DNV·GL

SEAFAN 7018/5-1

Environmental risk from drilling disposals at 7018/5-1

EQUINOR ENERGY AS

Report No.: 2020-0272, Rev. 00
Document No.: 711169
Date: 2020-03-16

Project name:	SeaFAN 7018/5-1
Report title:	Environmental risk from drilling disposals at 7018/5-1
Customer:	EQUINOR ENERGY AS, Forusbeen 50, 4035, Stavanger, Norway
Customer contact:	Linda-Mari Aasbø
Date of issue:	2020-03-16
Project No.:	10188694
Organisation unit:	Environmental Monitoring
Report No.:	2020-0272, Rev. 00
Document No.:	711169

DNV GL AS Region Norway
5373,Region Norway
P.O. Box 300,,
Tel: +47 67 57 99 00
CNORDNV11

Applicable contract(s) governing the provision of this Report:

Objective:

SeaFAN at 7018/5-1

Prepared by:	Verified by:	Approved by:
Ulfsnes, Amund Digitally signed by Ulfsnes, Amund Date: 2020.03.16 14:32:03 +01'00'	Møskeland, Thomas Digitally signed by Møskeland, Thomas Date: 2020.03.16 14:42:25 +01'00'	Jensen, Tor Digitally signed by Jensen, Tor Date: 2020.03.16 15:50:43 +01'00'
Amund Ulfsnes Principal Consultant	Thomas Møskeland Senior Principal Consultant	Tor Jensen Vice President - Head of Section

DNV GL Distribution:

☒ OPEN. Unrestricted distribution, internal and external.

☐ INTERNAL use only. Internal DNV GL document.

☐ CONFIDENTIAL. Distribution within DNV GL according to applicable contract.*

☐ SECRET. Authorized access only.

*Specify distribution:

Keywords:

Modelling, DREAM, corals, risk

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
00	2019-03-16	First issue			

Table of contents

1 INTRODUCTION

DNV GL has on behalf of Equinor Energy AS performed discharge modelling and following environmental risk assessment for the planned drilling campaign at 7018/5-1. Cold-water coral reefs are identified >400 m east and west of the PWL (Equinor 2018, ST18906-RE-01). This report presents a risk assessment based on the accumulated sediment deposition and suspended solids from the discharge at nearest coral structures from the discharge modelling.

2 DISCHARGE MODELLING

2.1 Discharge characteristic and methodology

The project used the model DREAM MEMW 11.0, and DNV GL's internal SeaFAN tool for statistical analysis and presentation of modelling results. A total of 24 parallel simulations using different high-resolution hind cast modelled current data (NORKYST800 – met.no) were applied in the modelling to create variance in the output results. The results from the simulations has been compiled statistically in discharge footprint map for sea floor deposition expressed as mm thickness, and exposure time above thresholds for water column concentrations. Modelling was carried out for two periods of 3 months, September - November and December - February respectively, using hind cast current data from 2017-2018 (met.no). Measured high resolution bathymetry was used in the model simulations. Discharge specific, and area/model specific elements used in the modelling is presented in Table 2-1. Drilling discharges (barite, bentonite, cement and cuttings) are modelled from the proposed well location (Lat: 70.658049, Long: 18.424069 WGS84) with discharge on the sea floor. Planned discharge durations and amounts is shown in Figure 2-1(see Appendix a for details). Results are presented as total amount of particles.

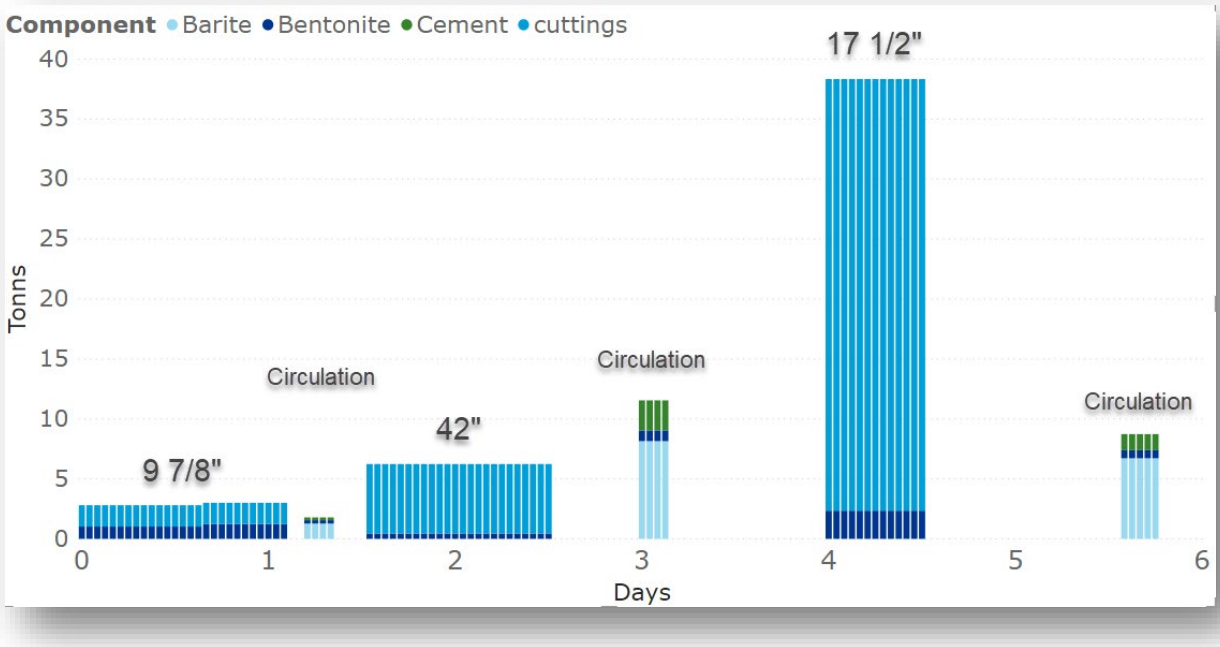


Figure 2-1 Planned/modelled discharge durations and amounts of barite, bentonite, cement and cuttings

Table 2-1 Area and model specific elements.

Element	Item	Specification
Site specific	**Current**	Norkyst800 (Hourly, 800*800m) (met.no)
	Bathymetry	High resolution measured data
	PSU	35 no halocline
	Temp	8 °C no thermocline
Model specific	**Number of particles**	2500
	Output interval	30 min
	Time step	10s
	Concentration z cell	10m (250-450m)
	Model grid	25*25m cells, 2*2km
	Output files	NETCDF4 (water column conc and sediment thickness)

2.2 Discharge Modelling Results

Drilling discharge footprint maps has been generated based on the modelling results and presented as sedimentation in mm for the intervals 1-3mm, 3-10mm and >10mm for the periods September-November and December-February (Figure 2-2 and Figure 2-3). The footprint maps are compiled from the hit probability maps for thickness intervals, where 90% of the modelling results are within the respective interval. The hit probability maps are presented in Appendix B.

For both modelling periods, the results are in line with our experience from dispersion studies of drilling discharges. There are minor differences between the two periods, with particle transport tending towards east. However, there are apparently more variance in the September-November results, creating a slightly larger footprint than the December-February period. The difference seen between the two periods are due to differences in the current regime at site.

