FEIRA INTERNACIONAL DE TECNOLOGIA, ENGENHARIA, APLICAÇÕES, EQUIPAMENTOS, LOGÍSTICA, PRODUTOS E SERVIÇOS PARA MERCADOS CONSUMIDORES DE EXPLOSIVOS.

EXPLO TECH 2018

16 e 17 de Outubro de 2018, São Paolo, Brazil

International fair for technology, engineering, applications logistics, products and services for explosive consumers markets

Underwater blasting of dioritic rock in challenging environment. Port of “Degrad des cannes” Cayenne, French Guiana in 2015

executed by the DUTCH DREDGING – NITREX JV

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Roberto Folchi, mining engineer
NITREX, Italy

Introduction

Background of the the underwater excavation project

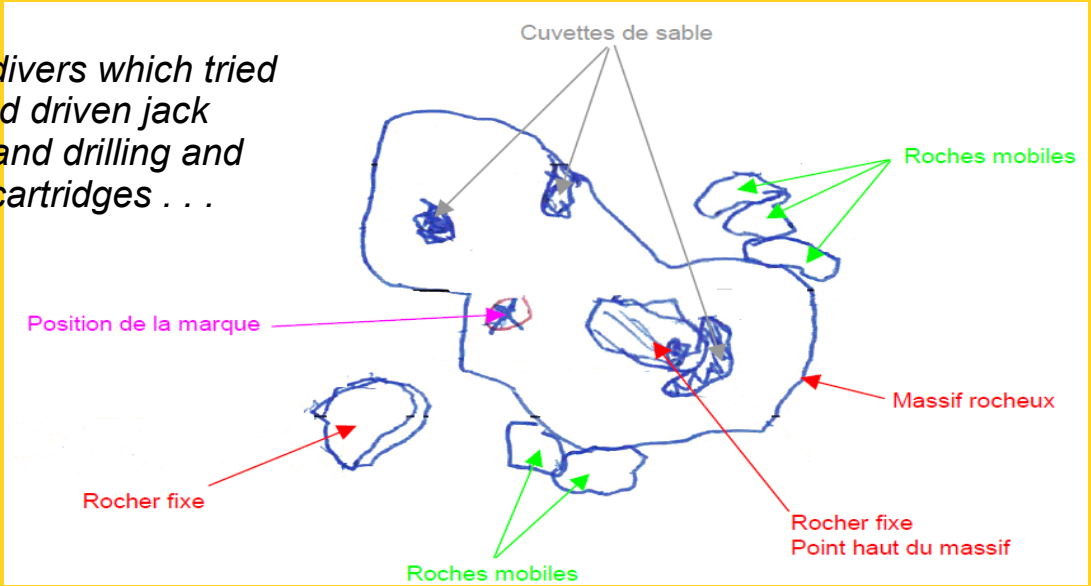
- To sustain the industrial development of the city of Cayenne the authority "Grand Port Maritime" needed to double traffic in its "*Degrad des cannes*" port.
- Consequently docking of larger container carrier ships was requested and, for this, ...
- … water clearance had to be increased to -8 m from "*cote marine*" (the lowest lever of the water table) for port and access channel.

Large container carrier ship docked, at underwater blasting work completion.

Preliminary attempts to excavate the rock without explosives

- Due to preconception for the use of explosives (considered d a n g e r o u s in a port also including an oil terminal) several attempts to remove the rock followed each other:
  - handheld jackhammers (?!?)
  - large hydraulic breakers on excavator on a barge
  - “low explosives” cartridges in boreholes (pneumatic) hand drilled by divers (?!?)
- After 2 years of attempts, each of them unsuccessful, it become evident that high explosives were the only possible way.

Original drawings from the divers which tried to excavate the rock by hand driven jack hammer and after that by hand drilling and blasting with black powder cartridges . . .



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Environmental and work context

Location (large scale)

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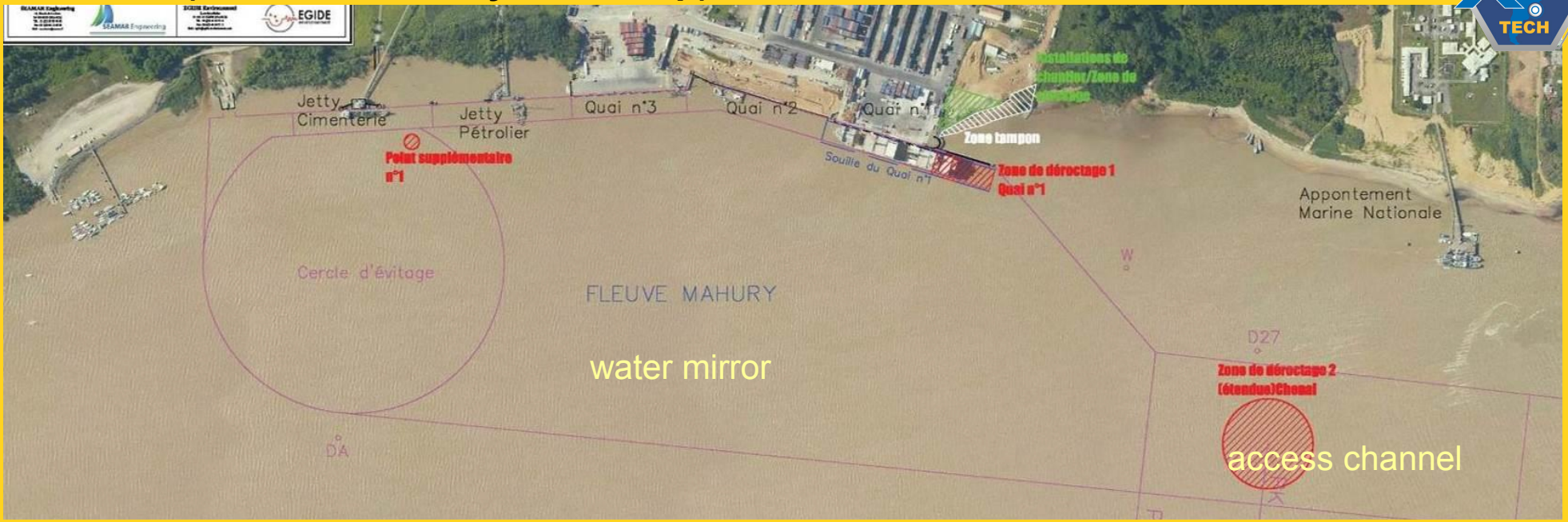
Location

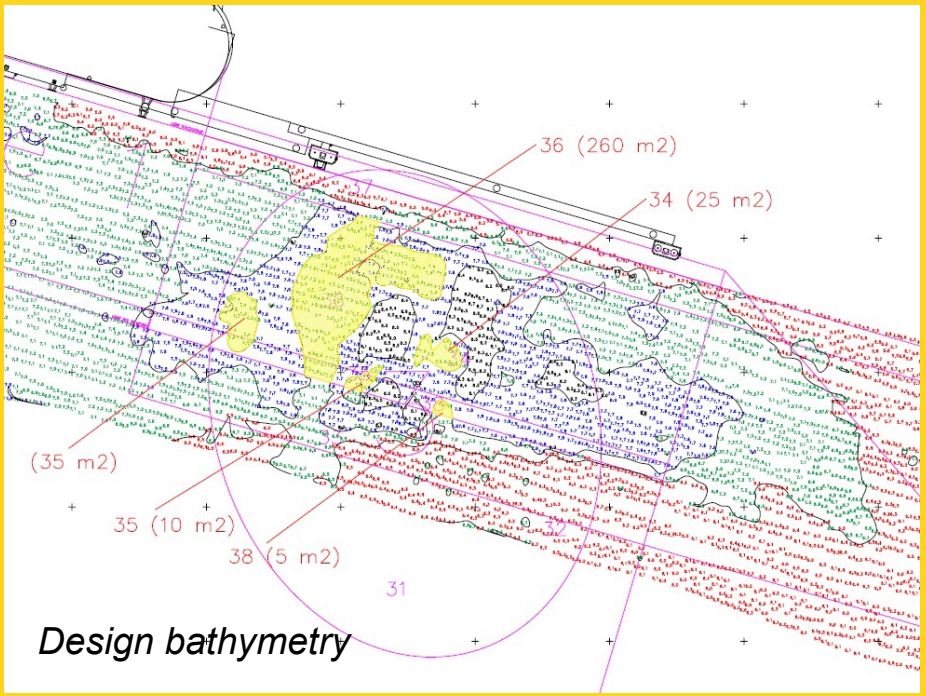

The city of Cayenne
Remire-Montjoly
Atlantic Ocean
Route de Remire RD2
D3
N4
D2
D2001
N3
D1
the underwater blasting working site
River MAHURY
Google Earth
Image © 2018 DigitalGlobe
© 2018 Google
N
4 km

Location (details and bathymetic map)



Bathymetry

- No single-beam or muti-beam sonar, any energising frequency and intensity, could provide accurate enough results (accuracy in the range of one meter: u s e l e s s !).
- Output had to be adjusted by means of extra mechanical survey with pattern in the range of meters (low accuracy).



Design bathymetry

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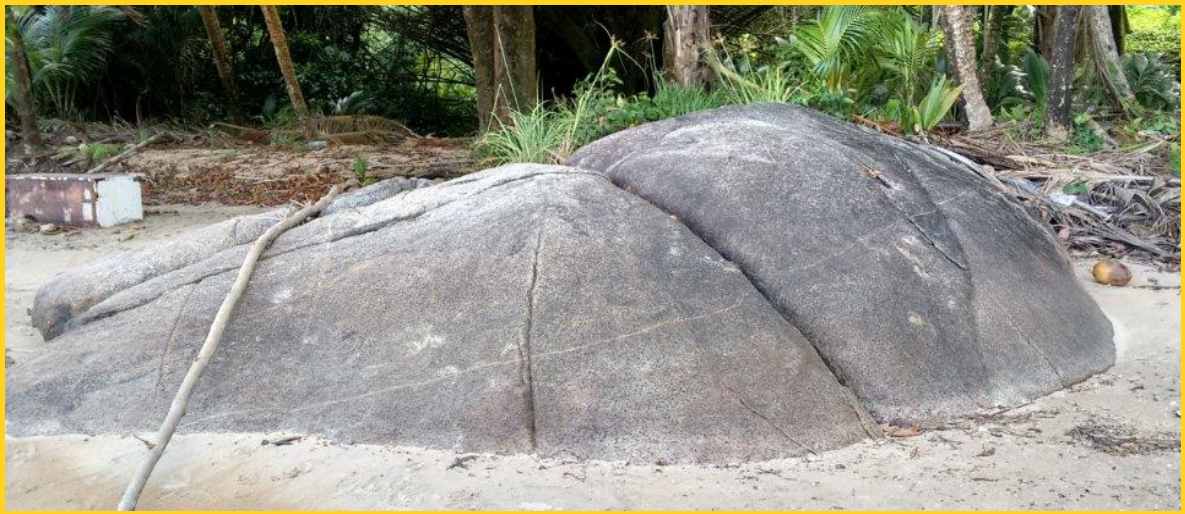
Overburden

- 3,000 m³ of overburden removed mechanically to expose the rock-mass-bed
- clay and silty dense mud layer, up to 2 meters thick, locally over-consolidated, including rounded rock boulders in the range of some meters
- non stationary overburden layer: drag of 1 m per day toward the sea, by bottom current

Rock mass to be fragmented at river bed

(port water mirror and its access channel)

- Medium to fine grained Dolerite rock mass.
- Tectonic joints closed and well-tight, intersected at 90°, sizing prismatic volumes ½ m to 2 m.
- Cooling up shrinkage joints spherical, seizing volumes in the range of 4 to 8 m.
- Density 2.7 t/m³, Uniaxial Compression Strength 300 MPa.
- Large rounded and flat boulders locally standing alone above the solid rock mass, detached by decimetric layer of over-consolidated mud (this causing frequent borehole displacement and loss or, even worse, drilling rod entrapment.
- 1,500 m³ of rock to be removed, with 2.500 m³ being blasted (extra quantity for redundancy)



Outcrop of the Doleritic rock mass to be blasted.

Outcrop of the silty and clay Overburden, overconsolidated.

Water

Density

- Water density exceeded the emulsion explosives density (> 1,2 kg/dm³) so explosives charges were floating (impossible to keep them into the hole, also because extra vertical force due to uplifting for detonators tube being drag by the current).
- To load the holes an explosives charge assembly with explosives cartridges into PVC pipe, including ballast, was foreseen.

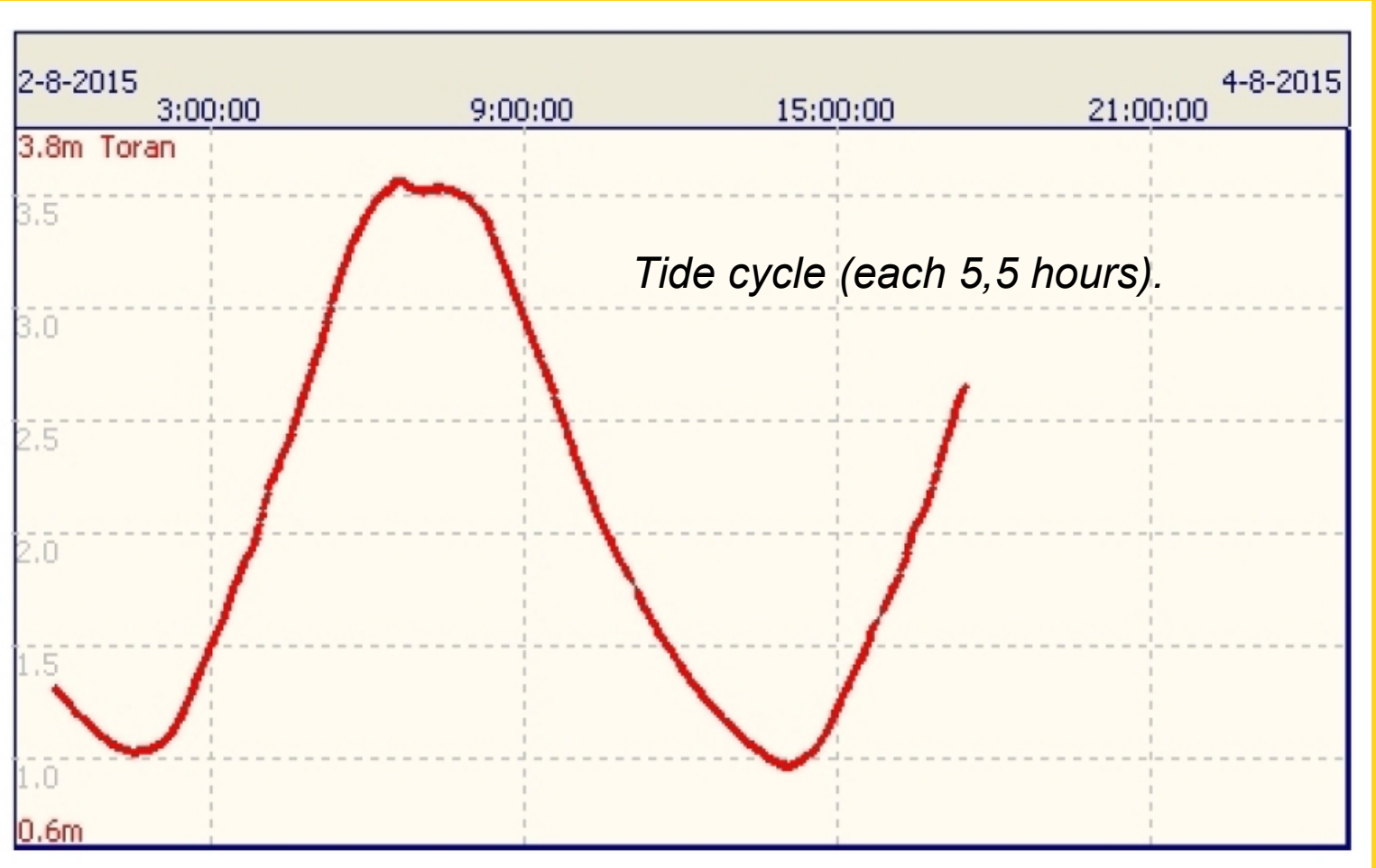
Visibility

- No visibility underwater: no underwater camera could be used.

