Undervannsstøy – risiko for fisk og dyreliv i forbindelse med aktiviteter i kystsonen.

2022-03-17

Tim Fristedt

Marine Technology

Tromsø

Water, Air and Ice

Sea, Lakes, Coastlines, Beaches,
Harbours, Breakwaters
Piers

multiconsult.no

Construction, Infrastructure and Passageways
We perform engineering for the coastal and ocean environment from the very early-phase to full detail engineering.

Ice and "snow how"
Our signature is cold climate engineering and we have specialised in ice physics and winterization on both ocean and land.

Environmental loads
We compute loads from waves, currents, winds and ice on a wide range of scales from single local point loads to global structural response.

Measurements, Modelling and Monitoring
We tailor metocean measurement services to fulfil required standards with optimal output at minimal cost. We perform analysis and modelling and simulation of water, ice as well as wind.

Aquaculture – Accredited services
We are certified by Norwegian Standards to supply accredited services for aquaculture industry

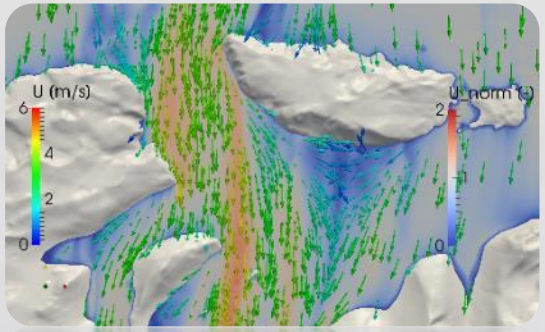
Energy - Renewable energy
We supply concept solutions for Wind power / Offshore wind / Floating Solar PV.

Marine Technology | Tromsø

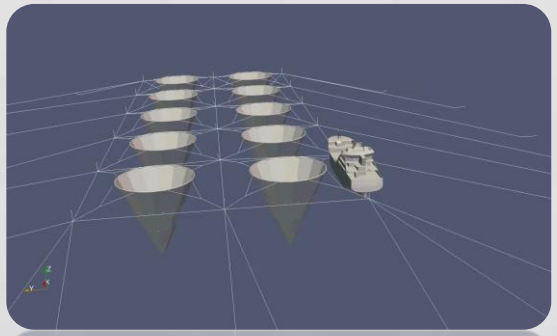
- **Hydrodynamics and sea ice**
  - Ice, wave and current loads
  - Mooring and motion analysis
- **Cold climate and metocean**
  - Metocean, cold climate
  - Aquaculture
- **Coastal constructions and harbours**
  - Construction (piers, docks)
  - Harbours, ports and routes

- **28 Marine technology engineers :**
  - 10 PhD (hydrodynamics, fluid mechanics, sea ice loads)
  - 14 MSc (marine technology, oceanography, mathematics)
  - 4 BSc (structures, CAD)

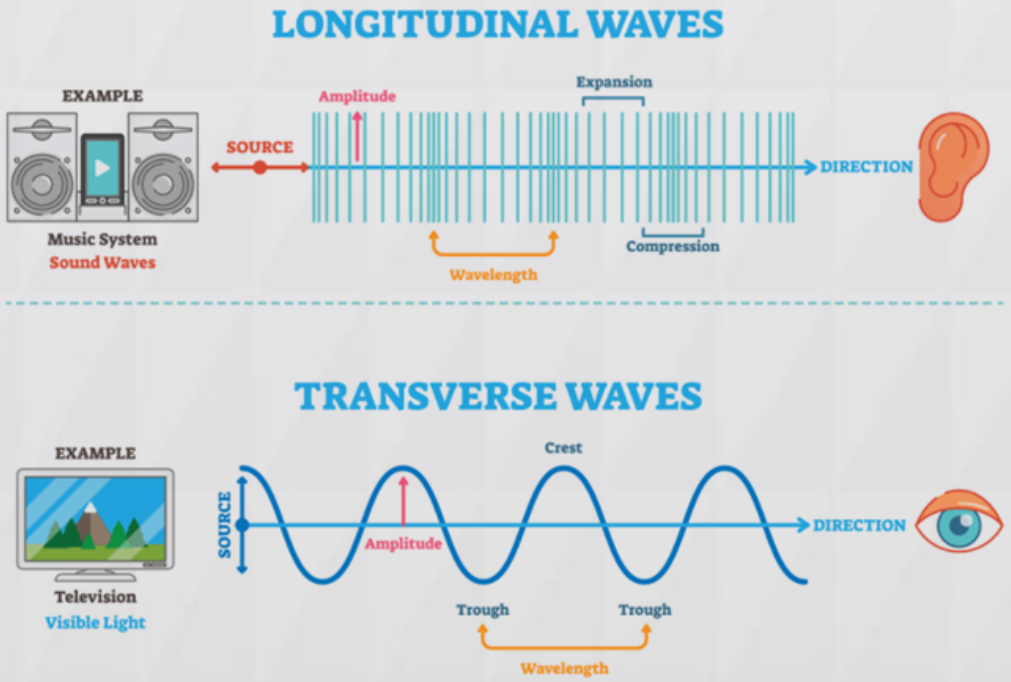
- **Core located in Tromsø, Norway**
  - 2 persons in Bergen
  - 3 persons in Oslo
  - 1 person in Stavanger
  - 1 person in Trondheim

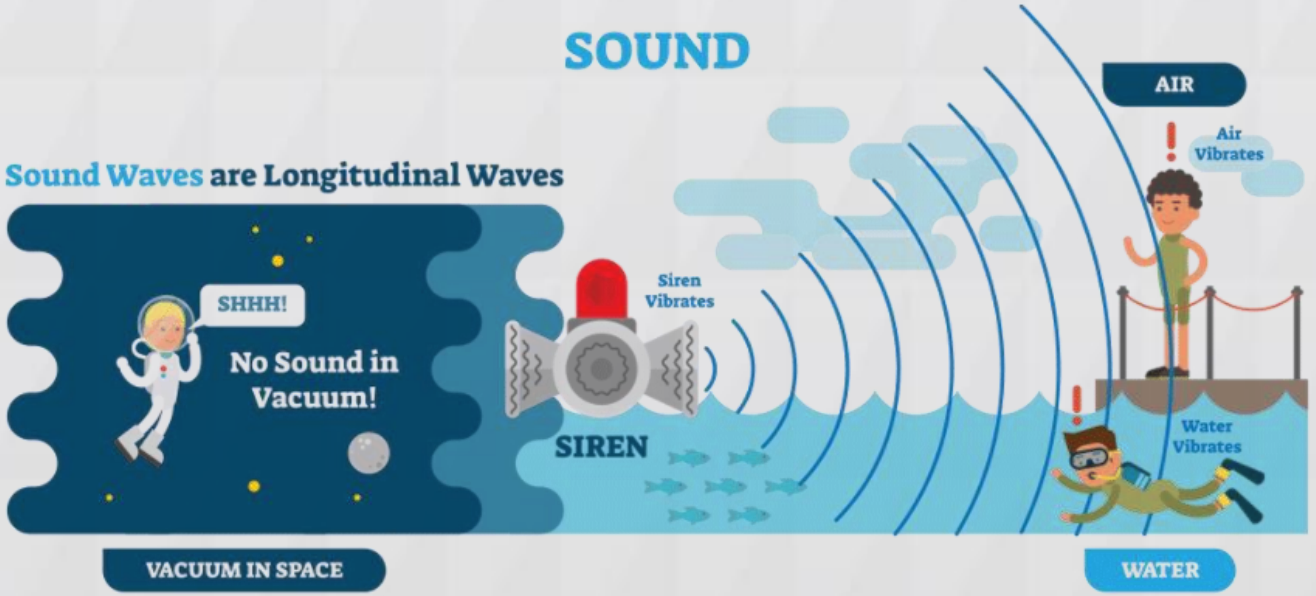






Undervannsakustikk – hva er det?