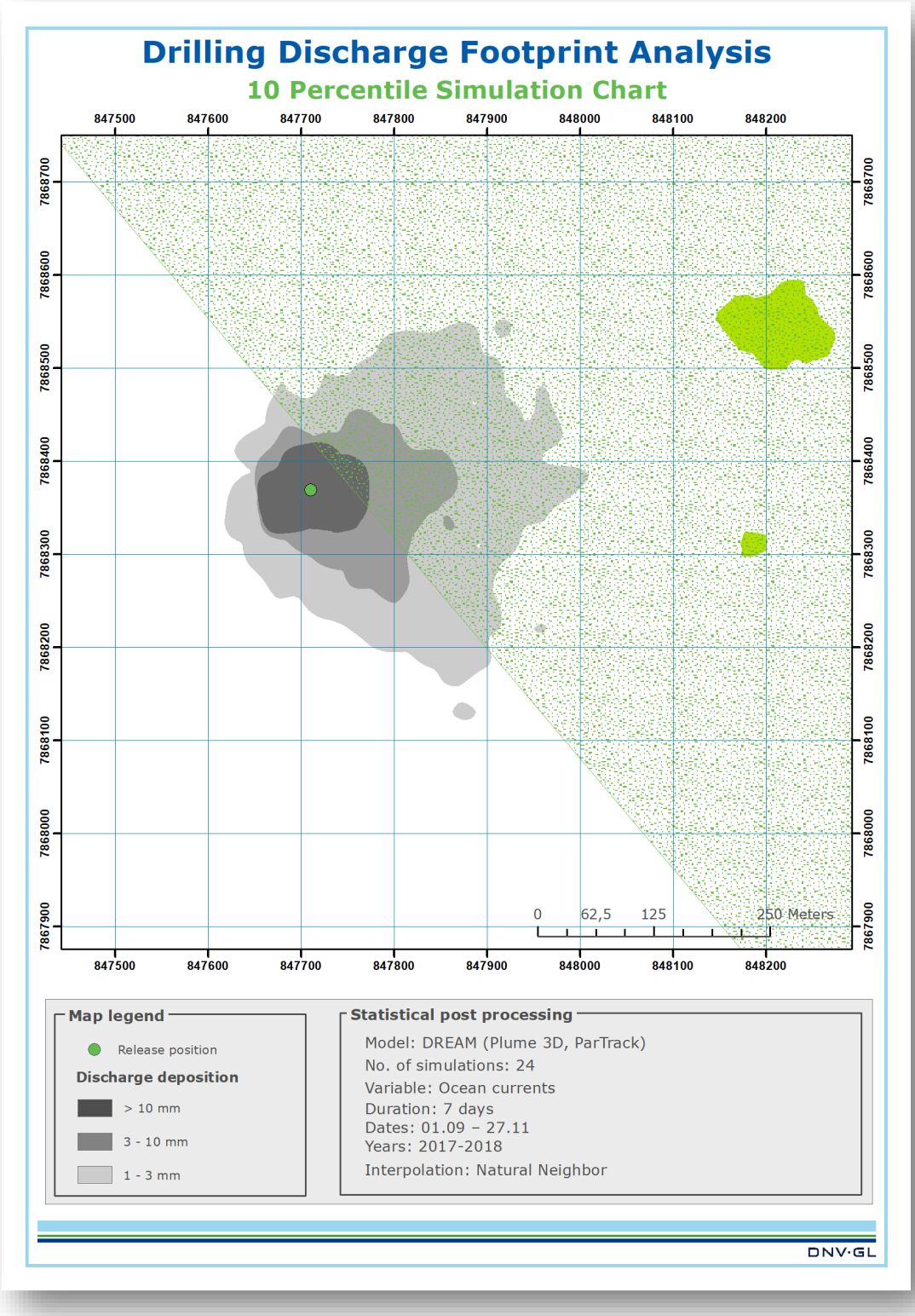


Figure 2-2: **Drilling discharge footprint map at 7018/5-1 in the period September-November 2017-2018, overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area).**

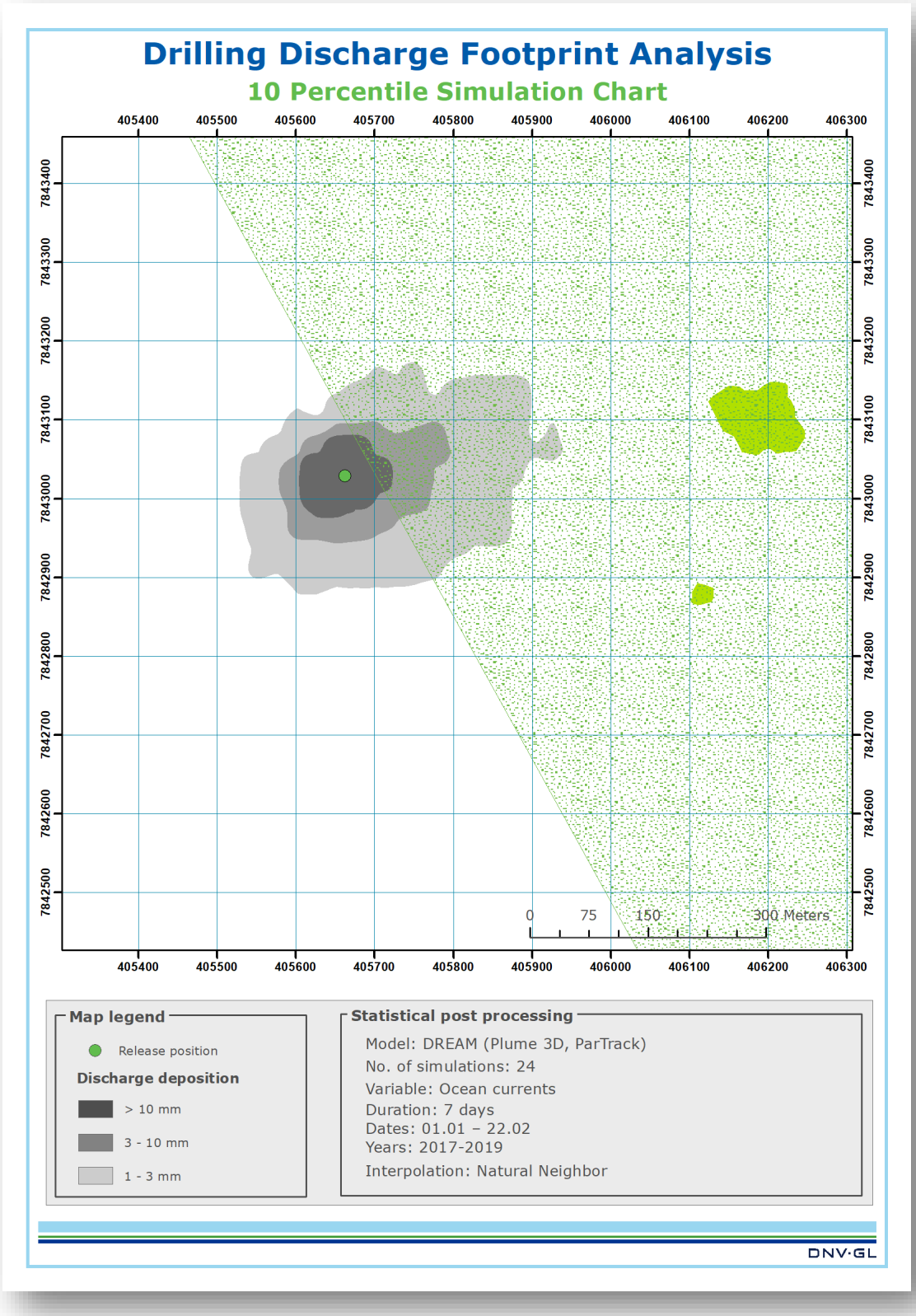


Figure 2-3 Drilling discharge footprint map at 7018/5-1 in the period December-February 2017-2019, overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area).

3 RISK ASSESSMENT

3.1 Methodology

Deriving threshold values of deposition of discharges

The risk assessment methodology and derived thresholds for effects from sediment deposition on corals applied is described in the "Handbook. species and habitats of environmental concern. Mapping, Risk Assessment, Mitigation and Monitoring. - In relation to Oil and Gas activities (NOROG, 2019). The applied threshold values for consequences are presented in Table 3-1 (same intervals as in the footprint maps).

Table 3-1 Threshold values for consequences for deposition of discharges (NOROG, 2019)

Deposition thickness	Degree of impact	Consequences
0.1-1 mm	Negligible	No detectable influence
1-3 mm	Low	Minor smothering Good ability to shed sediments, but might start to aggregate
3-10 mm	Significant	Moderate smothering Reduced ability to shed sediments. Some polyp mortality or sponge necrosis can occur.
>10 mm	Considerable	Considerable smothering Potential suffocation. Polyp mortality or sponge necrosis excpected. Potential for depletion of energy reserves.

Deriving threshold values of suspended solids

Thresholds for short term exposure of suspended solids of barite, bentonite and drill cuttings on *Desmophyllum pertusum* are under development. Several research projects have been performed in the period 2012 to 2019 under the Research Council of Norway's PROOFNY program in addition to Equinor initiated projects. The objective was to close the knowledge gap related to physical impact of suspended drilling discharges on cold-water coral (CWC), represented by the deep-water coral species *D. pertusum.*

New insight is gained into key physiological and health effect parameters (e.g. growth, mucus production, respiration, polyp activity/mortality and coensarc damage) as well as responses to natural variations in e.g. food availability on the coral species *D. pertusum*. This knowledge is important to understand how corals cope with natural seasonal variations in the ocean and further assess possible influence of our activities in relation to their tolerance to these natural variations. Physiological responses at varying food amounts and effects of particulate drilling discharges on adult corals, were obtained through laboratory experiments at NORCE conducted in the period 2012 to 2014. In these studies, impact of suspended drill cuttings (DC) on adult *Desmophyllum* with both short-term (2.5 weeks) continuous exposure and intermittent long-term discontinuous exposure (12 weeks) were measured after 4- and 16-weeks recovery in particle free seawater, respectively. Main findings from these experiments support earlier studies showing that adult *L. pertusum* is quite robust towards suspended DCs, indicating a DCs particle concentration of **10 mg/L** as a threshold for **long-term continuous exposure** (physiological and behavioral responses). The knowledge gained from these projects was published in a peer-review scientific journal (Baussant et al., 2018).