Tide

- Tide cycle lasted 5,5 hours, for a maximum excursion of about 2,5 meters.

- Above water current direction changed during the the tide excursion, heading to the sea at high tide (river delivering water to the sea) and backwards at low tide (sea delivering water to the river), with low water always heading to the sea.



Stream speed

- Water speed up to 3 m/s (10,8 km/h) in the upper layers.

- Water speed was a concern for integrity of the detonator shock tubes from down the hole, especially for the risk of them to be cut by floating wooden logs,

. . .

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. . .

but also for the strong drag on the shock tube itself, adding an upward force to one due to cartridges flotation, this forcing to a solution to fix charges into the hole for hours.

Marine mammals and tortoise to be safeguarded

- Big concern was posed by the Owner on the safeguard of river dauphins and tortoise which happened to romp about the blasting area.
- Dolphine, turtles and other fish had a safe overpressure in water threshold of 209 dBL (1µPa) [Tender document C.C.T.P.] - extremely low
- Safety distance was set at 20 meters.

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- To keep dauphins and tortoise outside the foreseen blasting safety area, a team of marine biologist was put together. They gave the green light for each blast, before that of the Coast Guard and of the Harbourmaster in coordination with Port Authority and with the Engineer (. . . with risk of misfires because of too long waiting time with firing line in water at 3 m/s current speed).
- The team roamed the area scanning it both visually and with a sonar specially fitted for the purpose of detecting dauphins.

Working hours and interference with port traffic

- Working hours from 08:00 to 17:00, set by port Authority to minimize interference with port traffic (adjustment in coordination with the port Authority but with little to no flexibility).
- Daily operations schedule was set for each of the 2 wagon drill, with reference to interfering port traffic and tides, with the purpose to minimize execution at maximum current speed.

45			46			47			48			49			50			51			52		
THU 3	C24 new + C25a		FRI 4	C25 (chenal, sect 51)		SAT 5	pas de tir		SUN 6	pas de tir		MON 7	C26 (chenal, sect 51)		TUE 8	C27 (chenal, sect 51)		WED 9	C23		THU 10	C22	
	HOLES	3		HOLES	12		HOLES	0		HOLES	0		HOLES	12		HOLES	10		HOLES	6		HOLES	6
	#1	#2		#1	#2		#1	#2		#1	#2		#1	#2		#1	#2		#1	#2		#1	#2
	2	1		6	6		0	0		0	0		6	6		5	5		3	3		4	2
5.00			5.00	EX		5.00	EX		5.00	EX		5.00			5.00	NAVIRE	Marfret + vega	5.00			5.00		
5.30			5.30			5.30			5.30			5.30			5.30			5.30			5.30		
6.00			6.00			6.00			6.00			6.00			6.00			6.00			6.00		
6.30			6.30	1	1	6.30			6.30	ACHEVEMENT DU MARINAGE SUR LA ZONE 1		6.30			6.30			6.30			6.30		
7.00			7.00			7.00			7.00			7.00	EX		7.00			7.00			7.00		
7.30			7.30	1	1	7.30			7.30			7.30			7.30			7.30			7.30		
8.00	NAVIRE		8.00			8.00			8.00			8.00	1	1	8.00	EX		8.00			8.00		
8.30			8.30	1	1	8.30			8.30	LEVE BATHYMETRIQUE (CONTROLE INTERIEUR) SUR LA ZONE 1		8.30			8.30			8.30	EX		8.30		
9.00			9.00			9.00			9.00			9.00	1	1	9.00	1	1	9.00			9.00	EX	
9.30			9.30	1	1	9.30			9.30			9.30			9.30			9.30	1	1	9.30		
10.00			10.00			10.00			10.00			10.00	1	1	10.00	1	1	10.00			10.00	1	1
10.30			10.30	1	1	10.30	NAVIRE	kerfons	10.30			10.30			10.30			10.30	1	1	10.30		
11.00	EX		11.00			11.00			11.00			11.00	1	1	11.00	1	1	11.00			11.00	1	1
11.30			11.30	1	1	11.30			11.30			11.30			11.30			11.30	1	1	11.30		
12.00	test	test	12.00	RIDEAU DES BULLES		12.00	DRAGAGES PREPARATOIRES ET ESSAIS PAR TIGES DE LA FOREUSE SUR LE POSTE PETROLIER		12.00			12.00	1	1	12.00	1	1	12.00			12.00	1	
12.30			12.30	TIR		12.30			12.30			12.30			12.30			12.30	RIDEAU DES BULLES		12.30		
13.00	test	test	13.00			13.00			13.00			13.00	1	1	13.00	1	1	13.00	TIR		13.00	1	
13.30			13.30	ENLEVEMENT DU RIDEAU DE BULLES		13.30			13.30	DRAGAGES PREPARATOIRES ET ESSAIS PAR TIGES DE LA FOREUSE SUR LE POSTE PETROLIER		13.30	RIDEAU DES BULLES		13.30	RIDEAU DES BULLES		13.30			13.30	RIDEAU DES BULLES	
14.00	1	1	14.00			14.00			14.00			14.00	TIR		14.00	TIR		14.00	ENLEVEMENT DU RIDEAU DE BULLES		14.00	TIR	
14.30			14.30			14.30			14.30			14.30			14.30			14.30			14.30		
15.00	1		15.00			15.00			15.00			15.00	ENLEVEMENT DU RIDEAU DE BULLES		15.00	ENLEVEMENT DU RIDEAU DE BULLES		15.00			15.00	ENLEVEMENT DU RIDEAU DE BULLES	
15.30	RIDEAU DES BULLES		15.30			15.30			15.30			15.30			15.30			15.30			15.30		
16.00	TIR		16.00			16.00			16.00			16.00			16.00			16.00			16.00		
16.30			16.30			16.30			16.30			16.30			16.30			16.30			16.30		
17.00			17.00			17.00			17.00			17.00			17.00			17.00			17.00		
17.30			17.30			17.30			17.30			17.30			17.30			17.30			17.30		
18.00	ENLEVEMENT DU RIDEAU DE BULLES SUR LE CHENAL ET SUR LA ZONE 1		18.00			18.00			18.00			18.00			18.00			18.00			18.00		
18.30			18.30			18.30			18.30			18.30			18.30			18.30			18.30		
19.00			19.00			19.00			19.00			19.00			19.00			19.00			19.00		
19.30			19.30			19.30			19.30			19.30			19.30			19.30			19.30		
20.00			20.00			20.00			20.00			20.00			20.00			20.00			20.00		
20.30	NAVIRE		20.30			20.30			20.30			20.30			20.30			20.30			20.30		
21.00			21.00			21.00			21.00			21.00			21.00			21.00			21.00		
21.30	MARINAGE C24new, C25a		21.30			21.30	NAVIRE	cayenne	21.30			21.30			21.30			21.30			21.30		
22.00			22.00			22.00			22.00			22.00			22.00			22.00			22.00		
22.30			22.30			22.30			22.30			22.30			22.30			22.30			22.30		
23.00			23.00			23.00			23.00	NAVIRE	vega zeta	23.00			23.00			23.00			23.00		

Acceptors to be safeguarded

Seismic measuring spots (MS):

1. *Pier Duc d'Albe du Quai (dock) n°1" ;*
2. *A. bulkhead Quai n° 1;*
2. *B. concrete structure on Quai n°1;*
3. *Concrete structure on "Quai n°1" at 80 m;*
4. *"Marine Nationale" pier;*
5. *Industrial building in "Marine Nationale" camp;*
6. *Steel Pier property of "Mineral company";*
7. *Steel Pier property of "Petroleum company";*
8. *Silo "Air liquide";*
9. *Concrete structure on Quai n°3.*

Measuring spots on shore

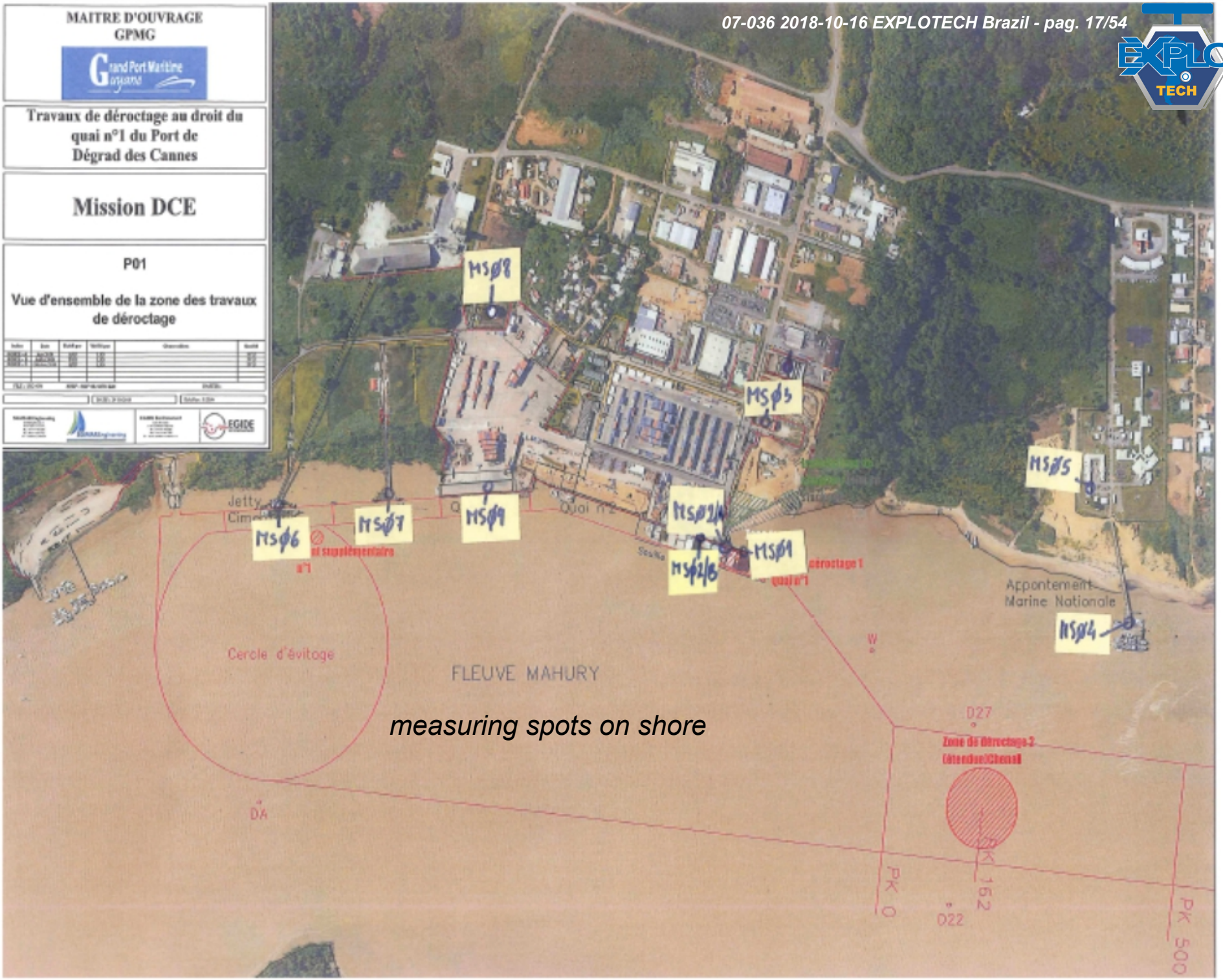

Figure 8-8: Vue en plan des points de mesure

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Owner and his Engineers

- Owner had no previous experience in similar blasting works and was not structured with own technical department.
- Owner choose a external consultants, to serve as Engineer for both tender design and execution stages, both without previous experience in similar blasting works.
- Both design and supervision were executed in lack of visit on site and of a study of the environmental constraints, first among all that of the maximum velocity of the water stream and also of the mud layer, quickly self regenerating and constantly moving.
- Lack of competence from side the Owner and his Engineer determined the biggest constraints to a safe, efficient and profitable execution of the job.
- All warnings for issues in executing were underestimated if not even situation being worsened by a stiff and contrasting attitude.
- Conflict of interest from side the Owner, with one of his directors being directly related to a competitor which had exposed interest in takeover (with 1 million Euro extra cost) encouraging Owner in terminating the ongoing contract.

Approach to the operations and resources set in place

Drilling work platform: a dredge instead of a jack-up

- Underwater rock excavation by drilling and blasting (D&B) is normally executed by means of OD (overburden drilling) wagon drills standing on a self rising platform (jack-up). Jack-up, floating on his work platform, is moved by a tugboat right above the drilling field. When above the drilling field, the jack-up (self) lifts its work platform on his 4 spuds.

- But no jack-up was available in the country and in near, and mobilization and demobilization of a jack-up would have had costs in the range of 1 million euro. This would have been a relevant impact on total costs, especially because of the small volume of rock mass to be excavated.

Jack-up "Sarais" with the 2 wagon drillls on board.

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- The job was executed in JV by **DUTCH DREDGING** (a leading international dredging company from Holland) and **NITREX** for the part related to controlled blasting.
- DUTCH DREDGING had the dredge “Delta Queen” available on site. MOB and DEMOB cost were just those to adjust on it a drilling work platform on the deck.
- “Delta Queen” had two spuds for stationing; it could not lift itself above the water but could keep position (geo referenced, with RTK-differential GPS) and adjust spuds height to follow the tide.
- A drilling work platform for the OD wagon drills was so gained on the “Delta Queen” deck.

The dredge “Delta Queen”.

