

HÖRNKOORDINATER

Projekt

Triton

Filnamn

Hörnkoordinater_Triton_2019-10-29.pdf

Koordinatsystem

WGS 84

Kontakt

Henrik Sjöström

Datum

2019-10-29