Most studies published have explored impacts of drilling discharges on adult *D. pertusum* with continuous and long-term exposure to suspended particles from drilling. Knowledge on short-term impact of exposure to more realistic conditions e.g. shorter duration and pulse exposure, both on early life stage of larvae and adults was scarce. Therefore, to mimic more realistic field condition, additional short-term pulse exposure

experiments have been performed to generate reliable effect data for establishing effect thresholds for use in impact and environmental risk assessments of drilling discharge scenarios related to e.g. exploration drilling.

A project collaboration (Coral-IDRET) was initiated in 2017 with NORCE and Ecotone performing effect studies designed for realistic exposure conditions on adults *D. pertusum*. Effects on survival and sub-lethal responses (growth, respiration rate, mucus production, polyp activity and damage on surface tissue) of exposure to realistic conditions of the particulate weight materials barite and bentonite, and DCs in suspension were performed. Corals were exposed repeatedly (pulses – 4 h on-off) over 5 days in the range (nominal concentration) 10 to 100 mg/L (actual ~ 4 to ~ 50 mg/L) and mortality and physiological endpoints were measured after 2 to 6 weeks recovery. In laboratory experiments performed under realistic conditions, the lowest effect concentration measured was around 20 mg/L (representative for DC, barite and bentonite). Respiration and growth rates were not significantly different in any of the treatments tested compared to control. Polyp mortality was observed at the two highest exposure concentrations (about 20 and 50 mg/L) for DC, barite and bentonite. Damage on coenosarc was observed on a few individuals but not extensively exposed to barite and bentonite. In conclusion, *D. pertusum* corals are resilient to a relatively high load of particles in suspension (~20 mg/L) exposed to a more realistic field condition. At higher load, the condition of some corals alters, and polyp mortality increases.

Based on this the no effect derived threshold for suspended solids used in this assessment are:

- Conservative: 10 mg/L over a period of 5 days
- Realistic: 20 mg/L over a period of 5 days

3.2 Risk Assessment Results

Burial and smothering

In the overlap analysis between nearby corals and the sediment footprint maps (>1mm) it is revealed that the reef building coral; *Desmophyllum pertusum* located in the vicinity of the planned drilling location at the exploration well 7018/5-1, will not be negatively influenced by smothering nor burial. The modelling indicates maximum sediment loads, from any of the simulations, on the nearby corals to be <0.7mm (Figure 3-1), well below the no effect threshold on corals (Table 3-1) for both periods. The closest coral area (id23 and 24) are located more than 200m east of the deposition influence area (>1mm) (Figure 3-2, and Figure 3-3). There are no significant differences between the two periods.

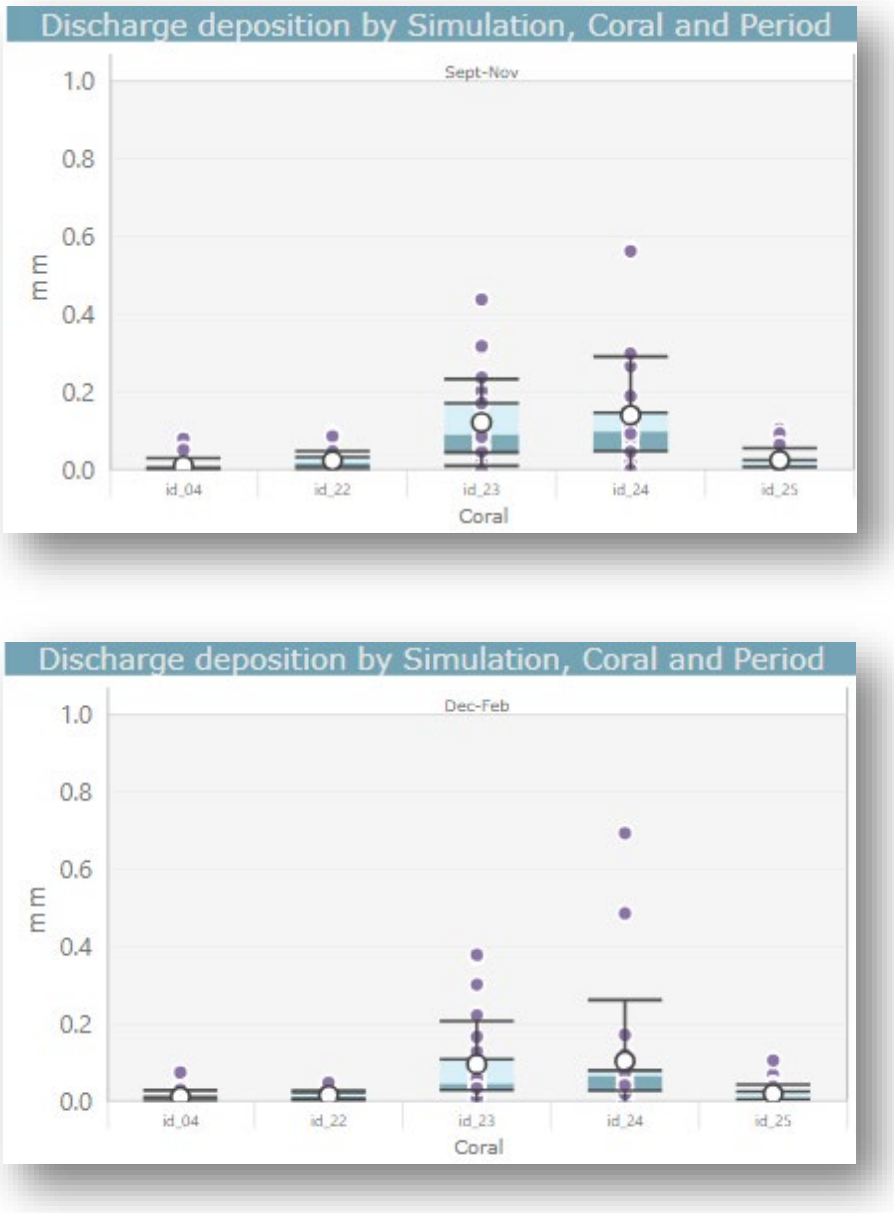


Figure 3-1: High-resolution presentation of the modelling results of maximum sediment deposition thickness (mm) on the seabed on each of the coral targets for all simulations in the period Sept-Nov (top) and Dec-Feb (bottom) at 7018/5-1.The whiskers are one standard deviation, and mean is illustrated as ◯.