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Wagon drills and spuds to be lifted by a crane on board the “Delta Queen”, for the underwater blasting service.

The 2 wagon drills on their work platform no the “Delta Queen” deck.

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wagon drills in place on their drilling work platform


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OD platform
and casing

- Drilling work platform was not as stable as if on a jack-up, but stable enough to permit drilling notwithstanding higher complexity (to follow the tide and dredge oscillation because of the waves), also with higher damage rate and extra time needed (12 holes to be drilled with one placement of the dredge against 60 with a jack-up (forcing to several replacement to cover the whole area of operation.

- Because of the less stable work platform and of the several dredge replacements, the whole D&B lasted 4 times more than what would have been possible with a jack-up.

- But considering time saved for no MOB – DEMOB, schedule was unchanged.

Drilling into a fractured rock mass, with mud coming out from the holes into the casing

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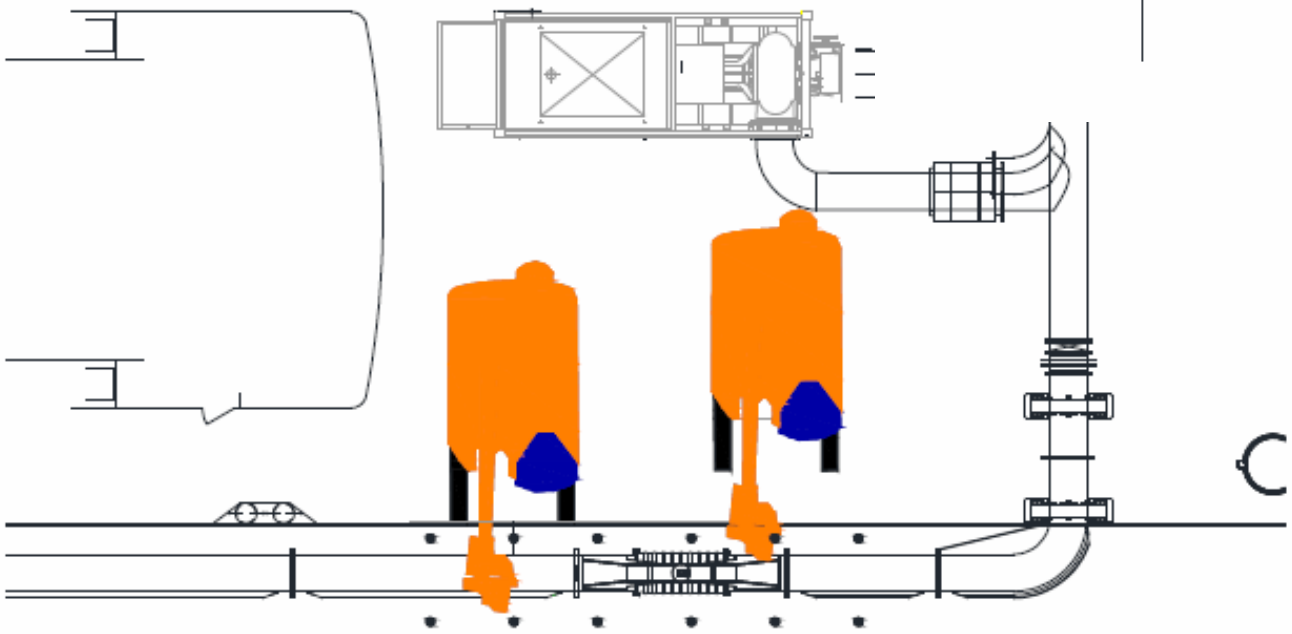
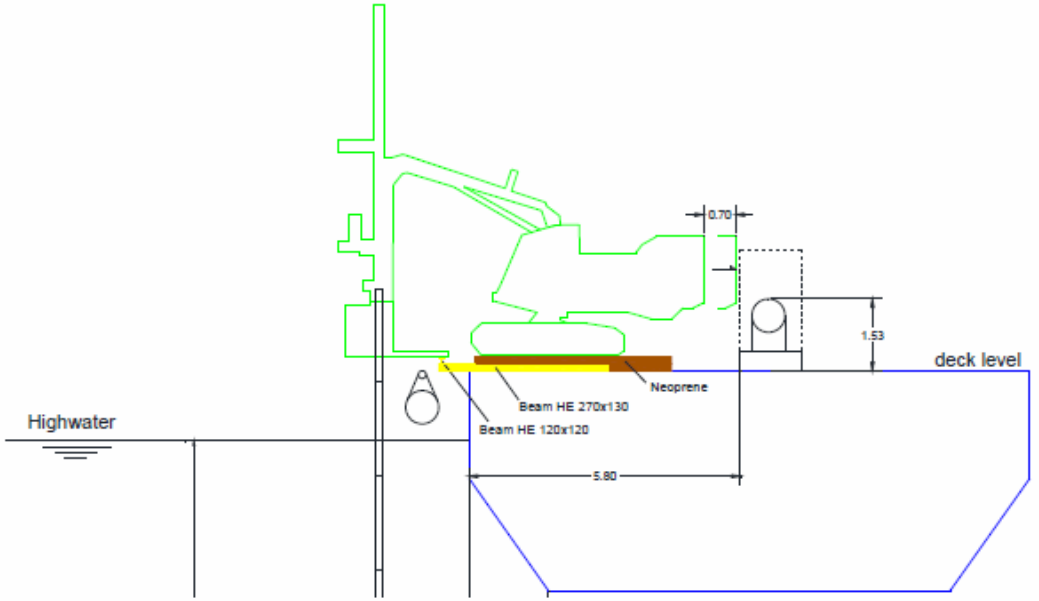
3.1.1 POSITIONNEMENT DE FOREUSES (WDs) SUR DELTA QUEEN

1. Les WDs seront placés sur le pont du DELTA QUEEN selon le schéma s



12 holes to be drilled with one placement of the dredge



A sketch of the work platform for OD drilling no the dredge

Overpressure in water

To foresee aplitude of the overpressure in water, reference was made to a decay law computed by monitoring in a previous similar job:
[rif. 02-030 reg OiW 2009-02-02]

Overpressure in water peak = P [psi] 90% = 615 * DS^-1,587 with DS [m/kgTNTeq.^1/3]

To do not overpass, at 90% probability, at 20 m distance, the given threshold of 209 dB (4,2 psi), the maximum charge per delay was set equal to 6,3 kg.

Threshold limits and preliminary assessment of the safety distance at given charge per time delay

SPL (sound pressure level) IN WATER [psi] = 615 · SD [m/kg^0,333]^-1,587
[02-030 reg OiW 2009-02-02]

R (distance)	*N.E.W. (Net Explosive Weight)*	*DS (scaled distance)*	*SPL overpressure (shock wave)*				
[m]	*[kgTNTeq]*	*[m/kgTNTeq^0,333]*	*[psi]*	*[MPa]*	*[Bar]*	*[kgf/cm²]*	*[dB ref. press. 1µPa]*
10	6,30	5,4	12,6	0,09	0,87	0,9	219
15	6,30	8,1	6,6	0,05	0,46	0,5	213
20	6,30	10,8	4,2	0,03	0,29	0,3	209
25	6,30	13,5	3,0	0,02	0,20	0,2	206
30	6,30	16,2	2,2	0,02	0,15	0,2	204
35	6,30	19,0	1,7	0,01	0,12	0,1	202
40	6,30	21,7	1,4	0,01	0,10	0,1	200
45	6,30	24,4	1,2	0,01	0,08	0,1	198
50	6,30	27,1	1,0	0,01	0,07	0,1	197
55	6,30	29,8	0,8	0,01	0,06	0,1	195
60	6,30	32,5	0,7	0,01	0,05	0,1	194
65	6,30	35,2	0,6	0,00	0,04	0,0	193
70	6,30	37,9	0,6	0,00	0,04	0,0	192

Figure 8-6: Surpressions subaquatiques avec rideau de bulles

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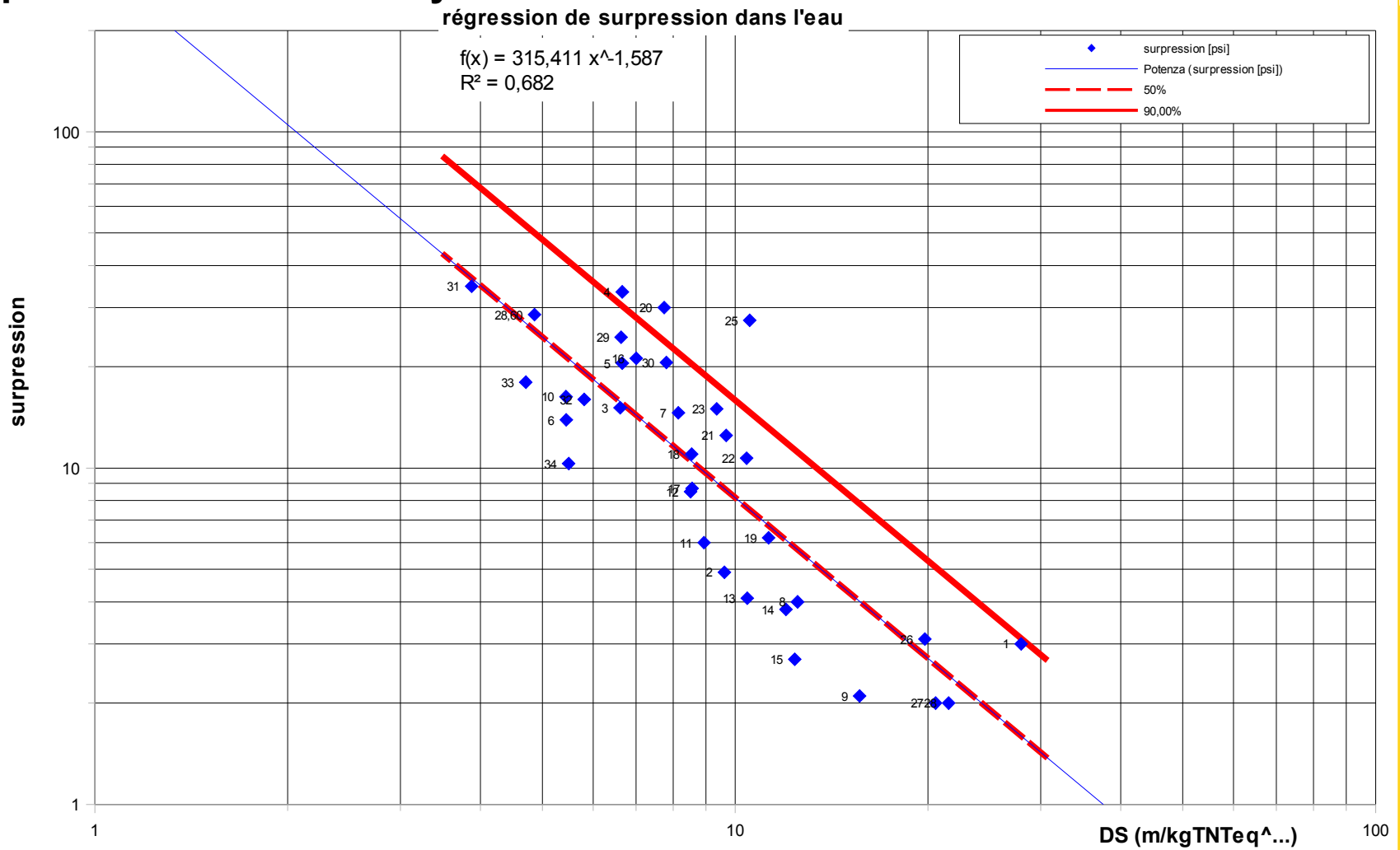
Overpressure in water decay law



Régression de surpression dans l'eau

vR,V,T 50% = 315 * (R/Q^ 0,333)^ -1,587

vR,V,T 90% = 615

	x1 (di R)	K
esp. Q | esp. R | val. K	-1,59	5,75
erreur standard pour les coefficients	0,19	0,43
coef. déterm. R² | erreur standard y	0,68	0,51
F statistiques | degré de liberté	68,49	32
	17,67	8,26

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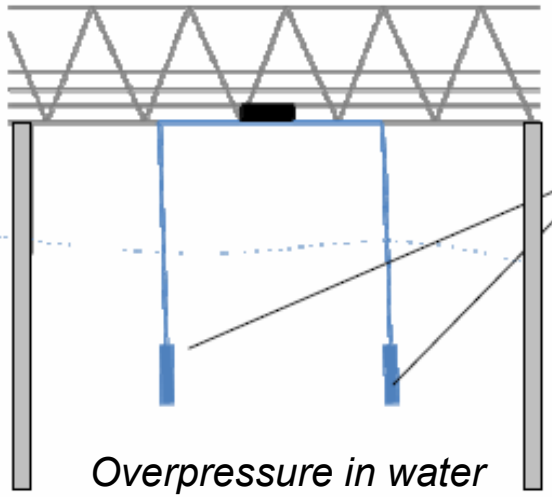
Overpressure in water monitoring

No. 2 Tourmaline sensors powered, conditioned and recorded by one “datalogger”, were sunk one of them very close to the blast spot and the other one at distance.
After each blast data were downloaded, printed and send to the Engineer.

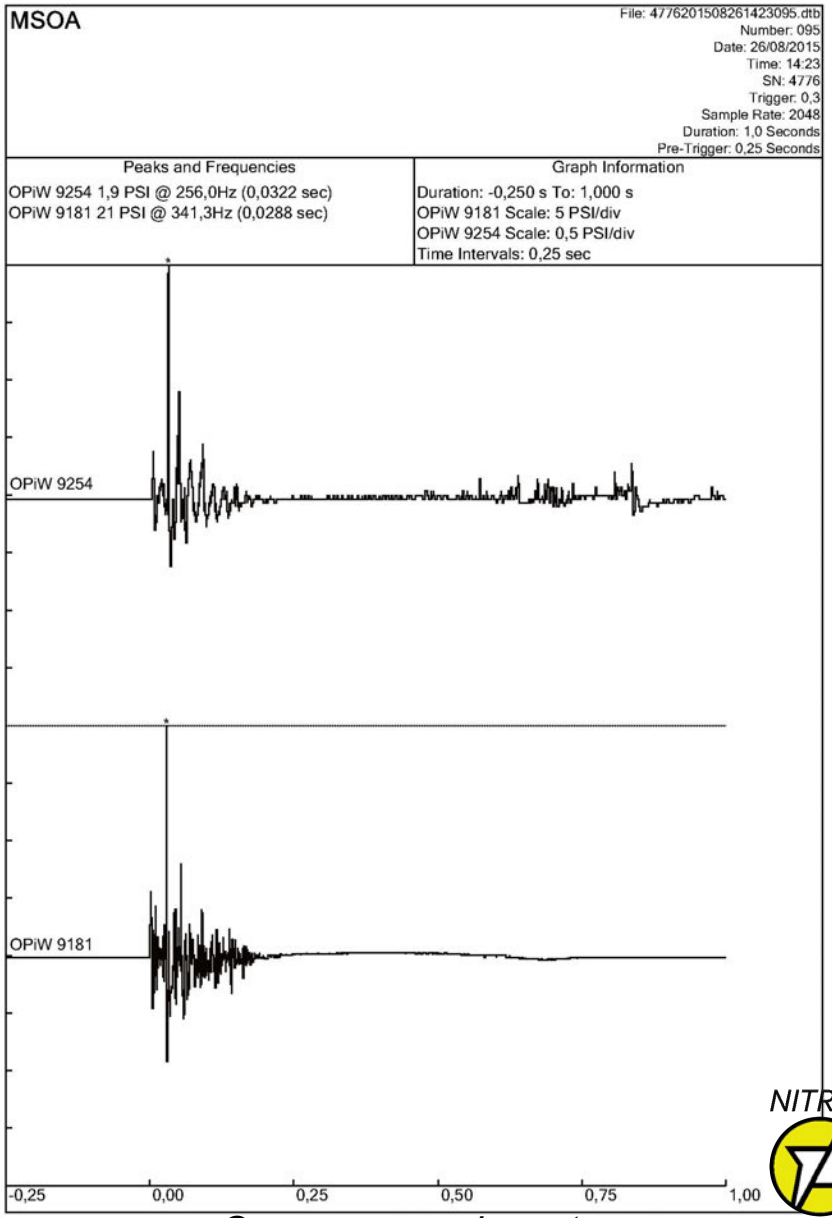
High pressure underwater dynamic pressure Tourmaline sensor.