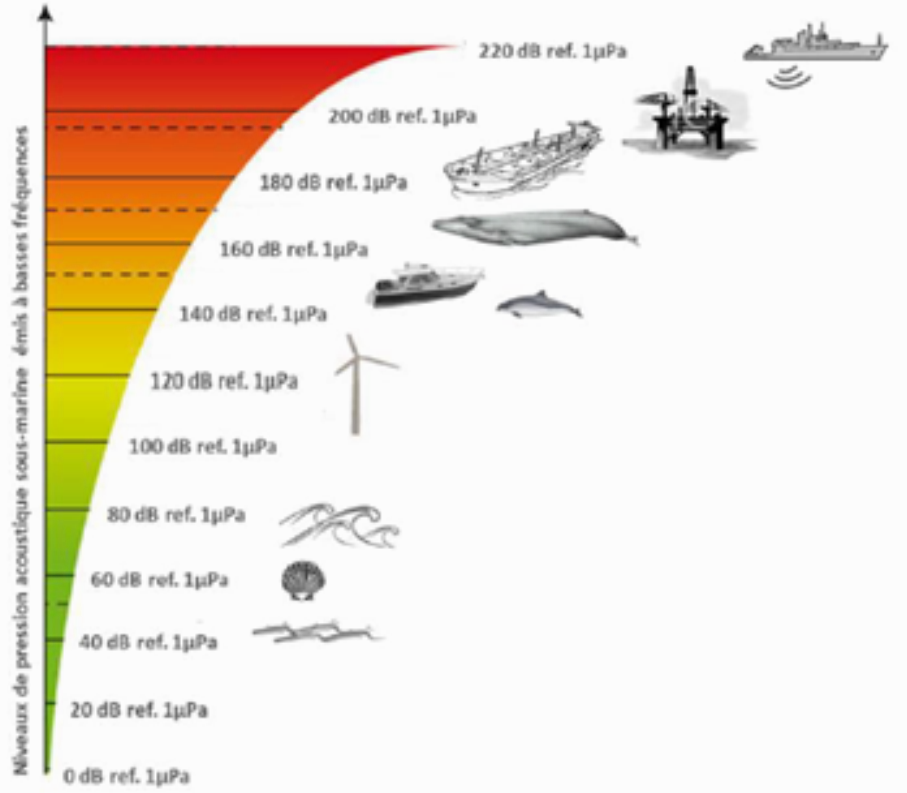
Undervannsakustikk – luftakustikk?

In air

	dB (A)	
Extremely Loud	120	Aircraft at take off
	110	Car horn
Very Loud	100	Subway
	90	Truck, motorcycle
	80	Busy crossroads
Loud	70	Noise level near a motorway
	60	Busy street through open windows
Moderate	50	Light traffic
	40	
	30	Quiet room
Faint	20	
	10	Desert
	0	Earing threshold

Source: https://soundproofempire.com/noise-level-chart-and-dba/

In water

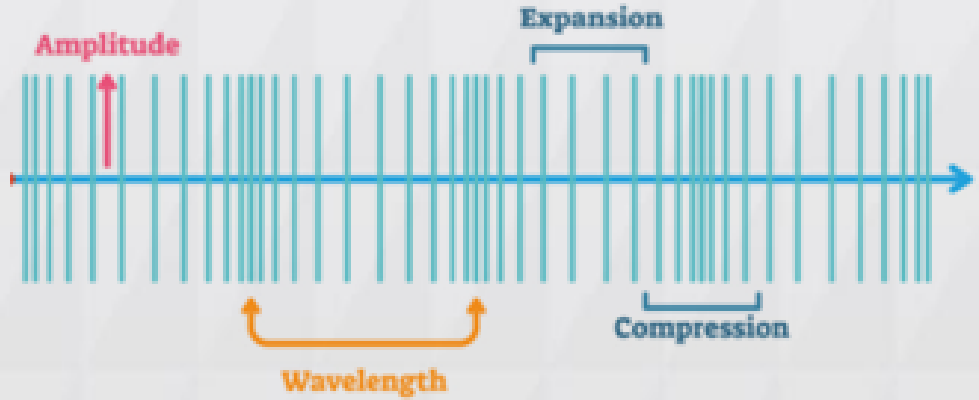


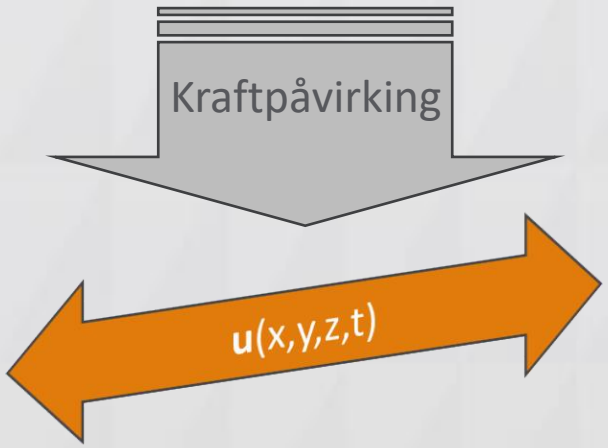
Source: Quiet-Oceans

Akustikk er trykk!

Pascal (kPa og MPa) som måleenhet.

- I eldre litteratur finnes iblant andre enheter som 1 Bar (=105 Pa), 1 mBar (= 100 Pa) eller 1 p.s.i
- Standarden innen Hydroakustikk er å bruke [dB re. 1 µPa] og årsaken er at den takler både lave og høye verdier takket være sin logaritmiske skala.
- En annen praktikalitet er at dB-enheten er naturlig uttrykt i desibel og da blir bruken av desimal-dB litt overflødig.





…men ikke bare trykk …

Partikkelbevegelse / Partikkelakselerasjon

- Trykkforskjell i en fluid gir bevegelse -> kobler til bevegelse gjennom akustisk impedans (treghet) i mediet
- Gir vektoriell informasjon
- Inneholder mye informasjon om avstand, retning og annen tilstand til mat, hot eller mulige partners.

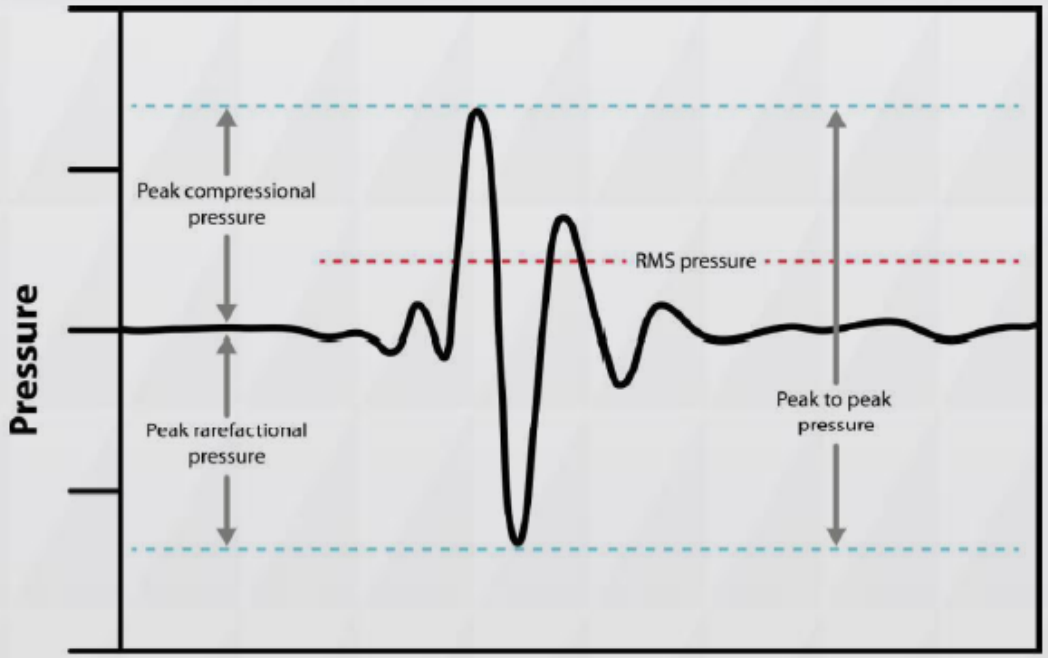
dB – de er for vanskelig ?