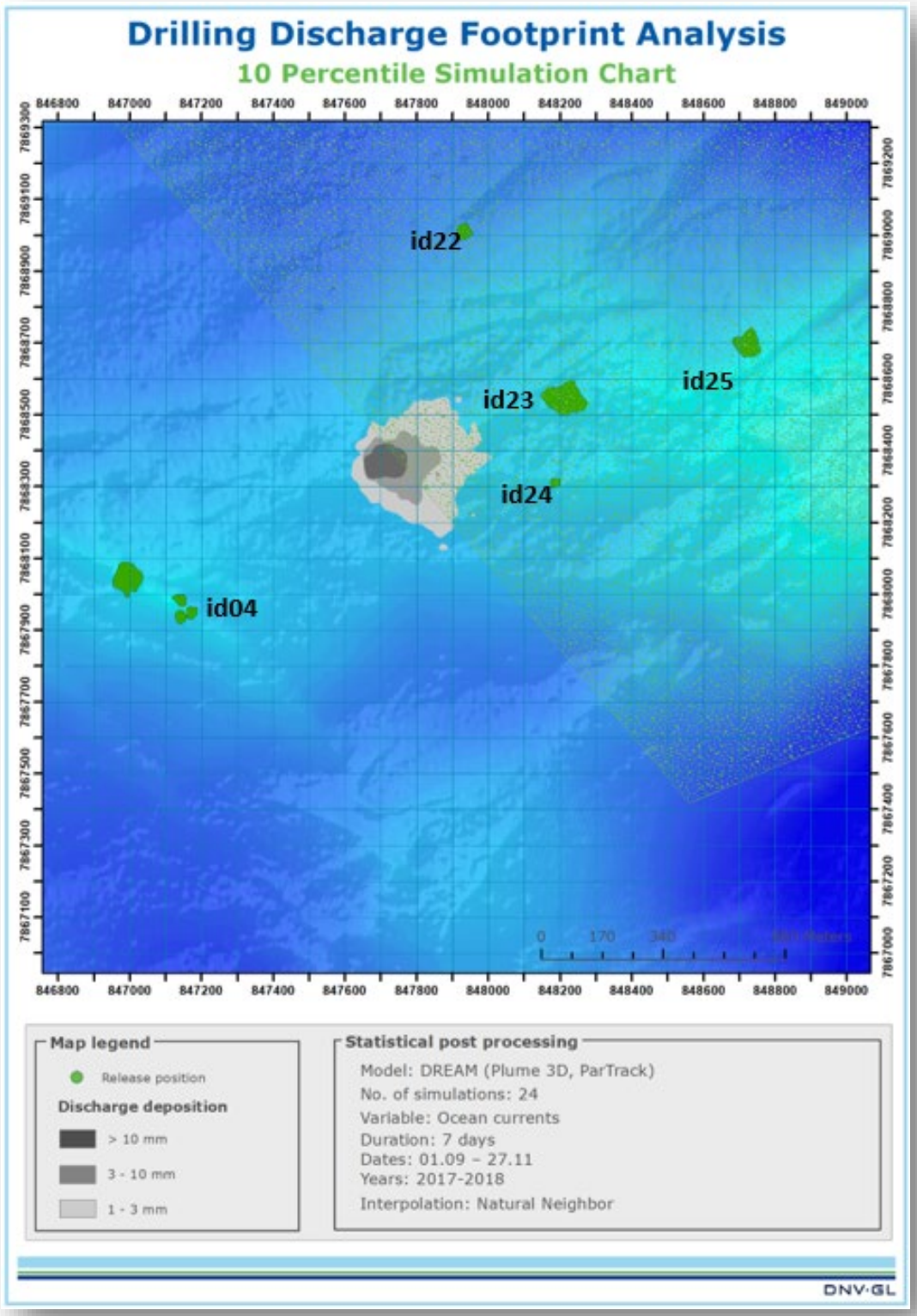


Figure 3-2 Cold water corals in the survey area overlaid with the discharge footprint map in the period Sept-Nov 2017-2018. Corals are in solid green (id numerated), while the Sotbakken

marine protection area are highlighted with green dots.

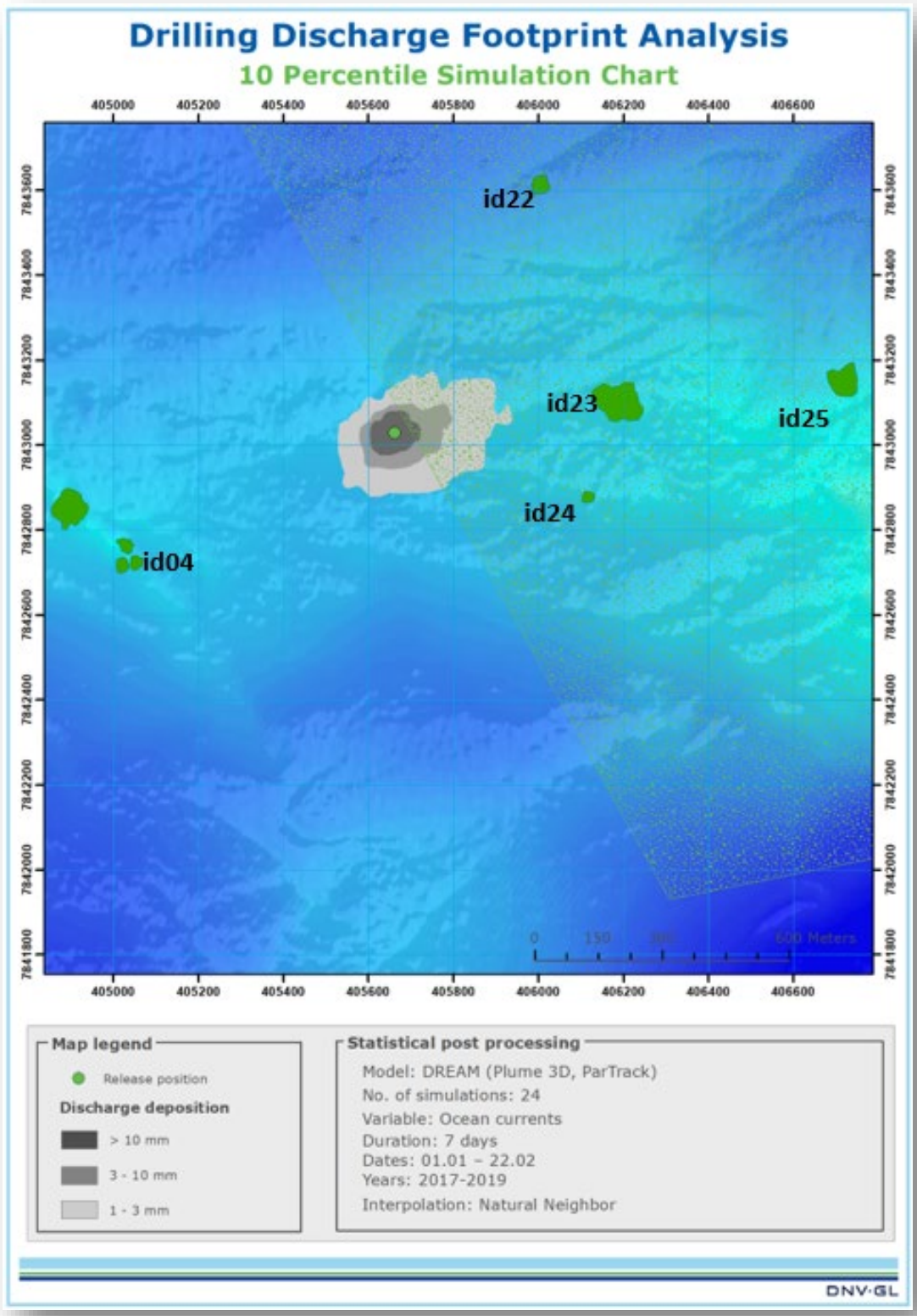


Figure 3-3 Cold water corals in the survey area overlaid with the discharge footprint for a discharge in the period Dec-Feb 2017-2019. Corals (id numerated) are in solid green, while the Sotbakken marine protection area are highlighted with green dots.

Suspended solids

Suspended solids exposure above thresholds may occur for short periods of time (<30min) throughout the drilling campaign. The average exposure time of total concentration of particles above the most conservative threshold (~10 mg/l) on any coral does not exceed 1 hour. This threshold is derived from experiments based on long-term exposure (up to 12 weeks) to suspended DC.

Similarly, average total particle concentrations exceeding the more realistic threshold of 20 mg/L (for barite, bentonite and DCs) on corals in the survey area, the modelling showed average exposure time above this threshold less than 1/2 hour. This threshold was based experiments with pulse exposure over 5 days. Considered the short period of suspended particle exposure of the corals in the survey area (based on model simulations for the two time periods), no or negligible impacts on corals are expected.