Les deux capteurs seront placés jusqu'à environ 2 mètres du fond, et à 20 mètres de distance entre eux.

Il faudra faire attention au positionnement des capteurs loin des structures importantes, afin d'éviter les effets de bord.

Overpressure in water transducers hanging at a near dock.



Overpressure in water.

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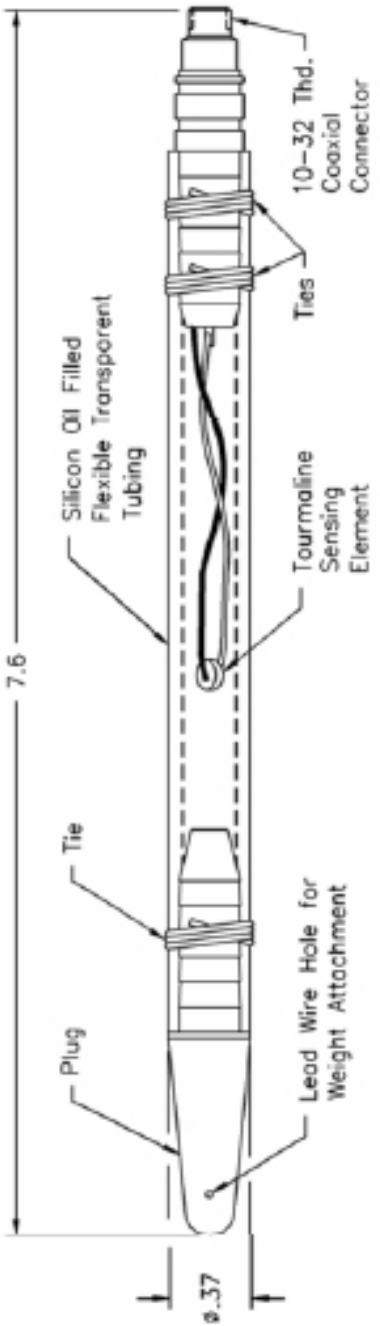
Overpressure in water monitoring

High pressure underwater dynamic pressure Tourmaline sensor.



Capteur de surpression:
Plage de mesure: 69 Mpa
Mesures max : 138 Mpa
Sensibilité: 73 µV/kPa
Surpression max: 345 Mpa
Résolution: 140 Pa
Réponse en basse fréquence: 2,5 Hz
Non-linéarité: 2,0 % FS
Poids: 21 g

Unité d'enregistrement:
Canaux d'enregistrement: jusqu'à 3
Taux d'échantillonnage: jusqu'à 2048 échantillons par seconde
Mémoire: jusqu'à 340 événements
Durée d'enregistrement: réglable de 1 à 24 secondes
Le niveau de déclenchement: réglable
Alimentation: batterie interne
Téléchargement des données: via un câble RS-232
Réponse en basse fréquence: 1 Hz

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Ground vibration

Threshold limits and preliminary assessment of the safety distance at given charge per time delay

- French Norm: **NF E90-020**

- Ground vibration decay law: **v MAX(R,V,T) 95% = 3,000 · (R/Q^ 0.50)^-1.80**
  with v [mm/s], R [m], Q [kg in TNTeq.], at 95% confidence limit according to “t Student distribution”, computed by power regression of data recorded in a similar job.

- Contractual thresholds for ground vibration were specified in the tender document C.C.T.P. (*Cahier des Clauses Techniques Particulières*). According to the French practice, the cut-off frequency of the transducers filter had to be normalized at 3 dB attenuation of the signal (75% of the amplitude at the cut-off frequency). Ground vibration was measured zero-peak levels of the vibration velocity, on the frequency-weighted vibration signal.

- Having conservatively considered a predominant frequency of seismic waves lower than 10 Hz, following values for zero probability of damage were set:

  1. INDUSTRIAL BUILDINGS recommended: 10.0 mm/s @ 75% = **7.50 mm/s**
  2. RESIDENTIAL BUILDINGS: 10 mm/s @ 75% = **7.50 mm/s**
  3. MASSIVE STRUCTURES IN REINFORCED CONCRETE: 75 mm/s @ 75% = **56.3 mm/s**

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Computation of the maximum charge per time delay

Ground vibration V = 7.5 mm/s max

Safety scaled distance SD = (7.5/3000)^(1/-1.8) =

27.9 [m * kg^-0.50]

V = 56.25 mm/s

SD = 9.11 [m * kg^-0.50]

The maximum charge per time delay "QMAX" to do not exceed given thresholds at varying distance, was so set equal to:

QMAX [kgTNTeq] = (R / SD)^(1/c)

QMAX [kgTNTeq] for 7.5 mm/s = (R / 9.11)^(1/0.50)

QMAX [kgTNTeq] for 56.25 mm/s = (R / 9.11)^(1/0.50)

QMAX values for each distance is given in the table. Those were kept ad reference values which were confirmed by firing tests and so left as reference for the duration of the job.

$V_{MAX(R,V,T)}$ [mm/s] =
VALEUR MAXIMALE **7.5** = 3,000 * (R/Q^ 0.50)^ -1.80

SD_{MIN} [m/kgTNTeq.^xxx] = 27.9 ^ -1.80

		MAXIMUM CHARGE COOPERANTES		
		OLD Emulsion	NEW Emulsion	dynamite
		MJ/kg:		
R	Q max	3.8	4.3	4.8
[m]	[kgTNTeq.]	[kg]	[kg]	[kg]
100	12.85	15.3	13.5	12.1
125	20.07	23.9	21.1	18.9
150	28.91	34.4	30.4	27.2
175	39.35	46.8	41.4	37.1
200	51.39	61.1	54.0	48.4
250	80.30	95.5	84.4	75.6

Figure 8-1: Charge maximale qui doit être détonée à la distance des récepteurs afin de respecter la valeur limite de 7.5mm/s, avec une probabilité de 95%.

$V_{MAX(R,V,T)}$ [mm/s] =
VALEUR MAXIMALE **56.25** = 3,000 * (R/Q^ 0.50)^ -1.80

SD_{MIN} [m/kgTNTeq.^xxx] = 9.1 ^ -1.80

		MAXIMUM CHARGE COOPERANTES		
		OLD Emulsion	NEW Emulsion	Dynamite
		MJ/kg:		
R	Q max	3.8	4.3	4.8
[m]	[kgTNTeq.]	[kg]	[kg]	[kg]
20	4.82	5.7	5.1	4.5
25	7.53	9.0	7.9	7.1
30	10.85	12.9	11.4	10.2
35	14.77	17.6	15.5	13.9
40	19.29	22.9	20.3	18.2
45	24.41	29.0	25.7	23.0
50	30.13	35.8	31.7	28.4
60	43.39	51.6	45.6	40.9
80	77.14	91.8	81.1	72.6
100	120.53	143.4	126.7	113.5

Figure 8-2: Charge maximale qui doit être détonée à la distance des récepteurs afin de respecter la valeur limite de 56.25mm/s, avec une probabilité de 95%.

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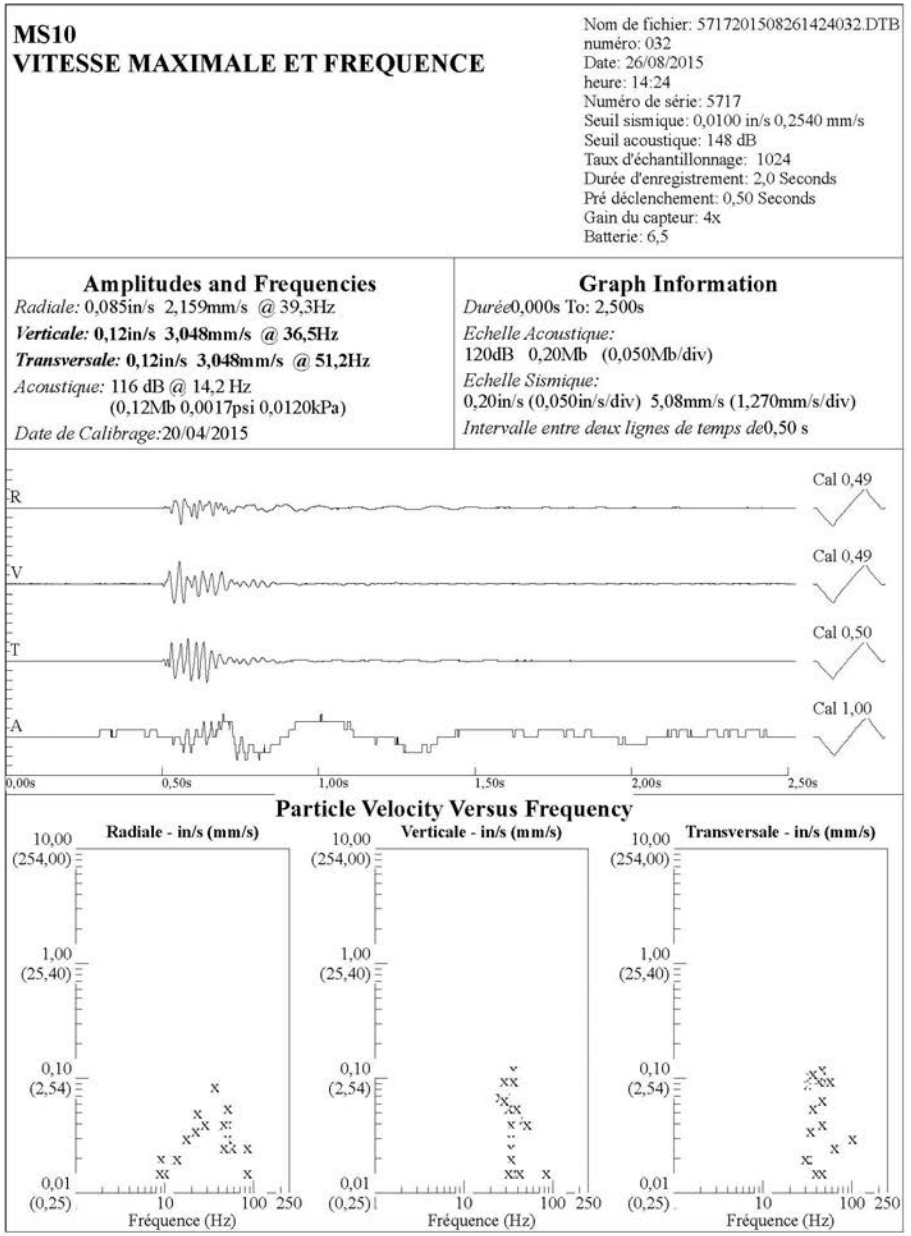
Ground vibration monitoring

No. 7 remote control-led seismographs fixed to nearest acceptors.
After each blast data were downloaded, analyzed and send to the Engineer.

Remote control ground vibration measuring units, triaxial velocity transducers and and overpressure in air transducers.



Ground vibration measured at measuring spot #10.

Layout of the safety distance at given charge per time delay on the base of the decay curve