Impulsive lyder (sprenging, seismikk, peling)

- Sound Pressure Level SPL or SPLrms
- Peak sound pressure level (SPL peak)
- Peak to peak sound pressure level (SPL pp)
- (Single pulse Sound Exposure Level)

Kontinuerlige lyder (skipstøy, mudring, dumping)

- Sound Exposure Level (SEL over a period)
- Single Strike Sound Exposure Level (SEL ss)
- Cumulative Sound Exposure Level (CSEL)



Lydtrykk i enheten dB [desiBel = 0,1 Bel]

$$SPL = 10\ \log_{10}\left[\frac{\hat{p}^2}{p_0^2}\right] = 20\ \log_{10}\left[\frac{\hat{p}}{p_0}\right]$$

Hydroakustikk p_0 = 1 µPa
Luftakustikk p_0 = 20 µPa
(menneskelige hørselsterskelen ved 1000 Hz)

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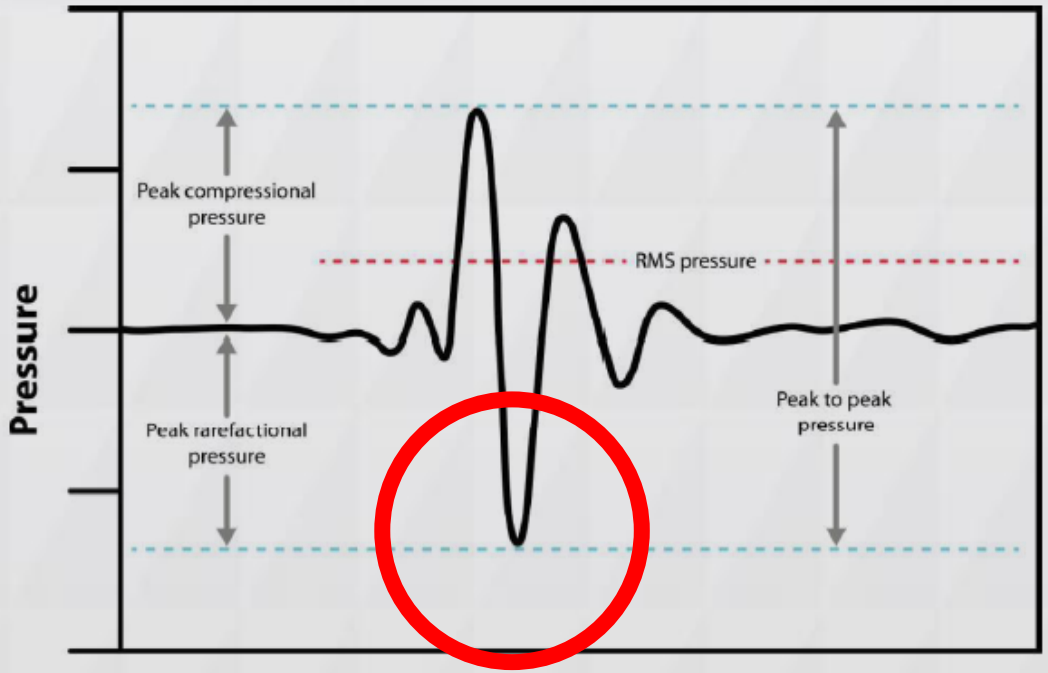

dB re. 1 µPa

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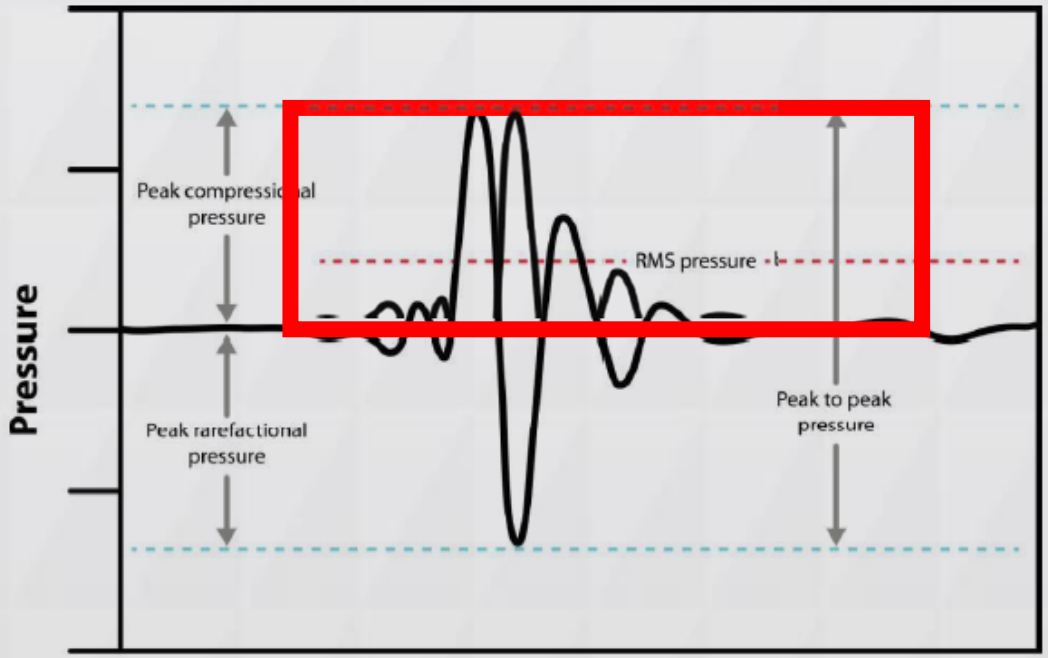
$$SEL = 10 \log_{10} \left(\int \frac{p(t)^2}{p_{ref}^2} dt \right)$$

dB re. 1 µPa^{2}s



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dB – de er ikke for vanskelig !

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dB re. 1 µPa

Kontinuerlige lyder (skipstøy, mudring, dumping)
Sound Exposure Level (SEL over a period)
Single Strike Sound Exposure Level (SEL ss)
Cumulative Sound Exposure Level (CSEL)

dB re. 1 $\mu Pa^2 s$

Støy=?

Undervannsstøy er et ekte lydkor hvor lyder av forskjellig natur og opprinnelse blandes sammen:

- Naturlig støy eller geofoni er støy fra sprekker i jorden, bevegelse av marine sedimenter, vær og vind, brytende bølger, nedbør, osv.
- Biologisk støy eller biofoni er støy av biologisk opprinnelse generert av marin fauna.
- Antropogen støy, eller antropofoni, er den menneskeskapte støyen som skapes av maritime aktiviteter, eks. skipsfart, vibrasjoner fra bil, tog og bane, osv …

Figure 10: Graduation of biological risks according to the distance from the source (s) of anthropogenic noise

Risikosoner

- **Skadesone/Sjokkbølgetrauma (220-260 dB)** prinsipp «Nærfeltsonen/dødelighetssonen».
- **Sone for nedsatt hørsel (180-220 dB)** analogt med «Overgangssonen/Skadesonen,

  PTS = Permanent Threshold Shift = Permanent Terskelskift

  TTS = Temporaray Threshold Shift = Temporær Terskelskift
- **Sone for endret adferd (140-200 dB) ,** omfatte både «Overgangssone» og «Fjernsonen». Undervannseksplosjoner kan forårsake en rekke atferdsreaksjoner hos dyr.
- **Maskeringssone (100-140 dB)** er i «Fjernsonen
- **Hørbarhetssonen (< 100 dB),** er en risikofri sone,