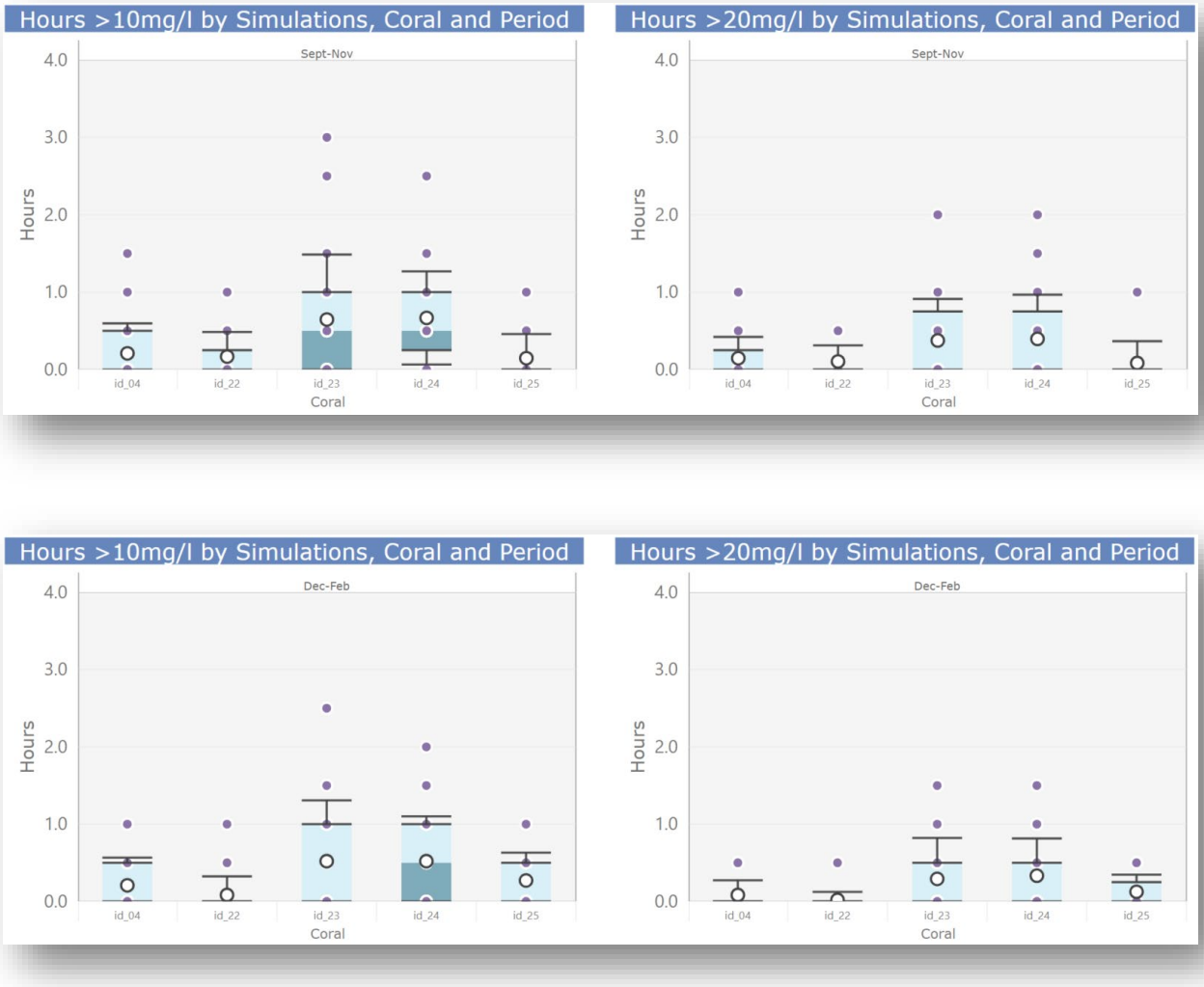


Figure 3-4 High-resolution analysis of the modelling results of sum exposure time per simulation of total concentrations of suspended solids above two thresholds (10 and 20 mg/L) at each of the coral targets for all timesteps and simulations at 7018/5-1. The whiskers are one standard deviation, and mean is illustrated as ◯.

4 CONCLUSIONS

High resolution modelling of planned discharges to the seabed from exploration drilling at 7018/5-1 has been performed. The results from discharge of particulate drilling waste (drill cuttings, cement, barite and bentonite) on depositions on the seabed and suspended solids concentrations in the water column are overlaid with coral structures in the proximity to planned well location at 7018/5-1, indicating no overlap exceeding any thresholds for effects from burial.

Suspended solids exposure above thresholds may occur for short periods of time (<30min) throughout the drilling campaign. The average exposure above the conservative threshold of ~10 mg/l and the more realistic threshold of 20 mg/L on any coral does not exceed 1 hour (mean <0.5hrs). Considered the short period of suspended particle exposure of the corals in the survey area (based on model simulations for the two time periods), no or negligible impacts on corals are expected.

The differences seen in the modelling results on the different corals between seasons (sept-nov and dec-feb) are minor or neglectable.

5 REFERENCES

Baussant, T., Nilsen, M., Westerlund, S., Ravagnan, E., and Ramanand, S. (2018). Effects of suspended drill cuttings on the coral lophelia pertusa using pulsed and continuous laboratory exposure scenarios *J. Toxicol. Environ. Health, A.*

Baussant, T. *et al*., 2020. Is the coral Desmophyllum pertusum resilient to offshore drill waste? A laboratory study performed under near-realistic conditions (in preparation).

Davies, A.J., Wisshak, M., Orr, J.C., and Murray Roberts, J., 2008. Predicting suitable habitat for the cold-water coral Lophelia pertusa (Scleratinia). Deep-Sea Research I, 55, 1048-1062.

DNV, 2013. Guideline. Monitoring of drilling activities in areas with presence of cold water corals. Report nr: 2012-1691, 2013-01-15, Rev 01.

Kiriakoulakis, K., Freiwald, A., Fisher, E., Wolff, G.A., 2007. Organic matter quality and supply to deepwater coral/mound systems of the NW European Continental Margin. International Journal of Earth Sciences, 96 (1).

Larsson & Purser, 2011. Sedimentation on the cold-water coral Lophelia pertusa: Cleaning efficiency from natural sediments and drill cuttings. Marine Pollution Bulletin 62 (2011) 1159-1168.

Miljødirektoratet. 2015.Veileder M300. Miljøovervåking av petroleumsaktiviteten til havs.

NOROG, 2019. Handbook: Species and Habitats of Environmental Concern - Mapping, Risk Assessment, Mitigation and Monitoring, in Relation to Oil and Gas Activities.

Mortensen, P.B., Hovland, M.T., Fosså, J.H., and Furevik, D.M., 2001. Distribution, abundance and size of Lophelia pertusa coral reefs in mid-Norway in relation to seabed characteristics. Journal of the Marine Biological Association of the United Kingdom, 81, 581-597.

OSPAR, 2008. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. OSPAR List of Threatened and/or Declining Species and Habitats (Reference Number: 2008-6, Replaces agreement 2004-6).

Smit, M. G. D, Holthaus, K. I. E,Trannum, H. C., Neff, J. M., Kjeilen-Eilertsen, G, Jak, R. G., Singsaas, I., Huijbregts, M. A. J., Hendriks, J. A., 2008. Species sensitivity distributions for suspended clays, sediment burial, and grain size change in the marine environment. Environmental Toxicology and Chemistry, Vol. 27, No. 4, pp. 1006–1012, 2008.

Thiem, Ø., Ravagnan, E., Fossa , J.H., Berntsen, J., 2006. Food supply mechanisms for cold-water corals along a continental shelf edge. Journal of Marine Systems 26, 1481–1495.

White, M., Mohn, C., de Stigter, H., Mottram, G., 2005. Deep-water coral development as a function of hydrodynamics and surface productivity around the submarine banks of the Rockall Trough, NE Atlantic. In: Freiwald, A., Roberts, J.M. (Eds.), Cold-Water Corals and Ecosystems. Springer, Berlin/Heidelberg, pp. 503–514APPENDIX 1.

	9 7/8" pilothull						42 " section					17.5" section			
	1	2	3		4		4	5		6		7	8		9
Drilling section:	9 7/8"	9 7/8"	Displacement 1,30 sg	Misc	Circulation	Misc	42"	Displacement 1,30 sg	Misc	Circulation	Misc	17 1/2"	Displacement 1,30 sg	Misc	Circulation
Start of discharge, h1)	**0.00**	**26.09**	**43.95**	**43.95**	**45.95**	**49.95**	**53.95**	**139.99**	**140.34**	**150.34**	**154.34**	**174.34**	**230.82**	**231.31**	**255.31**
Section length, m:	190	130					60					260			
Drilling rate m/h	12	12					3					20			
Discharge depth, m	0 m above seafloor						0 m above seafloor					0 m above seafloor			
Diameter of OH (m)	0.25	0.25	0.25	0.25	0.25	0.25	1.07					0.44			
Diameter of outlet opening (m)	0.25	0.25	0.25		0.25		1.07	1.07		1.07 til 0.79		0.79	0.79		0.79 til 0.31
Diameter of drill string (m)	0.2	0.15	0.15		0.15		0.2	0.2		0.91		0.13	0.13		0.13
Orientation of outlet opening	Vertical						Vertical					Vertical			
Duration best case 2):	15.83	10.83	0.00	2.00	4.00	4.00	24.00	0.34	10.00	4.00	20.00	13.00	0.48	24.00	5.00
Volume discharge, cuttings (m3)	10.3	7.0	n/a	n/a	n/a	n/a	62.0	n/a	n/a	n/a	n/a	43.5	n/a	n/a	n/a
Voulme discharge, seawater (m3)	2646	1771	7.0	n/a	n/a	n/a	6376	62.0	n/a	n/a	n/a	3191	87.0	n/a	n/a
Voulme discharge, sweeps (m3)	204	179	n/a	n/a	n/a	n/a	104	n/a	n/a	n/a	n/a	319	n/a	n/a	n/a
Voulme discharge, mud (m3)	n/a	n/a	n/a	n/a	7.0	n/a	n/a	n/a	n/a	62.0	n/a	n/a	n/a	n/a	43.5
Volume discharge, cement (m3)	n/a	n/a	n/a	n/a	6.4	n/a	n/a	n/a	n/a	161.9	n/a	n/a	n/a	n/a	39.5
Total water rate through discharge hose (lpm)	3000	3000	1000		1000		4500	3000	n/a	1000	n/a	4500	3000	n/a	1000
Calibration factor	1.10	1.10			1.00		1.15			3.00		1.10	2.00		1.00
Compound in discharge	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**	**Amount:**
	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes
Cuttings	28.50	19.50					139.00					612.00			
Bentonite	16.40	13.60			1.13		10.80			3.60		40.00			3.38
Barite	0.00	0.00			5.10					32.60					33.60
Soda ash	0.22	0.17			0.07		0.14			0.45		0.50			0.42
CMC	1.03	0.85			1.13		0.68			0.30		25.90			0.25
Cement G class - D907					0.92					9.99					6.71
Water	201.00	165.00			28.80		232.08			72.00		638.00			525.71
Total mud	**219**	**180**	**0**		**37**		**244**	**0**		**119**		**704**	**0**		**570**