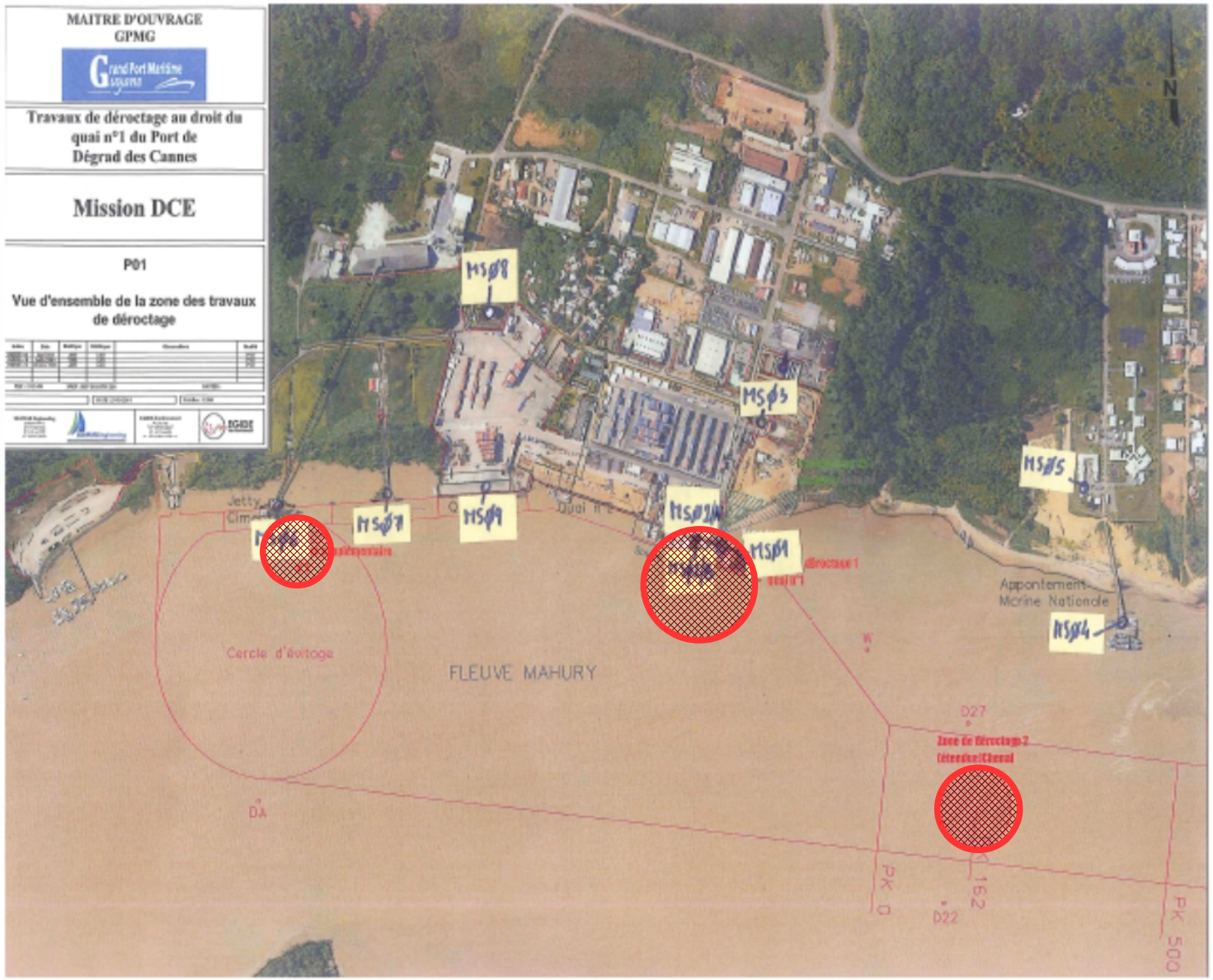


Figure 8-8: Vue en plan des points de mesure

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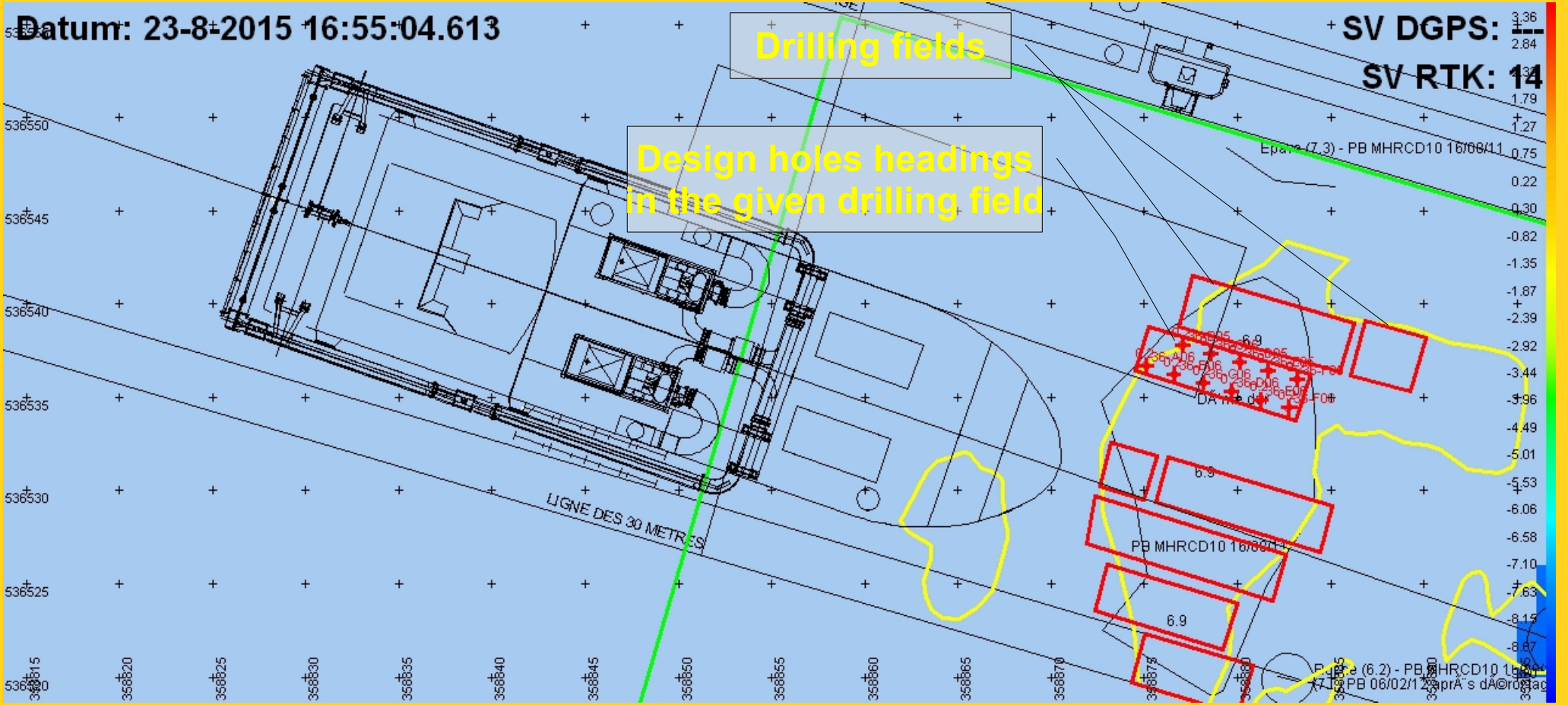
Drilling

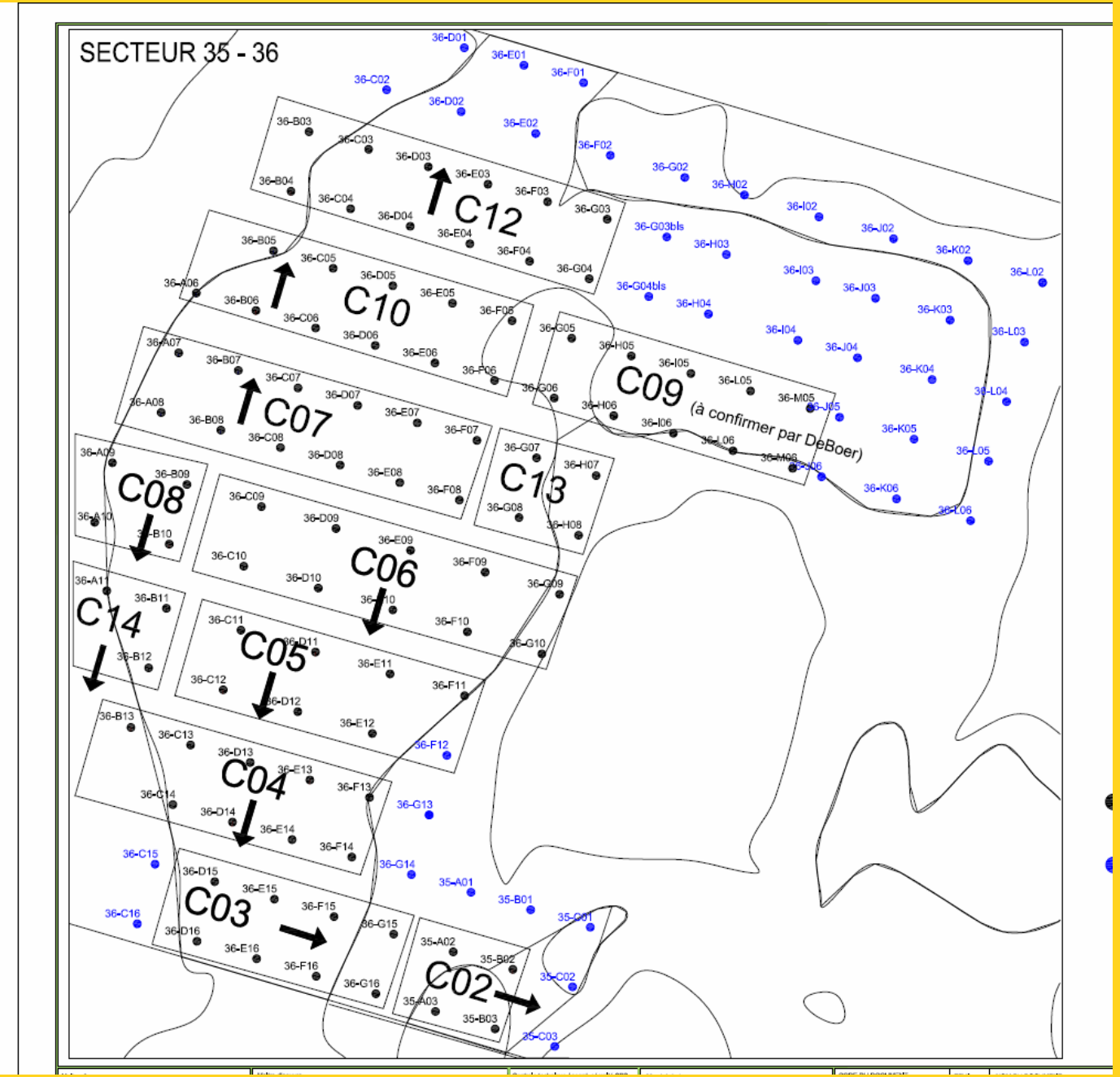
- Expected accuracy of the “Delta Queen” location system = 2 cm.
- Expected accuracy of the hole heading = 20 cm.



Drilling

- Design drilling pattern and holes identified for each drilling and blasting field.

- Holes grouped according to the area to be covered in one placement of the dredge.



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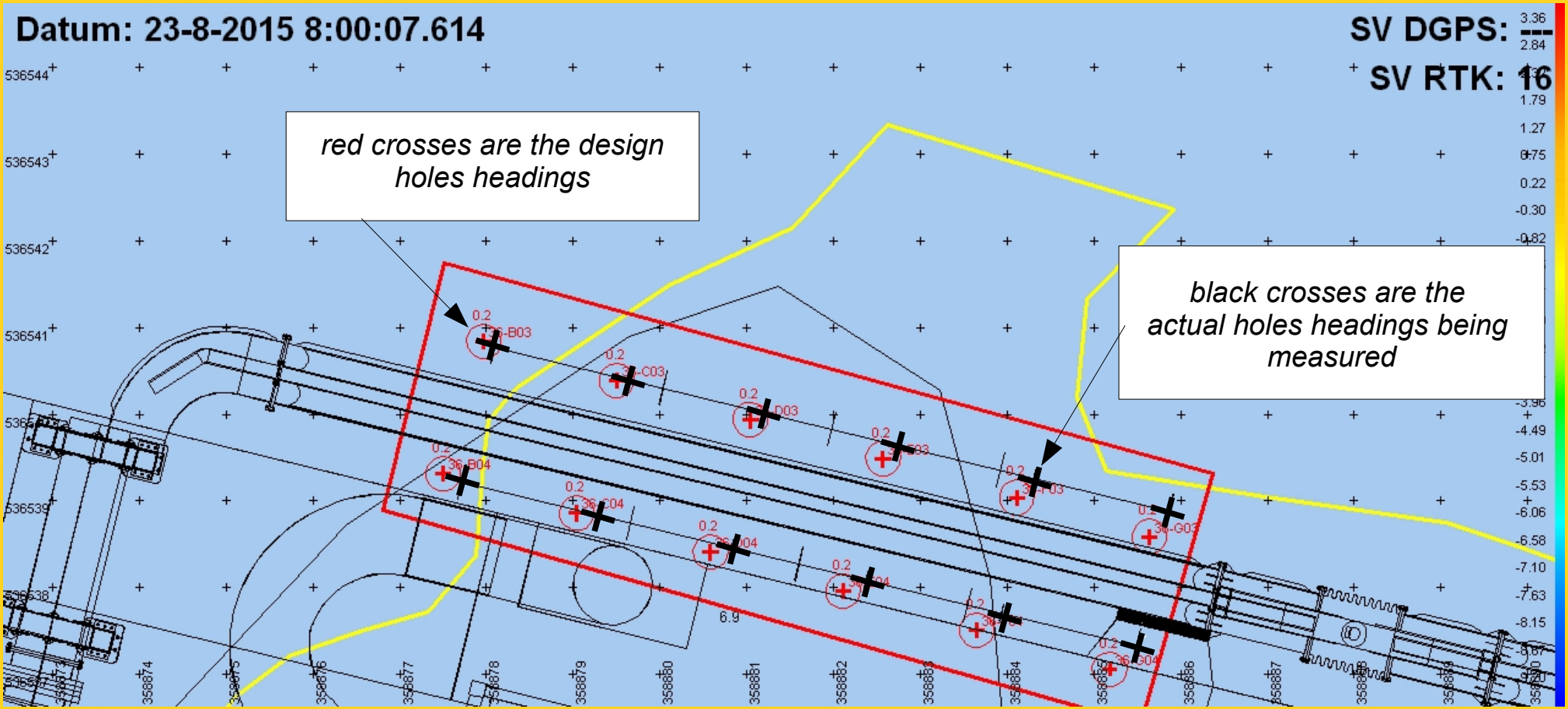
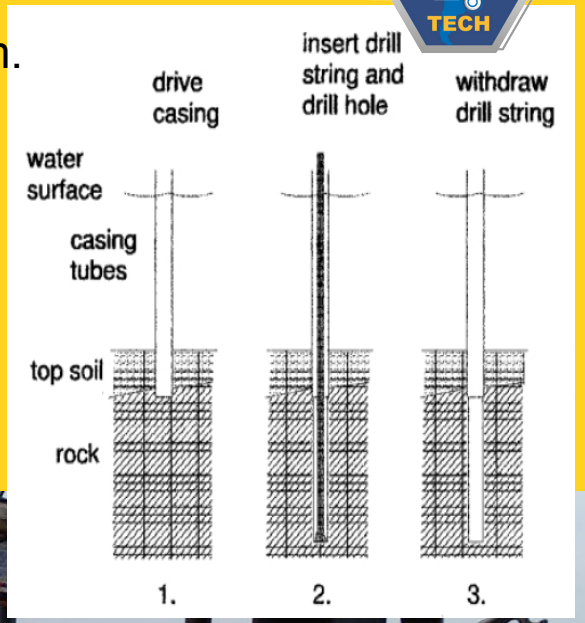
Drilling