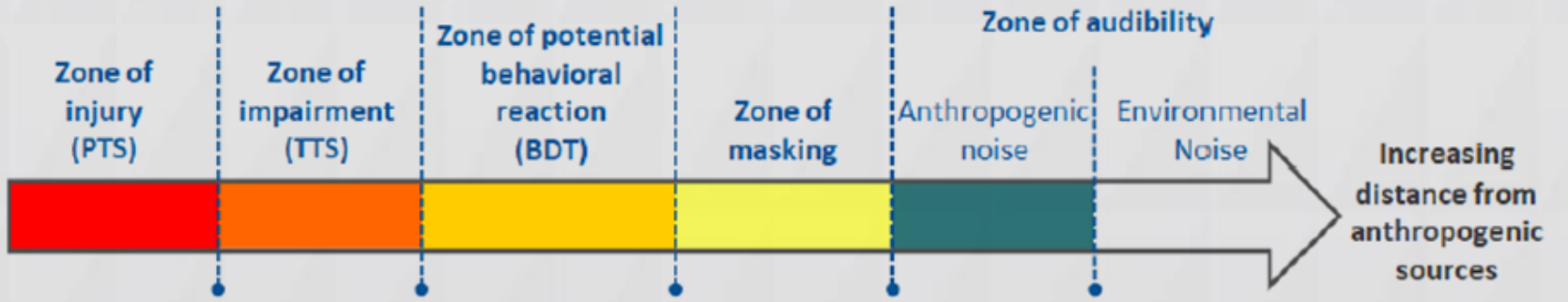


Figure 10: Graduation of biological risks according to the distance from the source (s) of anthropogenic noise

Forplanting

Lydforplanting

- Batymetri (bunntopografi)
- Havbunnens natur, eks. hard eller myk bunn og tykkelse av sediment
- Oseanografiske forhold, som temperatur, saltinnhold, strømmer og tidevann
- Værforhold - vind og bølger

Andre parametere vil også påvirke forplantning og støynivå, men i mindre grad:

- **Små vanndyp kan gi en kumulativ effekt** av batymetri og tidevann: Dette forårsaker et relativt høyere energitap gjennom hyppigere interaksjoner med overflate og bunn.
- **Grunne forhold** kan gi mer bidrag til omgivende støy siden dette fremmer brytende bølger
- Havbunnsediment laget av løse og fine korn (silt absorberer for eksempel akustiske bølger mer enn grus) eller leire, gir et relativt sett høyere energitap enn et sediment som er tettere. En bunn av **reint fjell** gir sterke refleksjoner hvilket resulterer i en lang etterklang og lange fortplantingsavstander.

Aktiviteter i strandsonen

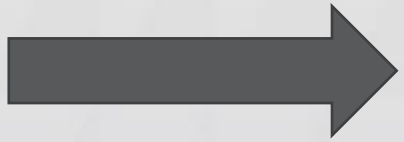
Aktivitet		Typiske nivåer
Sprenging i borede hull	SPL	> 220 dB
Peling	SEL	190-230 dB
Boring	SEL	130-150 dB
Dumping	SEL	170-200 dB
Mudring	SEL	170-190 dB
Skipstrafikk	SEL	160-200 dB

Rammer & Regulering

- Stadsforvalteren: Statsforvalterens slått fast i vedtaksbrev 19.05.2020 [9], hvor det antas at «marine arter i havet trolig kan tåle spisstrykk opp til 100 kPa (220 dB) uten å påføre langvarige skader».

- 4 kPa: Fauske, A.: Undervannssprengning i nærheten av Oppdrettsanlegg – begrensninger og krav til gjennomføring, Orica Mining Services, Fjellsprengningsteknikk, bergmekanikk/geoteknikk 2007