7 APPENDIX B

7.1 Hit probabilities September-November

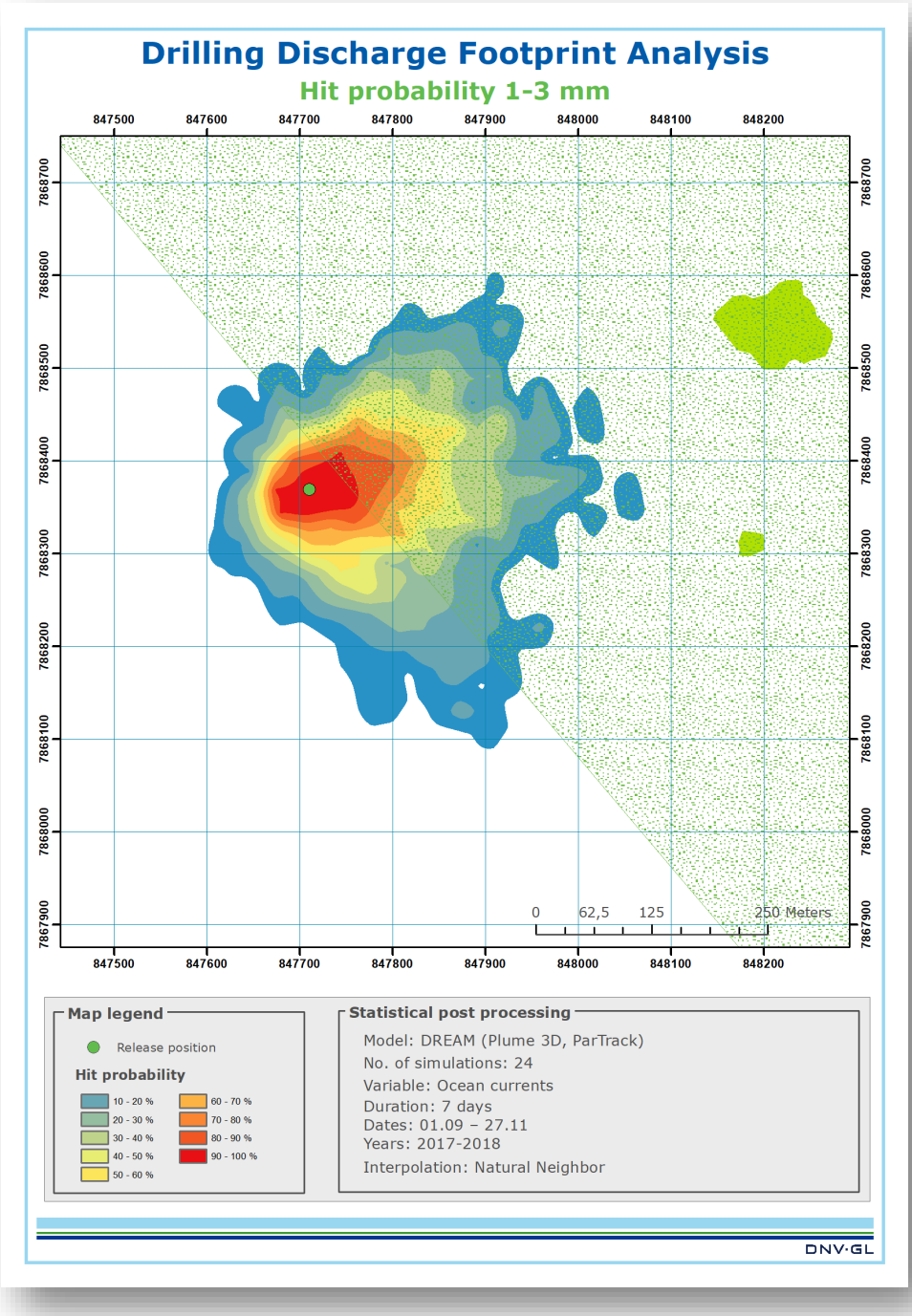
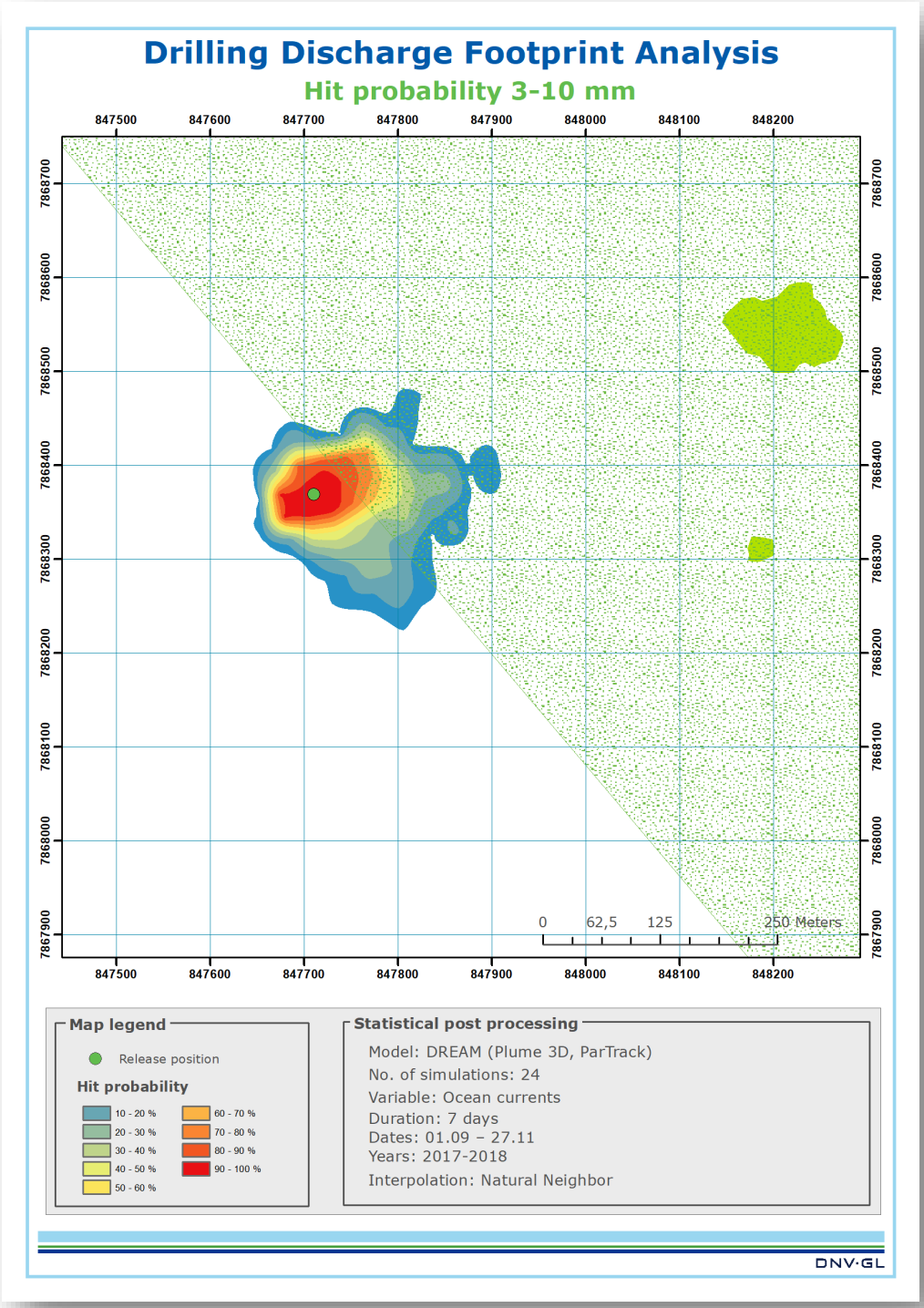
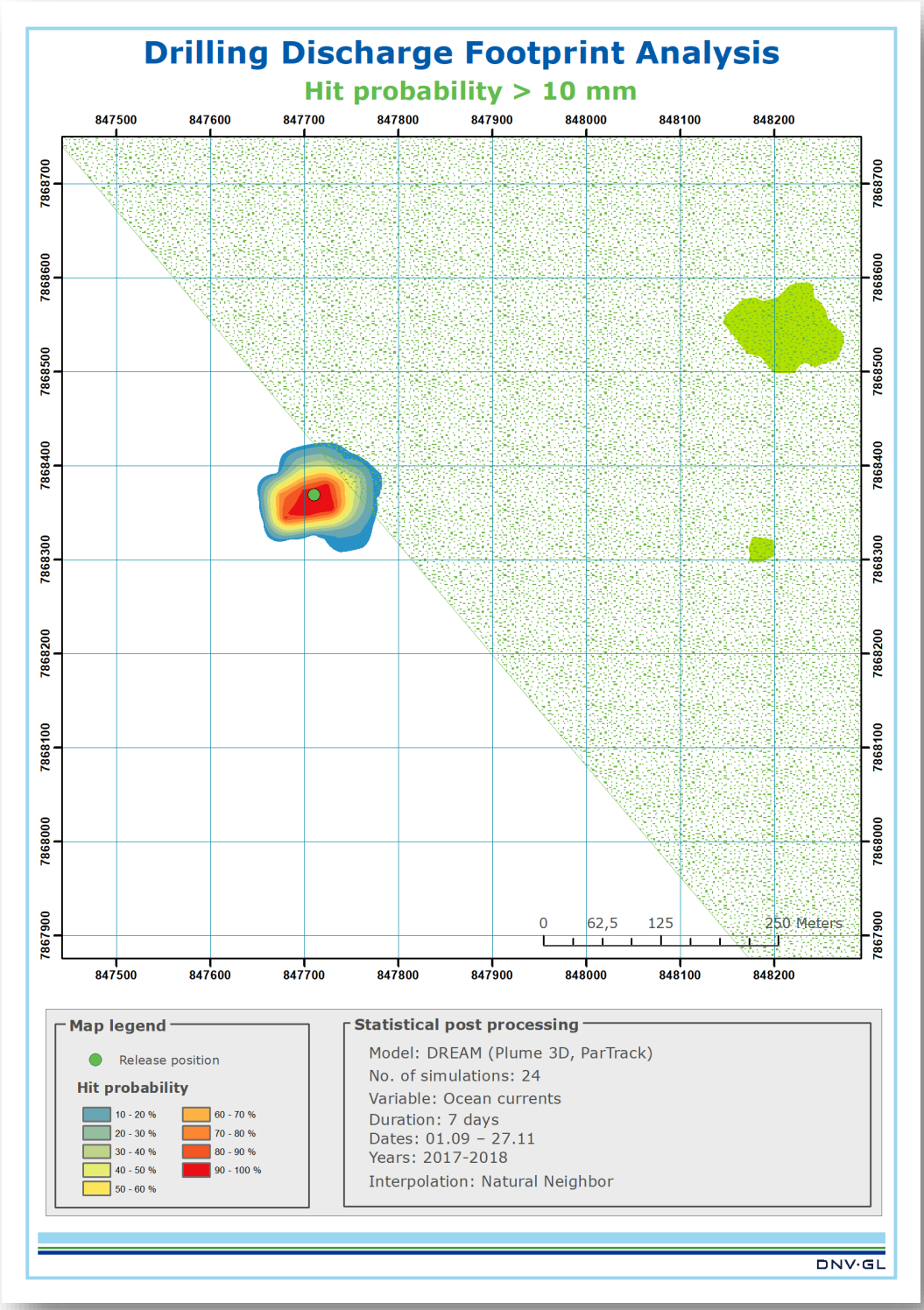