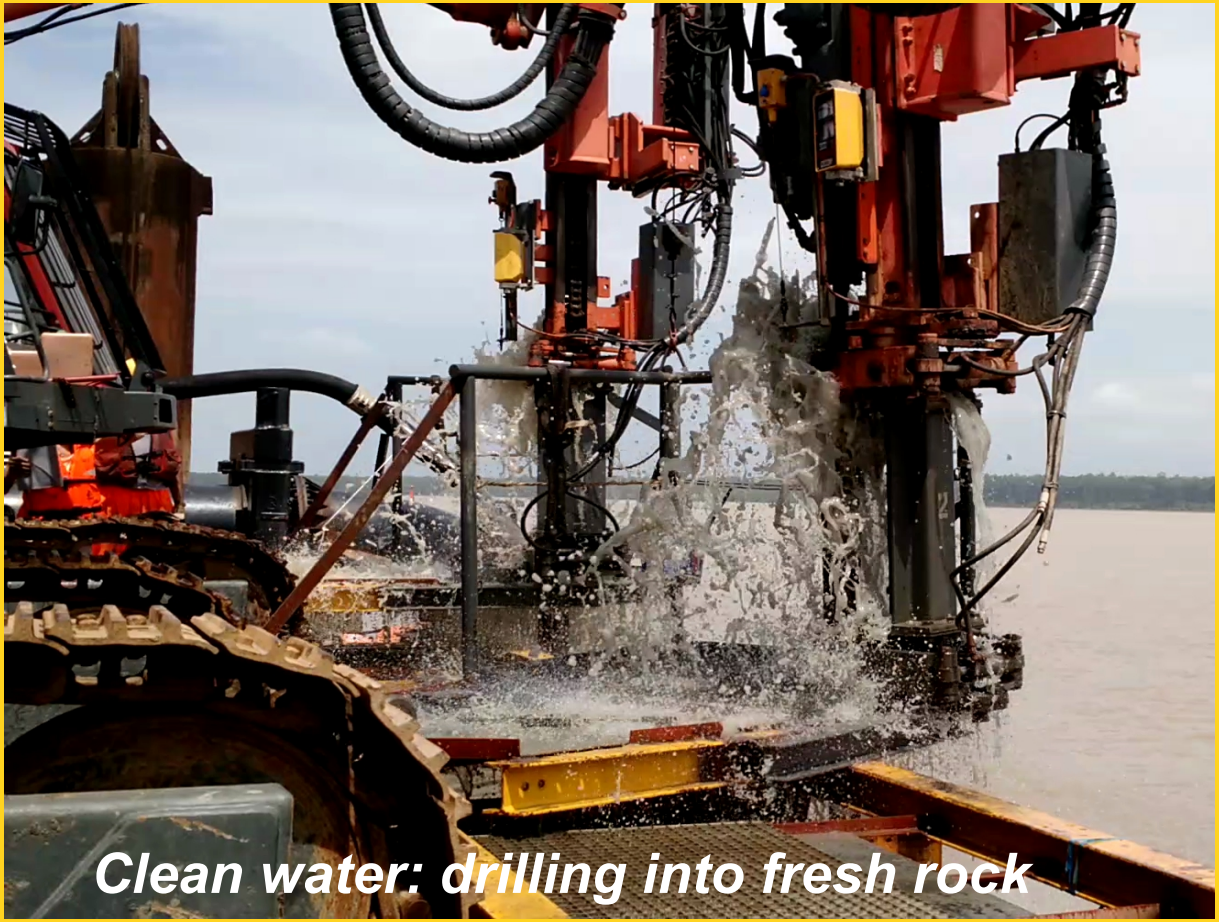
- Vertical boreholes, pattern 1.6 m x 1.6 m, 1 m under drilling (60% of the burden).

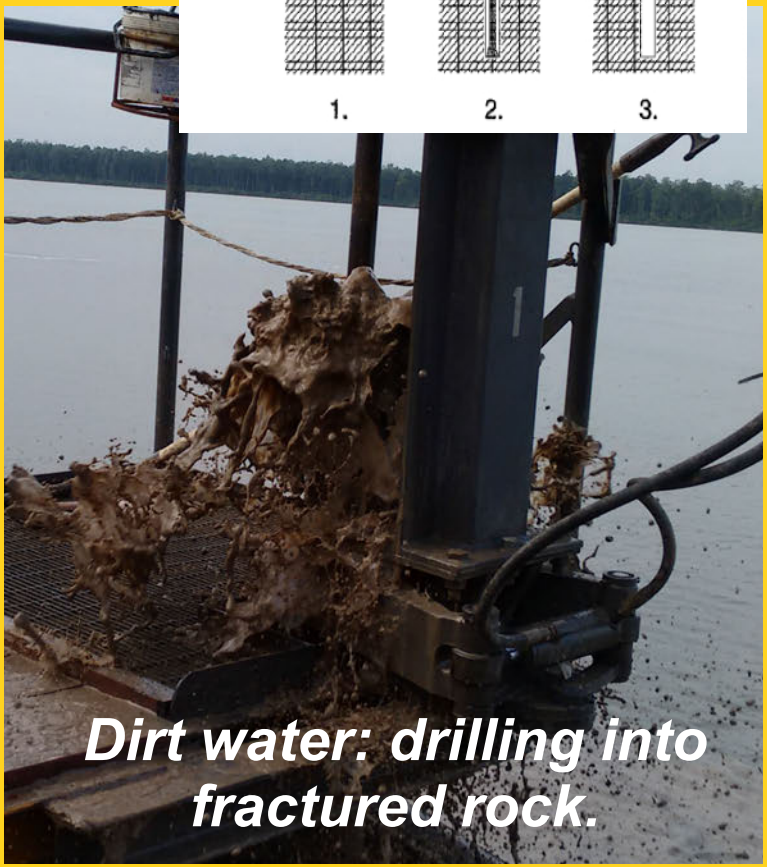
- Georeferenced track of each hole heading was kept adding a x-y-z stand-off to the "Delta Queen" location system RTK-GPS coordinates of each borehole being drilled.



- 2 (for redundancy) wagon drill SANDVIK DX 700, specially fitted for off-shore Overburden Drilling (OD), with own hydraulic winch on the boom.
- Casing Ø 115 mm with WiDia crown, drill hole button bits Ø 90 mm.
- Self-built work platform for OD, with hydraulic jaws for casing blocking managed by the WD cabin.
- Casing headed into the rock bed heading for some 50 cm, to Compensate short lifting of the WD due to waves and tide.




Clean water: drilling into fresh rock


Dirt water: drilling into fractured rock.

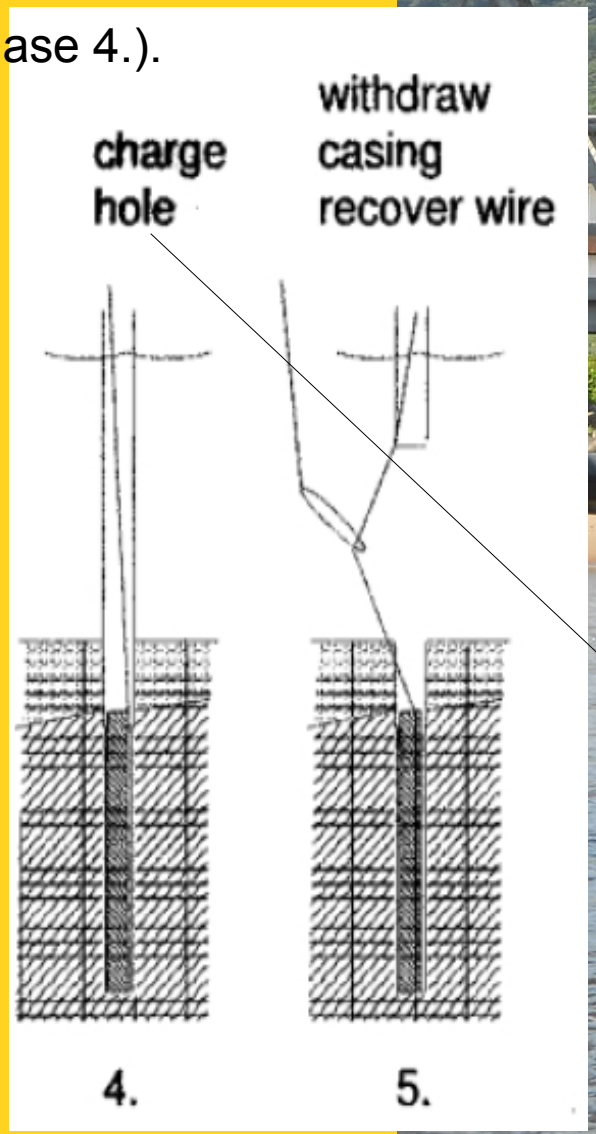
Charging

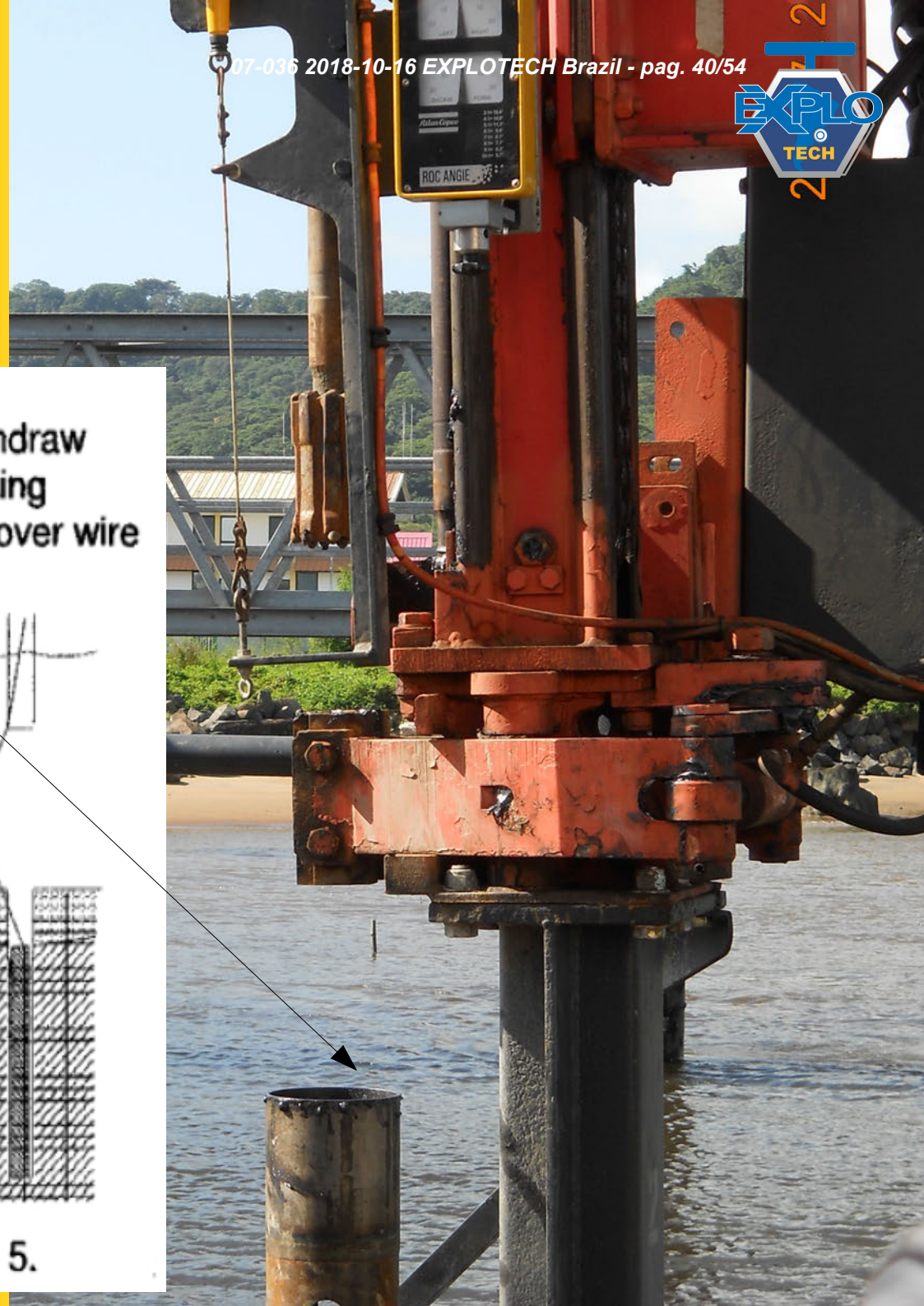
- Lowering the charge assembly with detonators (2, for redundancy) from the casing, with detonators tubes emerging from the casing top (phase 4.).

- Retrieving detonators tube by a side hole of the casing.

- Lifting the casing.

- Retrieving detonators tube from the casing bottom (phase 5).





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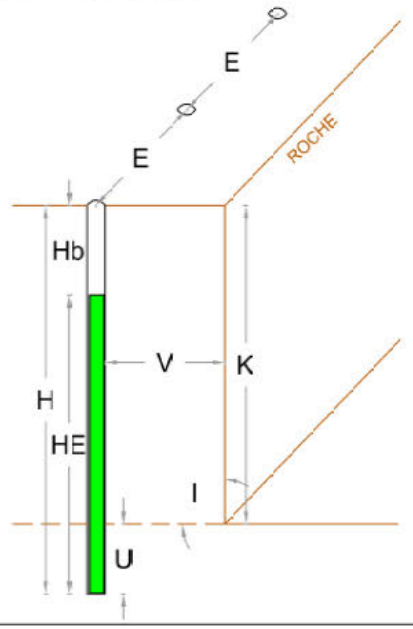
- BOREHOLE length 250÷260 cm (extra 50 cm for the ballast)
- Casing never more that 15 m from the drilling platform working area.