- HI, FFI, EU, etc etc



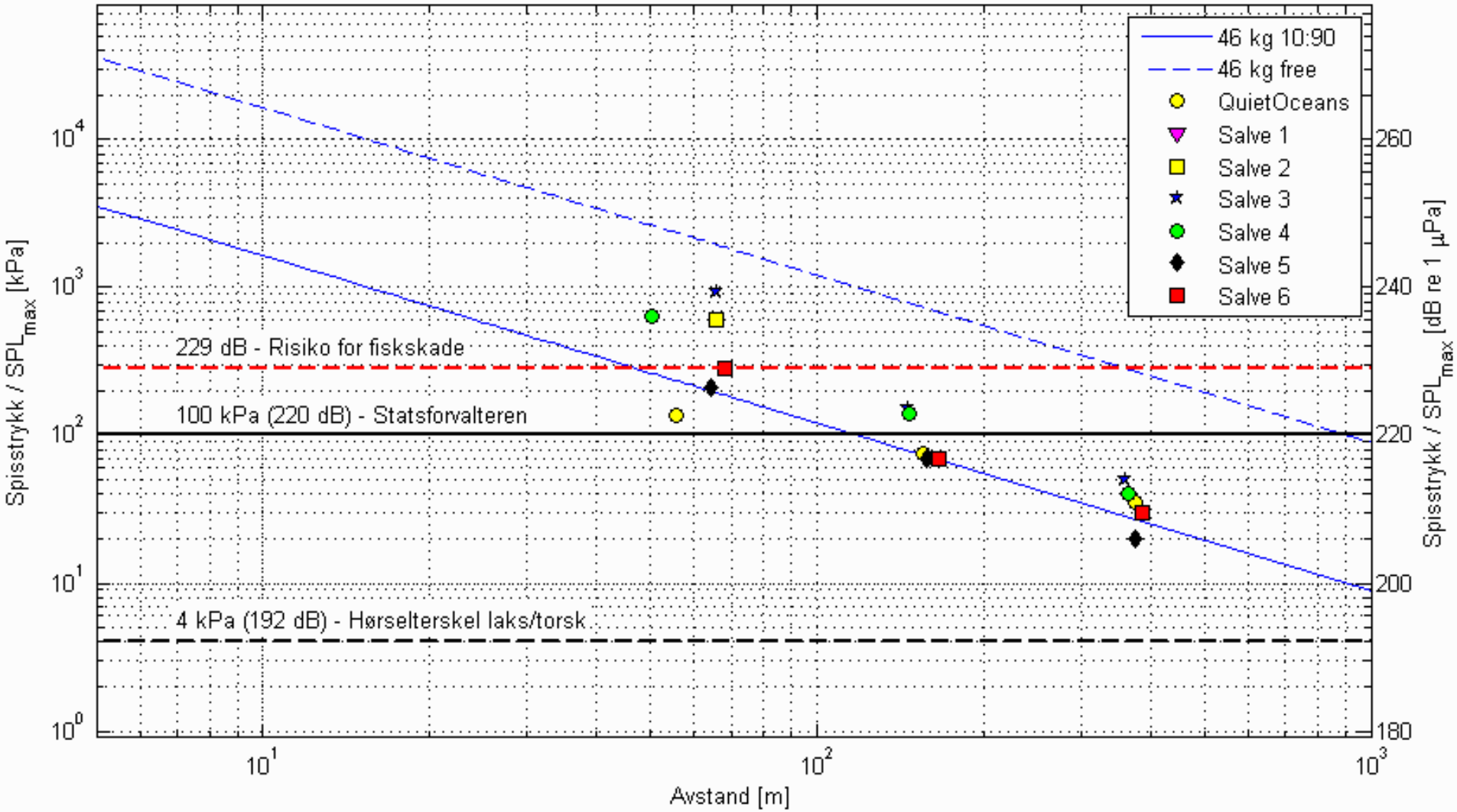
Cetacean and pinniped

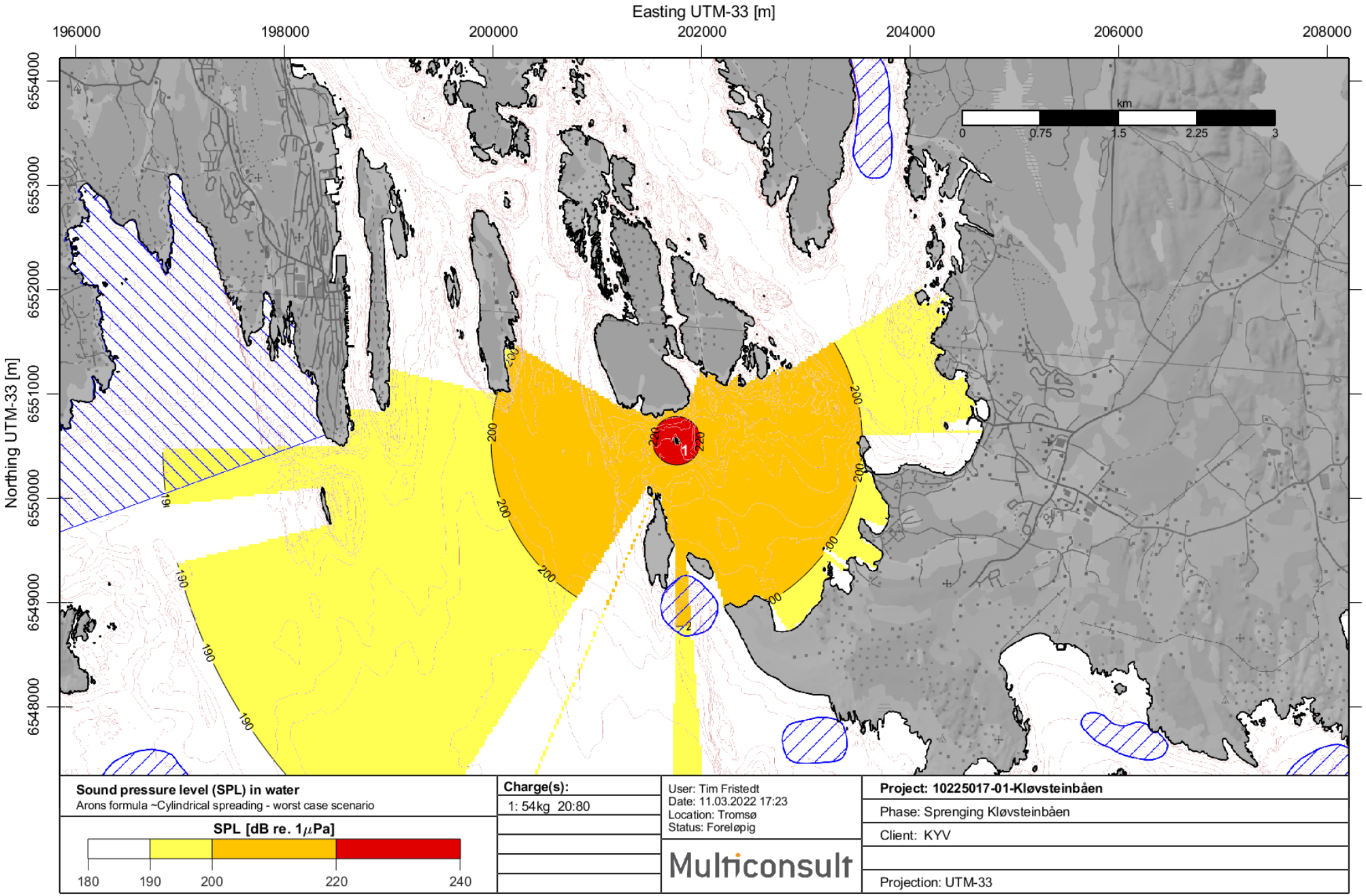
Species	Frequency range (kHz)	Impulse noise			
		Unit dB réf. 1µPa²s		Unit dB réf. 1µPa	
		Weighted // 24h		Unweighted	
		SEL	SEL	SPL 0-peak	SPL 0-peak
		TTS	PTS	TTS	PTS
Low frequency (LF)	0.2-19	168	183	213	219
Mid frequency (MF)	8.8-110	170	185	224	230
High frequency (HF)	12-140	140	155	196	202
Phocids (true seals) (PW)	1.9-30	170	185	212	218

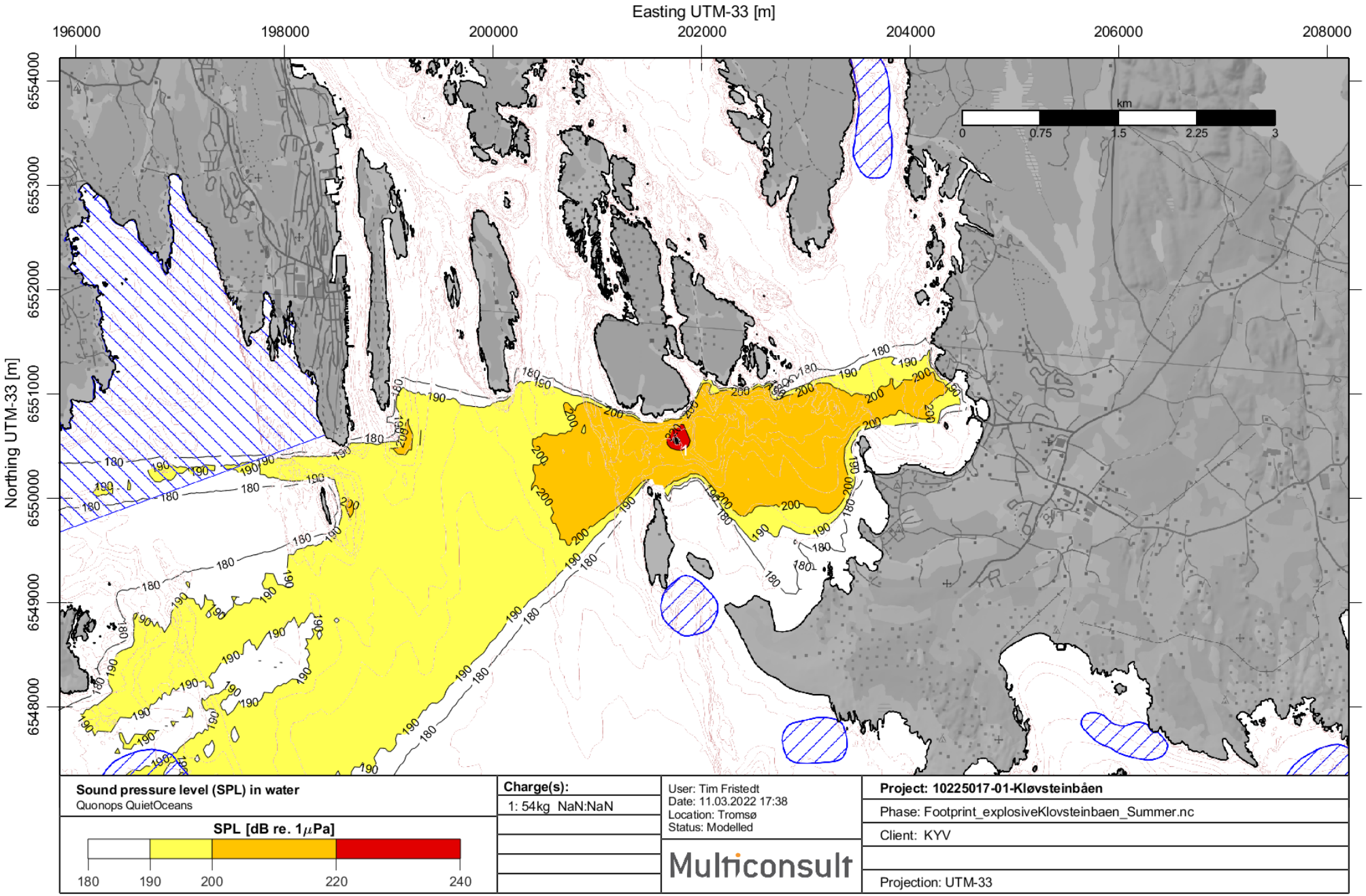
Fish and invertebrates

Species	Frequency range (kHz)	Impulse noise SPI 0_peak Unit dB réf. 1µPa		
		Behavior reaction	TTS	Mortality
Fish without swim bladder	< 1 kHz	NC	NC	229-234 dB 0-peak
Fish with swim bladder without sensitive	< 4 kHz	NC	NC	229-234 dB 0-peak
Fish with swim bladder with sensitive	< 1 kHz	NC	NC	229-234 dB 0-peak
Eggs	< 1 kHz	NC	NC	13mm.s peak velocity
Invertebrate	NC	NC	NC	NC