Figure 7-1 Drilling discharge footprint hit probability map (1-3 mm) at 7018/5-1 in the period September-November 2017-2018, overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area).



Drilling discharge footprint hit probability map (3-10 mm) at 7018/5-1 in the period September-November 2017-2018, overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area).



Drilling discharge footprint hit probability map (>10 mm) at 7018/5-1 in the period September-November 2017-2018 overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area).

7.2 Hit probabilities December-February

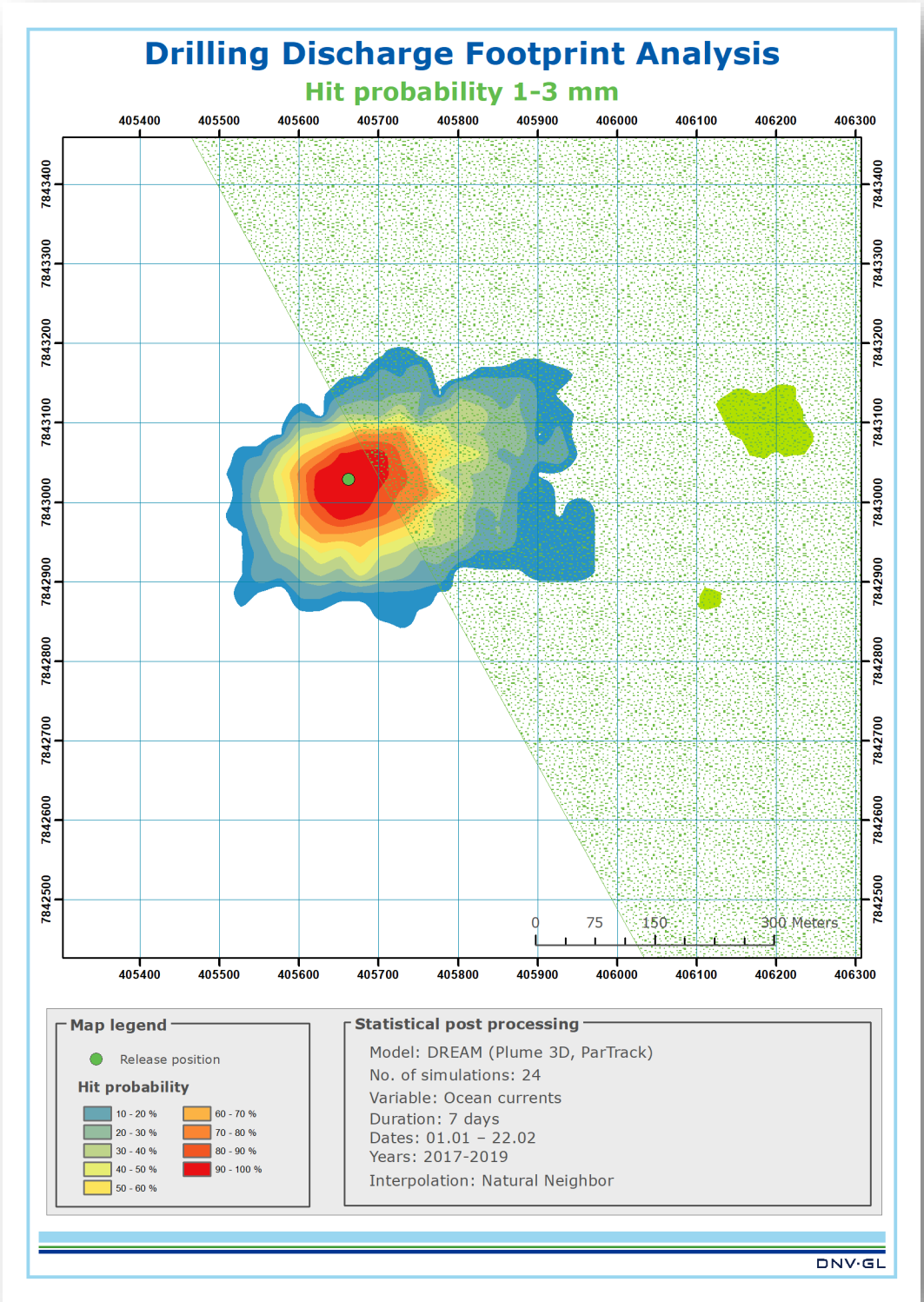


Figure 7-2 Drilling discharge footprint hit probability map (1-3 mm) at 7018/5-1 in the period December-February 2017-2019, overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area)