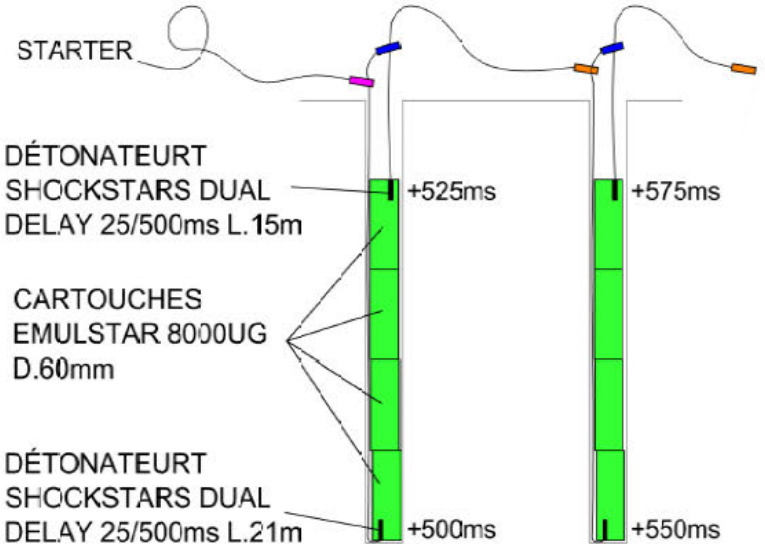
TABLE DES FORAGE ET LE CHARGEMENT

Diamètre de forage	ø [mm] =	89	
Inclinaison [°]	I	90	90
Hauteur du front [m]	K	1.50	1.50
Longueur de foration [m]	H	1.98	1.98
Surforation [m]	U	0.48	0.48
Banquette nominale [m]	V	1.60	1.60
	K/V	0.9	0.9
	E/V	1.00	1.25
Maille nominale [m]	E	1.60	2.00
Volume par trou (K*E*VA) [m³]		3.8	4.8
Note		Créer une Surface libre	Tirs de Production
Type d'explosif	EX		
Densité moyenne d'encartouchage [kg/dm³]		1.250	1.250
Hauteur cartouche [cm]		44	44
Diamètre ø [mm]		60	60
Poids [kg]		1.56	1.56
Cartouches par boite [n]		16	16
Energie moyenne [MJ/kg]		3.80	3.80
Découplage (ø cartouche / ø trou) [%]		67%	67%
Numéro de cartouches EMULSION d60mm dans le trou [n]	En	4	4
Compaction de la cartouche [cm]		0	0
Hauteur de la charge [m]	HE	1.76	1.76
Bourrage [m]	Hb	0.22	0.22
Quantité d'explosif dans le trou [kg]	QE	6.2	6.2
Quantité d'explosif dans le trou [kgTNTeq.]	NEQ	5.2	5.2
Charge unitaire [kg./m³]	QEsp	1.6	1.3
Charge unitaire [kgTNTeq./m³]	QM	1.4	1.1
Détonateurs par trou [n]	QD	2.0	2.0
Quantité spec. détonateurs [n/m³]	QDsp	0.52	0.42
Quantité spec. foration [m/m³]	QPsp	0.52	0.41
muckpile diameter [m]	S80	0.079	0.100

SYSTÈME DE CHARGEMENT D'UN TROU



DÈTAIL DE CHARGEMENT ET D'AMORÇAGE



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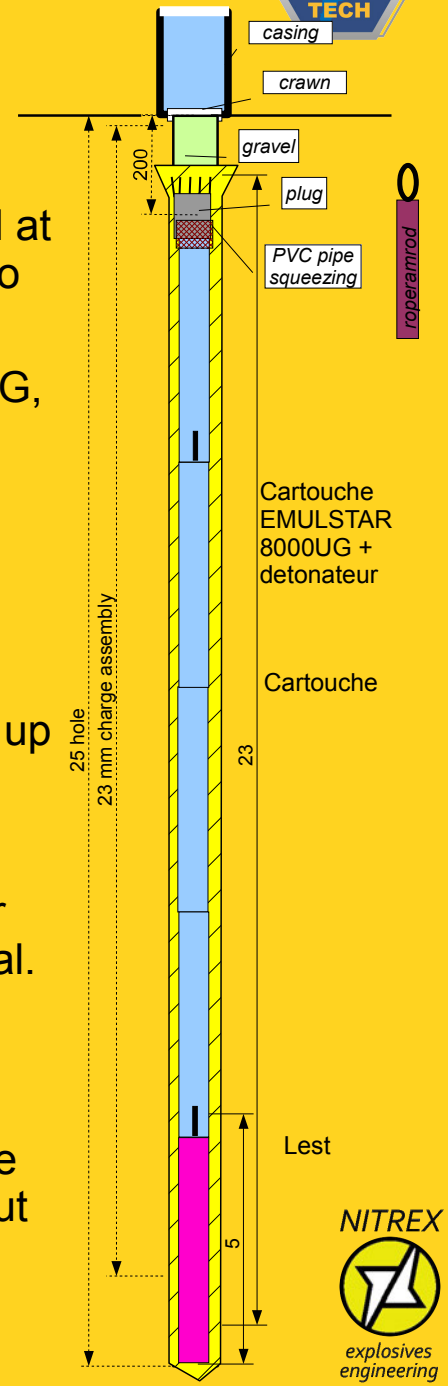
Column charge assembly and deployment

1. PVC-pipe length 230 cm, D60, cut along the longitudinal ax;
2. 8 cuts 5 cm l the upper part with resulting “wings” opened as a flower, to create friction against the hole walls, opposing its upward movement;
3. bottom melted with heat, to be closed.
4. 8 pieces of rebar D16mm 45 cm long as ballast (7 kg dry – some 6 kg wet) added at the bottom of the PVC-pipe (proper blasting practice would have recommended it to be placed at the top, working also as stemming).
5. First (lower) cartridge armed with shock tube detonator 21 m: EMULSTAR 8000UG, D60 mm, 1,6 kg, L45 cm; second and third cartridges plus forth cartridge armed (shock tube 15 m) added.
6. Little stemming (plug) made of a 0,5 liter water bottle filled with gravel added.
7. Charge assembly lowered into the hole through the casing, by keeping it thorough the 2 shock tubes.
8. With charge assembly at hole bottom, “rope ramrod” with is launched above it for up to 5 times, keeping the 2 shock tubes in tension to prevent their damaging.
9. 5 kg of extra gravel D 6 mm are poured into the casing as attritive stemming.
10. Steel rope (D 3 mm, 12,5 m) coupled (with a D-ring) to a ring taped on the upper part of the 2 shock tubes by the surface connectors, as safety extension for retrieval.
11. Casing is uplifted 2 m, slowly.
12. Heavy retrieval ring is placed around the casing and lowered in water.
13. With tension from the pull of the retrieval ring detachable at steel rope, steel rope is released into the casing and retrieval ring (with the shock tubes in it) is carried out of water.
14. Connectors are secured to the dredge (to be later coupled all together in line).



Charge assembly

Explosives charges assembly into PVC pipes, including ballast and stemming

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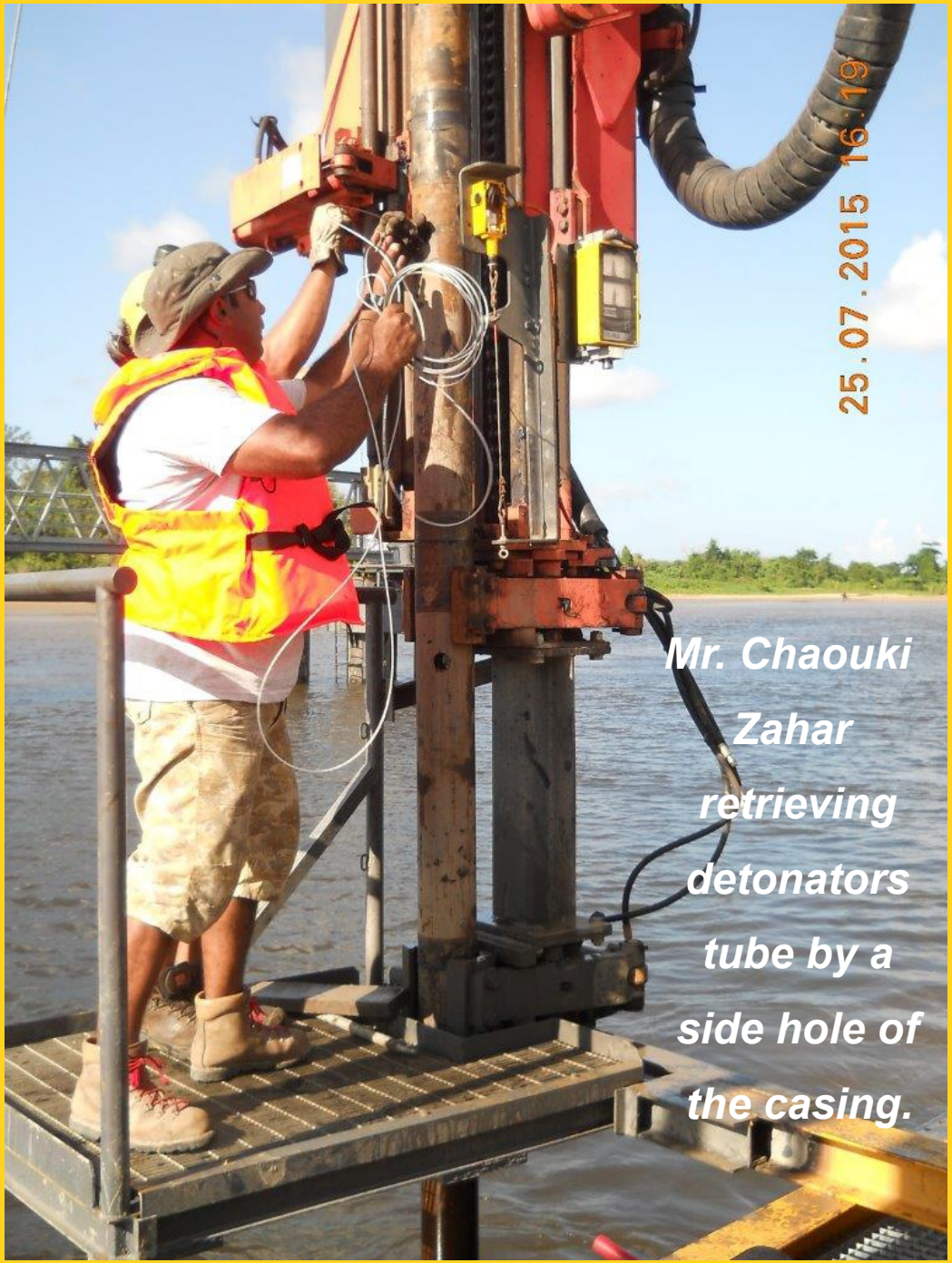
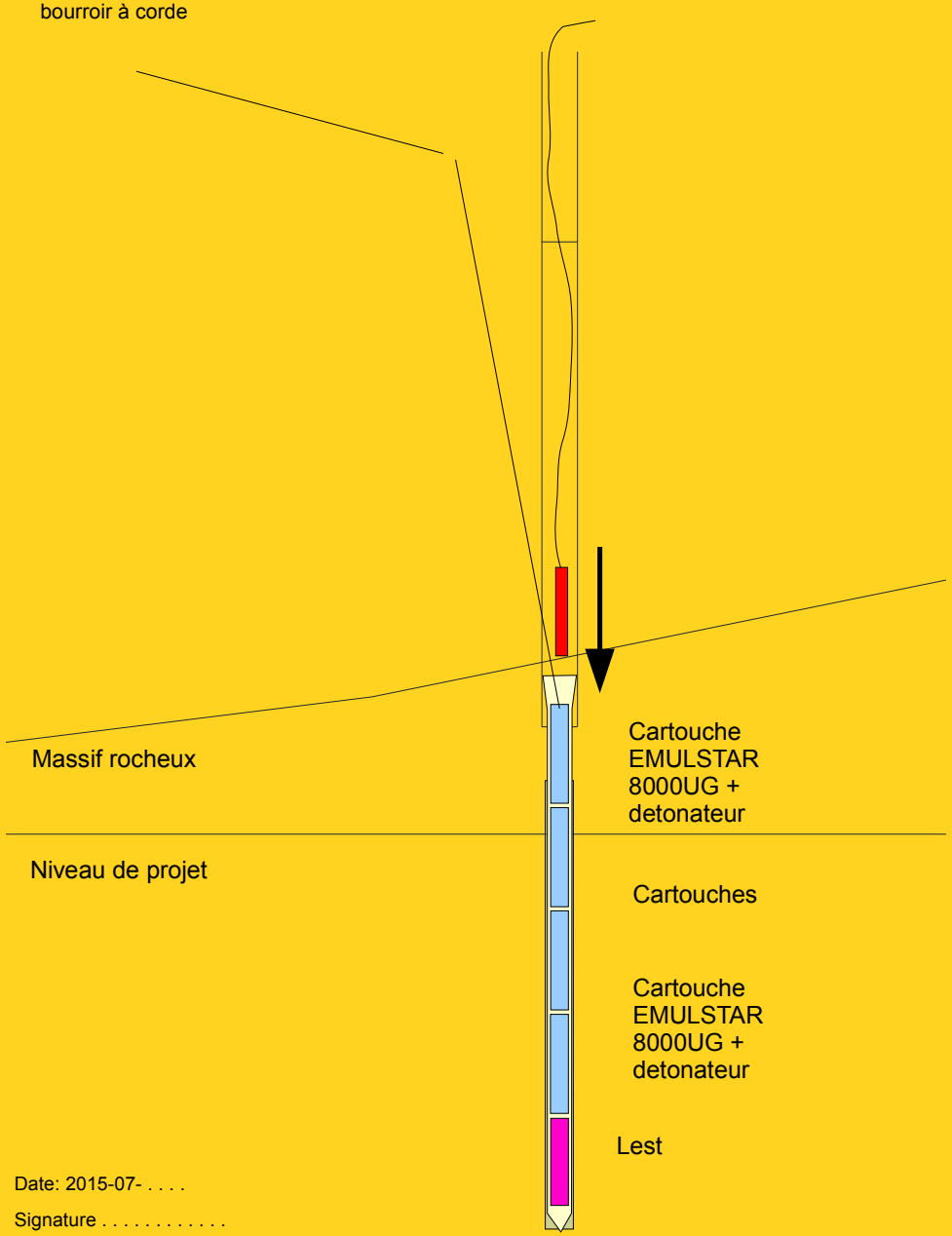


Mr. Chaouki Zahar retrieving detonators tube by a side hole of the casing.

PHASE 7 – Introduction de l'ensemble tube PVC + charges dans le trou. Compression par bourroir à corde

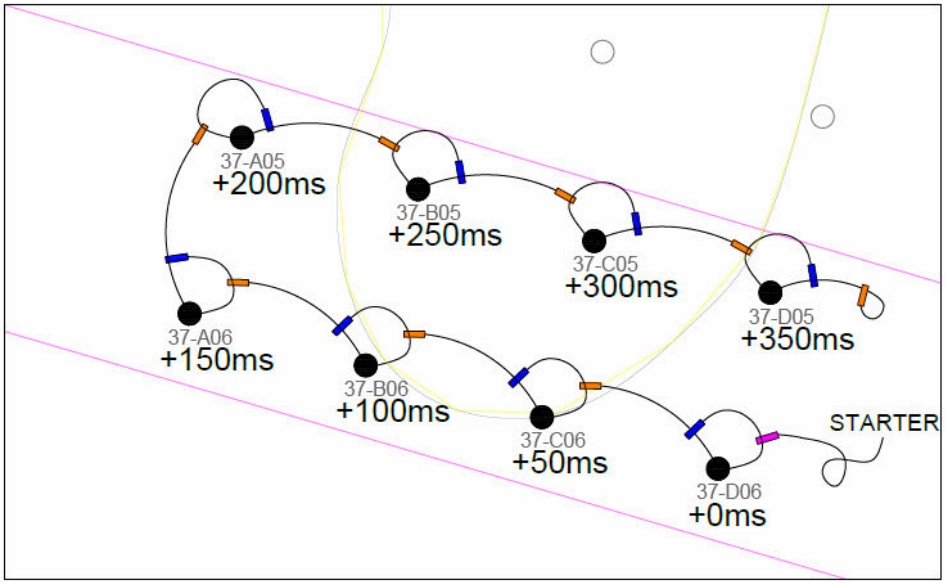


Date: 2015-07- . . . .

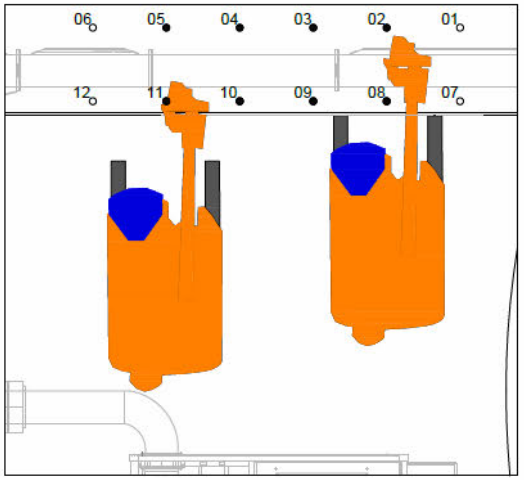
Signature . . . . . .