Eksempel fra Kløvsteinbåen




Easting UTM-33 [m]
196000
198000
200000
202000
204000
206000
208000
Northing UTM-33 [m]
6554000
6553000
6552000
6551000
6550000
6549000
6548000
km
0
0.75
1.5
2.25
3
Sound pressure level (SPL) in water
Arons formula ~Cylindrical spreading - worst case scenario
SPL [dB re. 1μPa]
180
190
200
220
240
Charge(s):
1: 54kg 20:80
User: Tim Fristedt
Date: 11.03.2022 17:23
Location: Tromsø
Status: Foreløpig
Multiconsult
Project: 10225017-01-Kløvsteinbåen
Phase: Sprenging Kløvsteinbåen
Client: KYV
Projection: UTM-33


Easting UTM-33 [m]
196000
198000
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204000
206000
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6554000
6553000
6552000
6551000
6550000
6549000
6548000
km
0
0.75
1.5
2.25
3
Sound pressure level (SPL) in water
Quonops QuietOceans
SPL [dB re. 1μPa]
180
190
200
220
240
Charge(s):
1: 54kg NaN:NaN
User: Tim Fristedt
Date: 11.03.2022 17:38
Location: Tromsø
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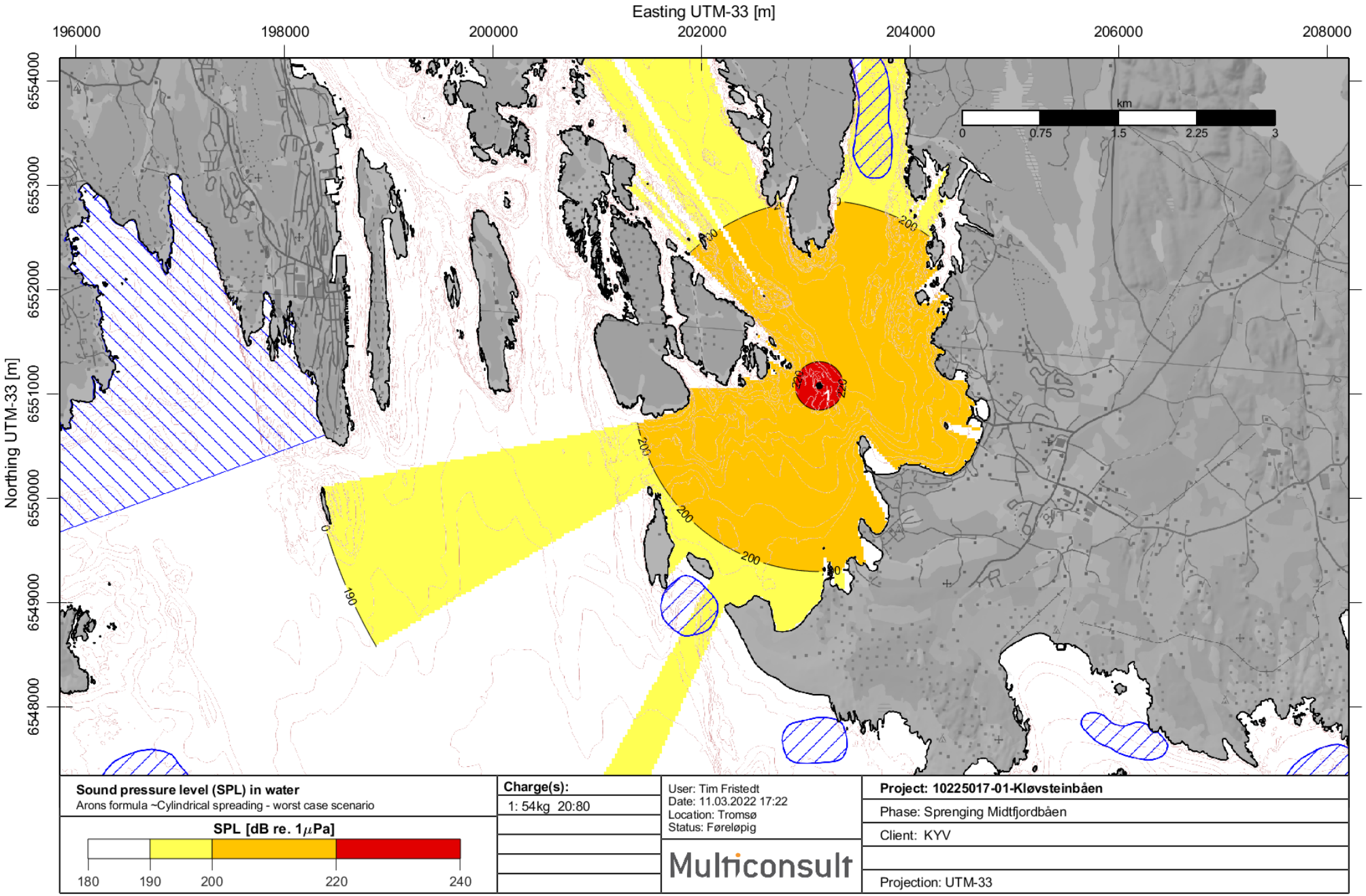
Phase: Footprint_explosiveKlovsteinbaen_Summer.nc
Client: KYV
Projection: UTM-33