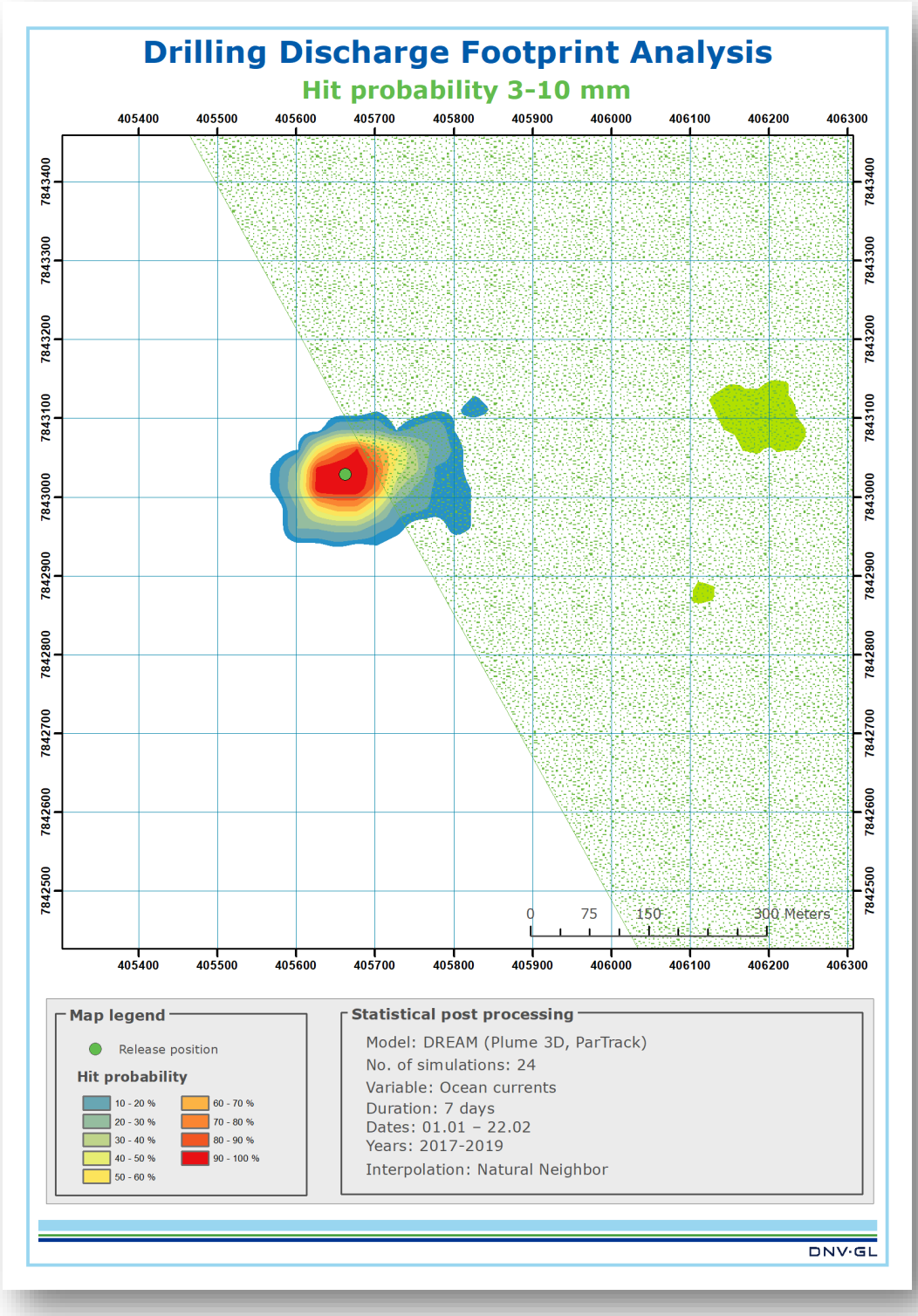


Figure 7-3: **Drilling discharge footprint hit probability map (3-10 mm) at 7018/5-1 in the period December-February, 2017-2019, overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area).**

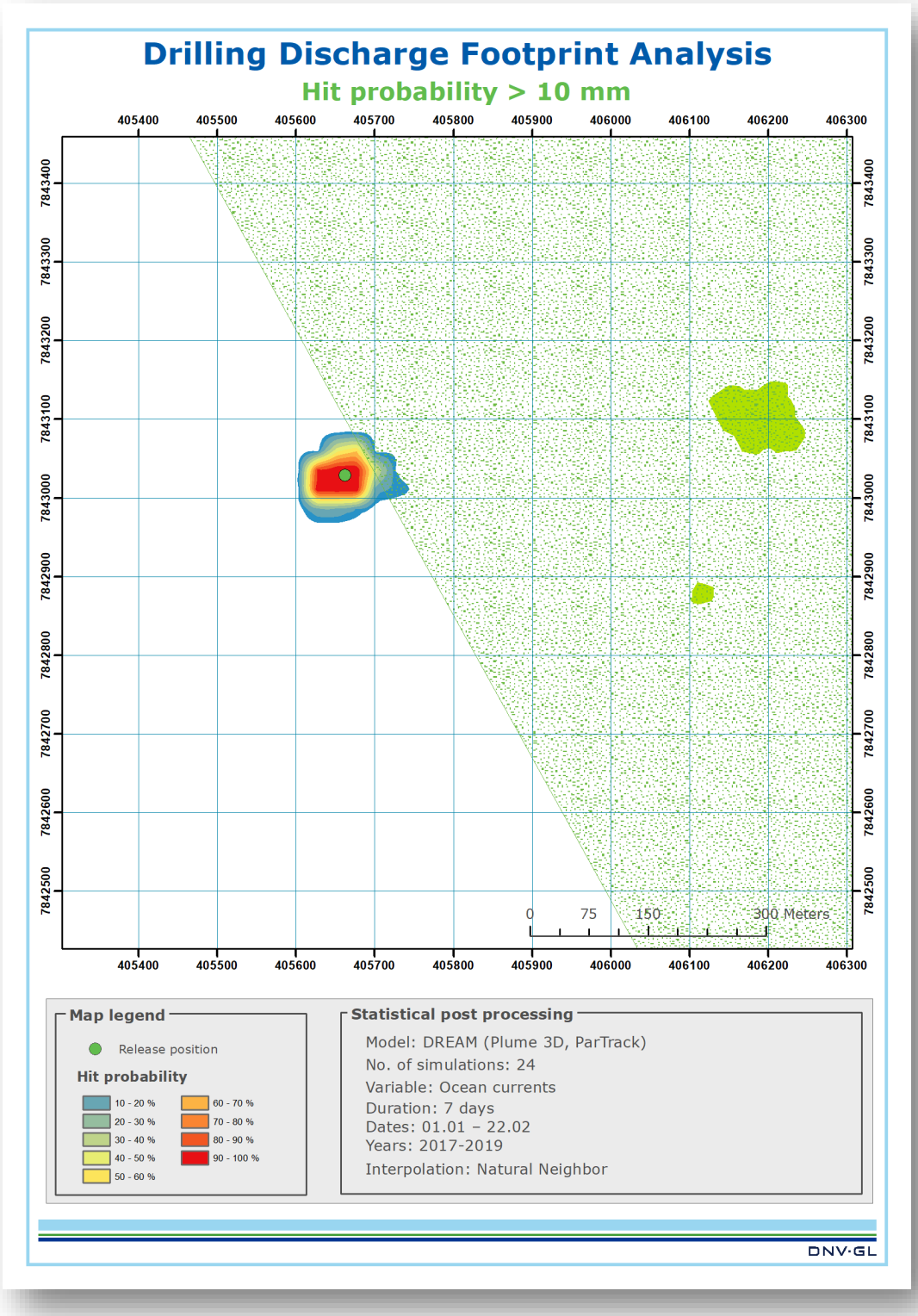


Figure 7-4: **Drilling discharge footprint hit probability map (>10 mm) at 7018/5-1 in the period December-February 2017-2019, overlaid with Sotbakken marine protected area (green transparent area) and nearby coral areas (solid green area).**

About DNV GL

DNV GL is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.