Easting UTM-33 [m]
196000
198000
200000
202000
204000
206000
208000
Northing UTM-33 [m]
6554000
6553000
6552000
6551000
6550000
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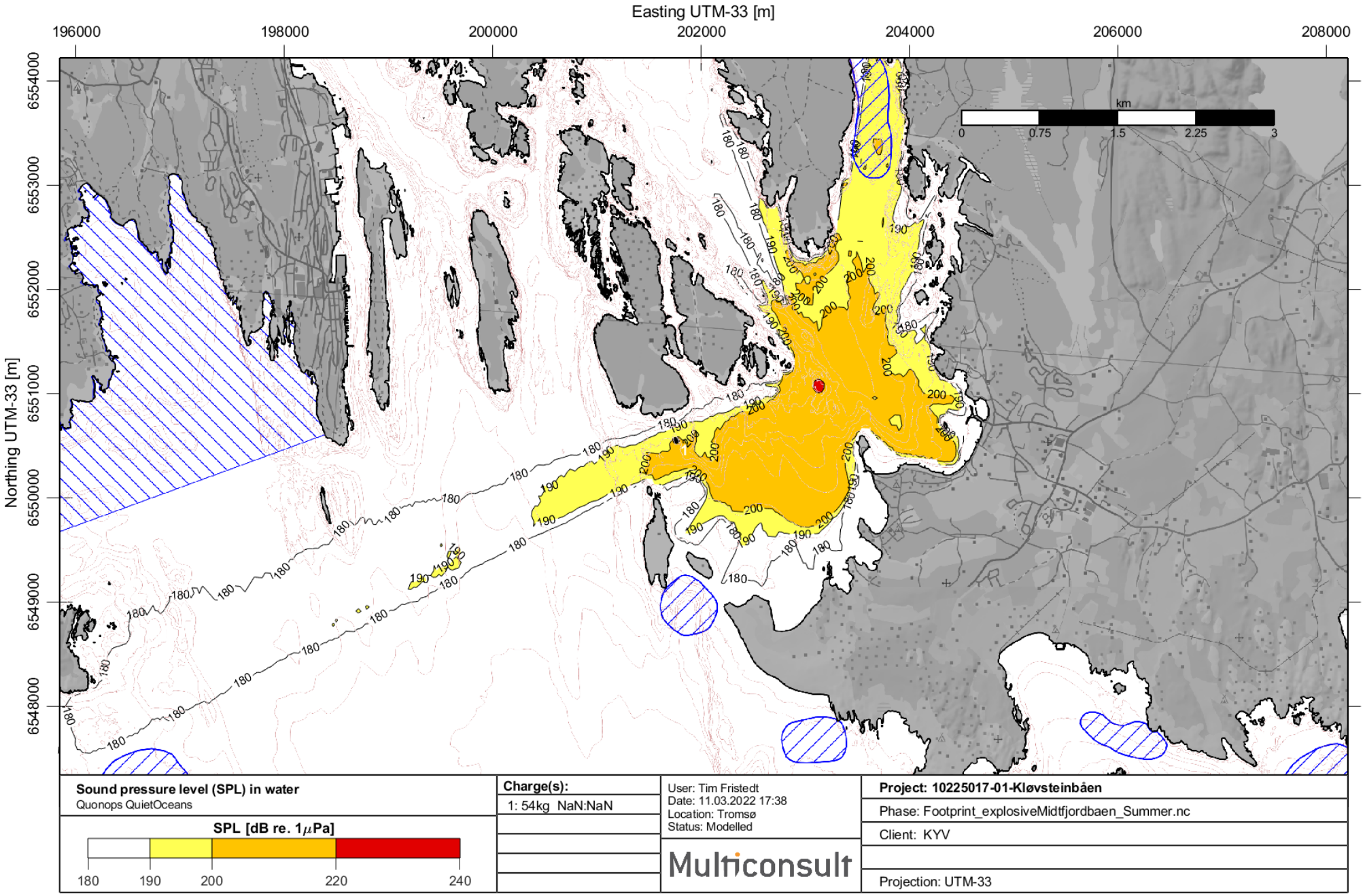
6548000
km
0
0.75
1.5
2.25
3
200
190
Sound pressure level (SPL) in water
Arons formula ~Cylindrical spreading - worst case scenario
SPL [dB re. 1μPa]
180
190
200
220
240
Charge(s):
1: 54kg 20:80
User: Tim Fristedt
Date: 11.03.2022 17:22
Location: Tromsø
Status: Føreløpig
Multiconsult
Project: 10225017-01-Kløvsteinbåen
Phase: Sprenging Midtfjordbåen
Client: KYV
Projection: UTM-33


Easting UTM-33 [m]
196000
198000
200000
202000
204000
206000
208000
Northing UTM-33 [m]
6554000
6553000
6552000
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6549000
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km
0
0.75
1.5
2.25
3
Sound pressure level (SPL) in water
Quonops QuietOceans
SPL [dB re. 1μPa]
180
190
200
220
240
Charge(s):
1: 54kg NaN:NaN
User: Tim Fristedt
Date: 11.03.2022 17:38
Location: Tromsø
Status: Modelled
Multiconsult
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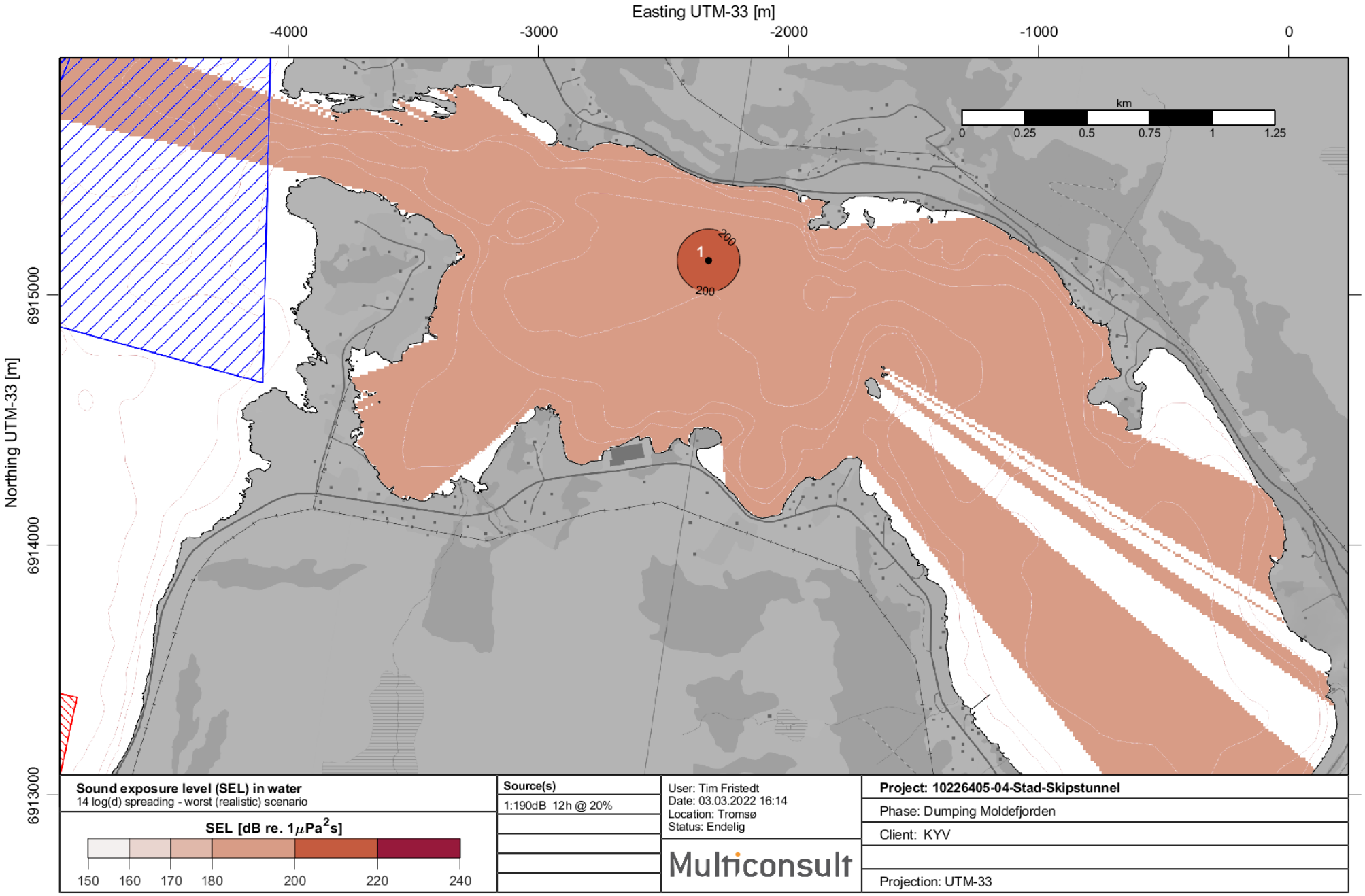
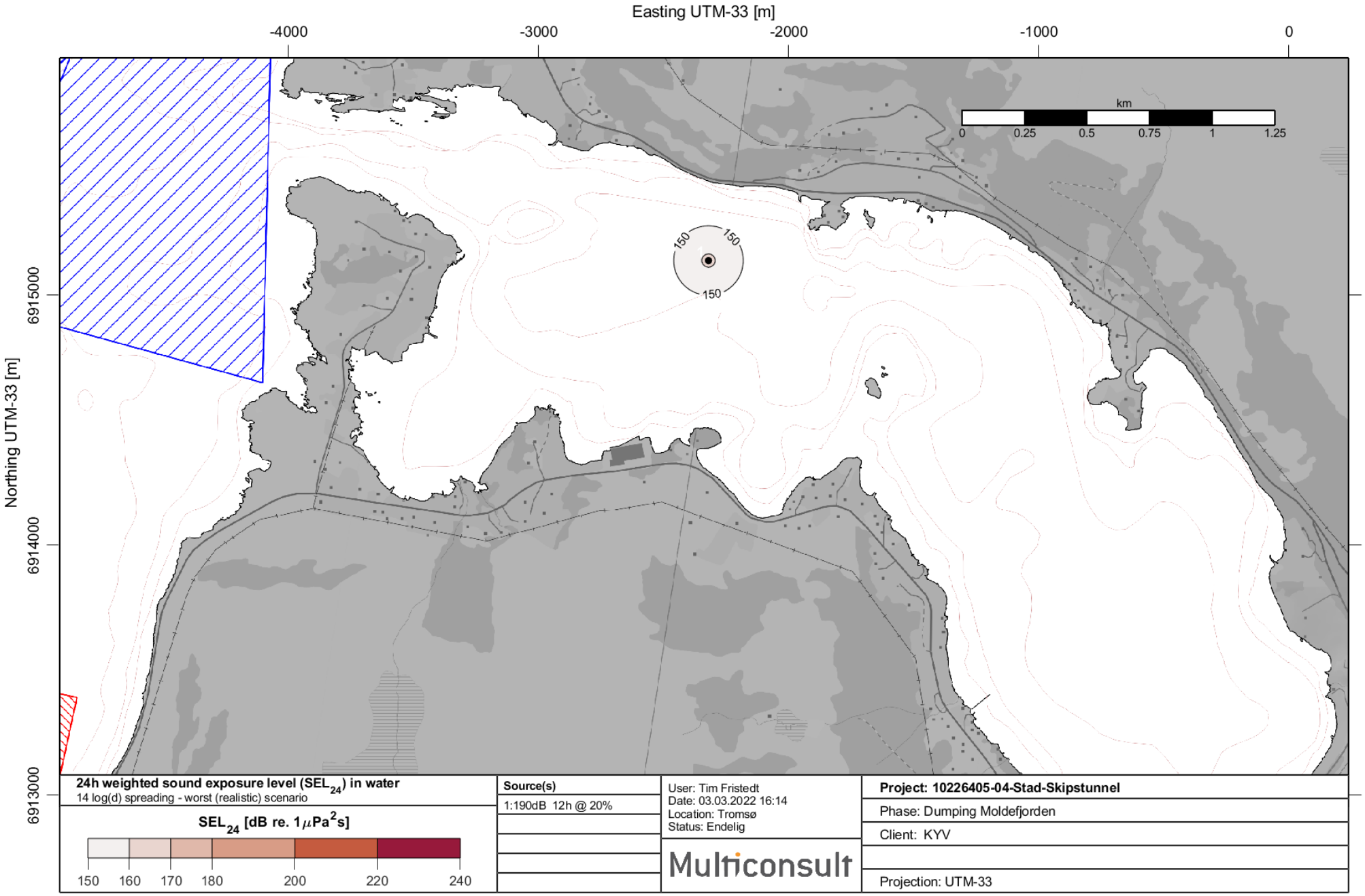
Phase: Footprint_explosiveMidtfjordbaen_Summer.nc
Client: KYV
Projection: UTM-33


Easting UTM-33 [m]
-4000
-3000
-2000
-1000
0
Northing UTM-33 [m]
6915000
6914000
6913000
km
0
0.25
0.5
0.75
1
1.25
200
1
200
Sound exposure level (SEL) in water
14 log(d) spreading - worst (realistic) scenario
SEL [dB re. 1μPa²s]
150
160
170
180
200
220
240
Source(s)
1:190dB 12h @ 20%
User: Tim Fristedt
Date: 03.03.2022 16:14
Location: Tromsø
Status: Endelig
Multiconsult
Project: 10226405-04-Stad-Skipstunnel
Phase: Dumping Moldefjorden
Client: KYV
Projection: UTM-33


Easting UTM-33 [m]
-4000
-3000
-2000
-1000
0
Northing UTM-33 [m]
6915000
6914000
6913000
km
0
0.25
0.5
0.75
1
1.25
150
150
150
24h weighted sound exposure level (SEL24) in water
14 log(d) spreading - worst (realistic) scenario
SEL24 [dB re. 1μPa2s]
150
160
170
180
200
220
240
Source(s)
1:190dB 12h @ 20%
User: Tim Fristedt
Date: 03.03.2022 16:14
Location: Tromsø
Status: Endelig
Multiconsult
Project: 10226405-04-Stad-Skipstunnel
Phase: Dumping Moldefjorden
Client: KYV
Projection: UTM-33

Hva er viktig….?

- Sprenging: Ladningsvekt per interval
- Sprenging: Avstander – er det oppdrettanlegg/gytefelt nært?
- Lag konservative avstander gjennom at anta fjell i bunn.
- Heller 20:80 enn 10:90

- Aktiviteter: Eksponering
- Aktiviteter: Peling kan være mye utfordende
- Aktiviteter: Tid – er døgnsmiddel relevant?

- Det er ikke bare trykkbølge og annen aktivitet som er en utfordring
  - Rystelse
  - Partikkelrørelse
  - Tid på året - gytefelt
  - It is more than meets the eye …

TAKK

- Spørsmål?

Table 1: Natural and human-made source noise comparisons (source https://fas.org/man/dod-101/sys/ship/acoustics.htm)

Noisy Source	Maximum Source Level dB ref 1µPa@1m	Remarks	Reference
Undersea Earthquake	272	Magnitude 4.0 on Richter scale (energy integrated over 50 Hz bandwidth)	Wenz, 1962.
Seafloor Volcano Eruption	255	Massive steam explosions	Deitz and Sheehy, 1954; Kibblewhite, 1965; Northrop, 1974; Shepard and Robson, 1967; Nishimura, NRL-DC, pers. comm., 1995.
Airgun Array (Seismic)	255	Compressed air discharged into piston assembly	Johnston and Cain, 1981; Barger and Hamblen, 1980; Kramer et al., 1968.
Lightning Strike on Water Surface	250	Random events during storms at sea	Hill, 1985; Nishimura, NRL-DC, pers. com., 1995.
Seismic Exploration Devices	212-230	Includes vibroseis, sparker, gas sleeve, exploder, water gun and boomer seismic profiling methods.	Johnston and Cain, 1981; Holiday et al., 1984.
Container Ship	198	Length 274 meters; Speed 23 knots	Buck and Chalfant, 1972; Ross, 1976; Brown, 1982b; Thiele and Ødegaard, 1983.
Supertanker	190	Length 340 meters; Speed 20 knots	Buck and Chalfant, 1972; Ross, 1976; Brown, 1982b; Thiele and Ødegaard, 1983.
Blue Whale	190 (avg. 145-172)	Vocalizations: Low frequency moans	Cummings and Thompson, 1971a; Edds, 1982.
Fin Whale	188 (avg. 155-186)	Vocalizations: Pulses, moans	Watkins, 1981b; Cummings et al., 1986; Edds, 1988.
Offshore Drill Rig	185	Motor Vessel KULLUK; oil/gas exploration	Greene, 1987b.
Offshore Dredge	185	Motor Vessel AQUARIUS	Greene, 1987b.
Humpback Whale	180 (avg. 175-180)	Fluke and flipper slaps	Thompson et al., 1986.
Bowhead Whale	180 (avg. 152-180)	Vocalizations: Songs	Cummings and Holiday, 1987.
Right Whale	175 (avg. 172-175)	Vocalizations: Pulsive signal	Cummings et al., 1972; Clark 1983.
Gray Whale	175 (avg. 175)	Vocalizations: moans	Cummings et al., 1968; Fish et al., 1974; Swartz and Cummings, 1978.
Open Ocean Ambient Noise	74-100 (71-97 dB in deep sound channel)	Estimate for offshore central Calif. sea state 3-5; expected to be higher (= or > 120 dB) when vessels present.	Urick, 1983, 1986.