Time delay and connectors assembly above water

CHAMP 19

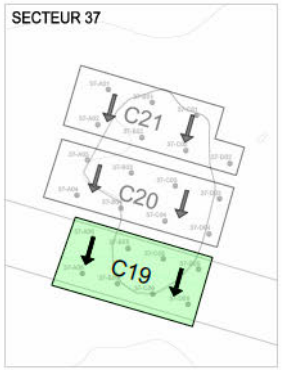


WDs placing



Ref.	Trous	Coord. GPS (Zone 22N)		H Longueur de foration	QE Expl. Dans le trou
	[n.]	[m E]	[m N]	[m]	[m]
CHAMP 19					
01	n.a.	358868.474	536523.737	n.a.	n.a.
02	37-D05	358866.939	536524.187	1.98	6.3
03	37-C05	358865.403	536524.637	1.98	6.3
04	37-B05	358863.868	536525.087	1.98	6.3
05	37-A05	358862.3325	536525.5373	1.98	6.3
06	n.a.	358860.7971	536525.9875	n.a.	n.a.
07	n.a.	358868.0178	536522.203	n.a.	n.a.
08	37-D06	358866.4824	536522.6532	1.98	6.3
09	37-C06	358864.947	536523.103	1.98	6.3
10	37-B06	358863.412	536523.554	1.98	6.3
11	37-A06	358861.8763	536524.0037	1.98	6.3
12	n.a.	358860.341	536524.4539	n.a.	n.a.

SECTEUR 37



DÉTONATEURT SHOCKSTARS DUAL DELAY 25/500ms L.15m - FOND DE TROU

DÉTONATEURT SHOCKSTARS DUAL DELAY 25/500ms L.12m - AMORCÉE EN TETE DE LA CHARGE D'EXPLOSIFS

STARTER

Ref.	Trous	Effets sur les récepteurs plus critiques Vitesse de sécurité = 56.75mm/s R	Vmax (AVPD) 3000*(R/QE^0.5)^-1.6	Surpressions sub. 615 DS[ft lb/ft^0.33]^-1.59	Surpressions sub. 615 DS[ft lb/ft^0.33]^-1.59	Effets sur les récepteurs plus critiques Vitesse de sécurité = 7.50mm/s R	Vmax (AVPD) 3000*(R/QE^0.5)^-1.6
	[n.]	[m]	[mm/s]	[PSI]	[dB ref. Pres. 1 µPa]	[m]	[mm/s]
CHAMP 19							
01	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
02	37-D05	**37.7**	22.86	5	211	**223**	0.93
03	37-C05	**36.9**	23.76	5	211	**224**	0.92
04	37-B05	**36.1**	24.72	5	211	**224**	0.92
05	37-A05	**35.4**	25.60	6	212	**225**	0.92
06	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
07	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
08	37-D06	**39.0**	21.51	5	210	**221**	0.95
09	37-C06	**38.3**	22.22	5	211	**222**	0.94
10	37-B06	**37.5**	23.08	5	211	**222**	0.94
11	37-A06	**36.8**	23.88	5	211	**223**	0.93
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

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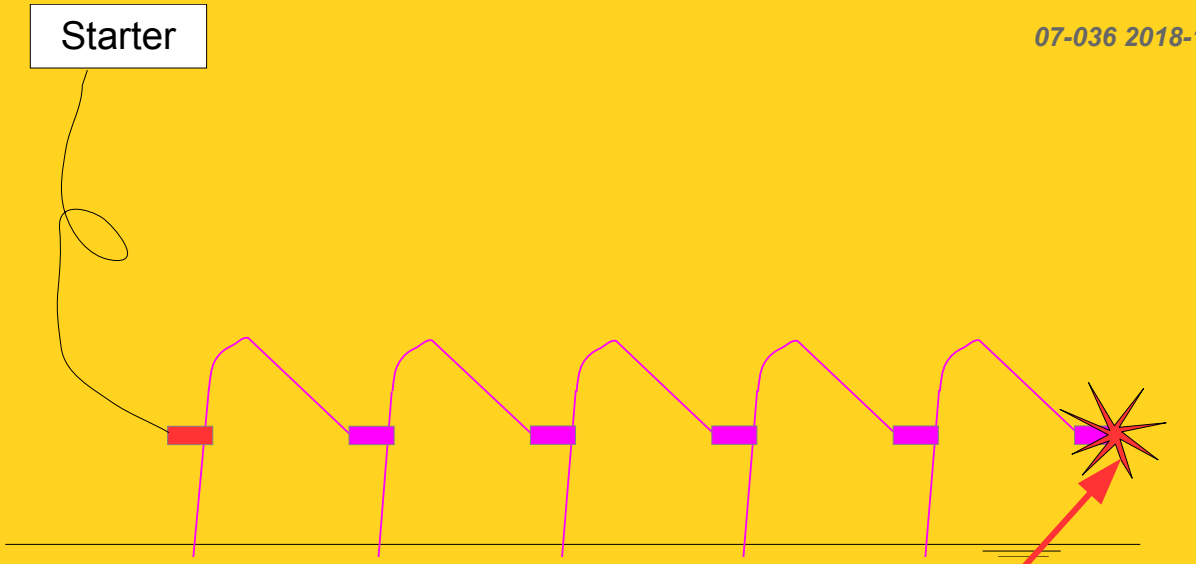

Surface connectors on a floating bar.
The last two surface connector
for full detonation check.

Air bubble curtain

- *Double concentric air bubble curtain was set in place.*
- *Special self sinking hose with holes in it, to release air volume sufficient to damp peak overpressure amplitude to 1/40.*
- *No reduction of the overpressure impulse is to be expected trough the bubble curtain (effect of air bubble curtain to fish safety is therefore insignificant).*
- *When at its maximum speed, water current reduced drastically efficiency of the air bubble curtain, by displacing the bubbles of several meters from the vertical, wile gaining the surface).*
- *Biologist team expressed their opinion against the air bubble curtain but customer engineer insisted for its deployment).*

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About the “air bubble curtains”:

« … The German Federal Armed Forces Underwater Acoustics and Marine Geophysics Research Institute (FWG) investigated means of reducing the shock wave of underwater Detonations. The efficiency of various bubble curtain configurations (single, double, triple) were tested with control detonations (1 kg charges). The best result was obtained using a double bubble curtain (at 4.75 and 5.75 m distance from the detonation, an air volume flow rate 20 m³/min), where a mean attenuation of 15.4 dB was achieved. This design would reduce the danger zone by over 98 %. A single and a triple bubble curtain with the same air volume flow were less efficient. A single bubble curtain with a reduced air volume flow rate was the least efficient. A triple bubble curtain could work more efficiently if the spacing between rings was increased to a value larger than the acoustic wave length of the spectral maximum (3 m at 500 Hz in the case of test detonations). When larger charges are used the diameter of the bubble curtain and the air volume flow have to be increased … »

[ref. S. Koschinski, K. H. Kock “Underwater Unexploded ordnance – Methods for a cetacean-friendly Removal of Explosives ad alternatives to blasting,]

Clearance zone as defined by the owner “GPMG Impact Study ”

“Risks for human activities

The only effect of the work on human activities is in limiting the traffic of the port during the duration of the works.

4.4.1 Safety area

1. A 150 m zone around the shots, which includes [**30 m WOULD HAVE BEEN SUFFICIENT IN A CONSERVATIVE APPROACH**]

· Exclusion of ships,

· Prohibition of access to land (port and coastal infrastructure).

In this zone there are no "residential" structures.

2. An area of 500 m around shots [**100 m WOULD HAVE BEEN SUFFICIENT IN A CONSERVATIVE APPROACH**]

· Prohibition for swimmers,

· Vigilance on land and on ships.

This limit of 500 m integrates the port domain (infrastructures, medians, warehouses, offices, ships docked ...), the wharf of the naval base, the marina, part of the area of activities and part of the area of spontaneous habitat, the coastline and surrounding natural areas. [**30 m WOULD HAVE BEEN SUFFICIENT IN A CONSERVATIVE APPROACH**]

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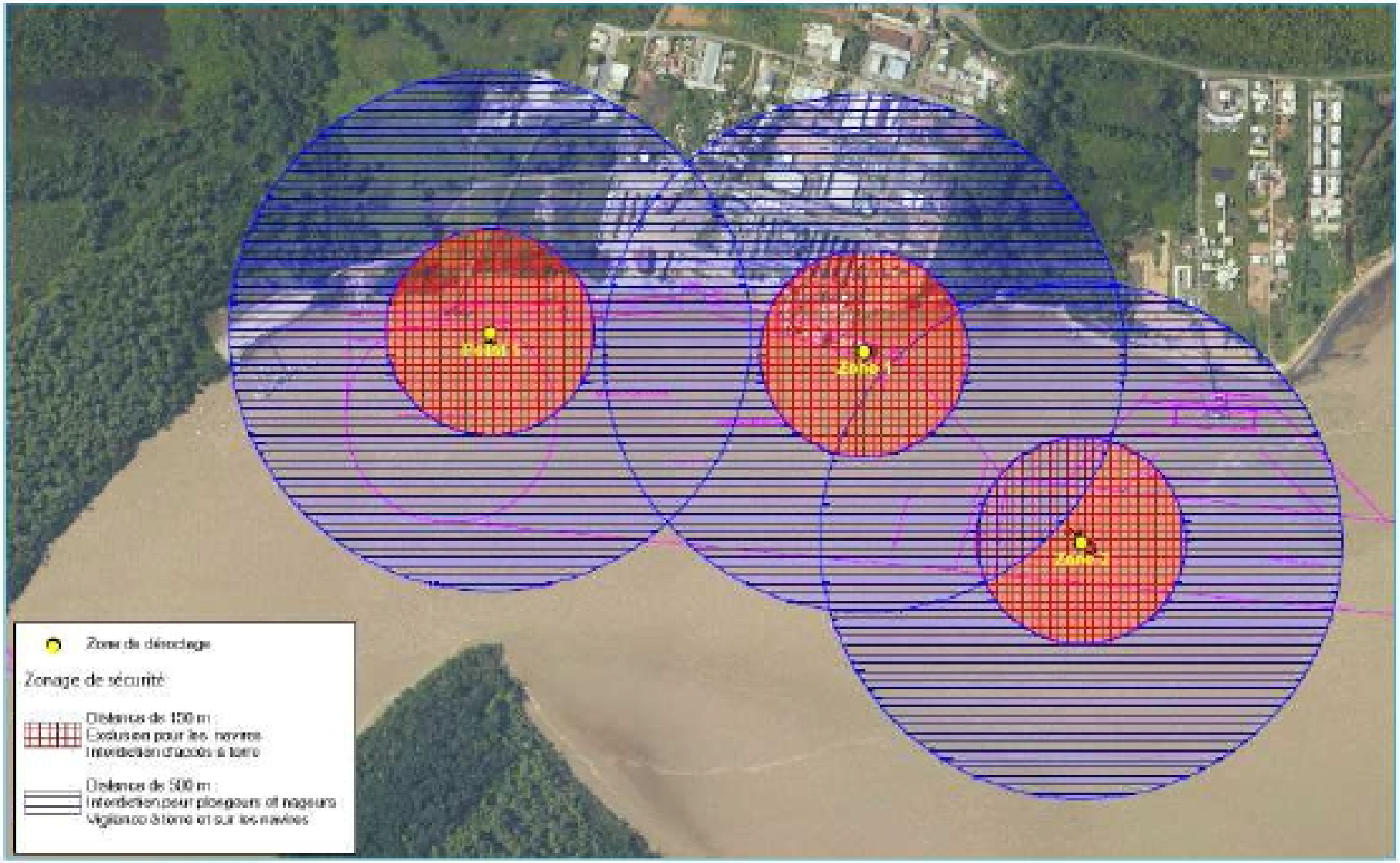


Figure 4-5: Zonage de sécurité

“Fire in the hole”

Blast signalization

ALERT – 30 minutes before shoot:
5 horns, each lasting ten (10) seconds and separated by ten (10) seconds from each other.

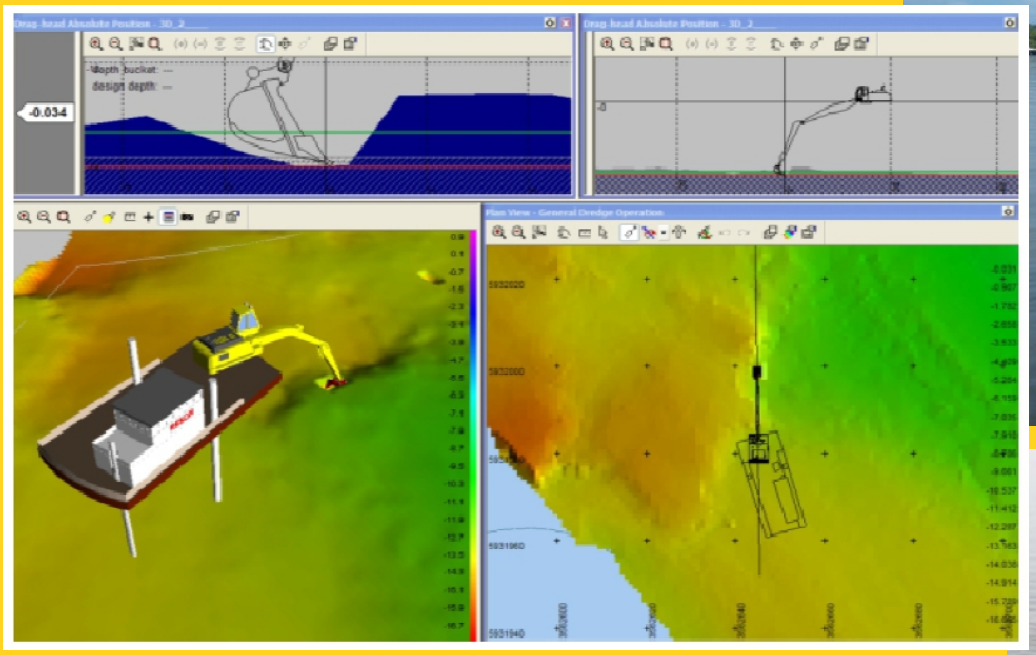
ALERT - 5 minutes before shoot:
Three horns each lasting ten (10) seconds and separated by ten (10) seconds from each other.

ALERT – 5 SECONDS BEFORE SHOOT and DURING THE SHOOT:
Continuous horn blow from five (5) seconds before shooting until ten (10) after the shot.

All cleaning signal:
5 horns alternating one short and one long.

Mucking

- CAT 345BL with long reach boom,
  on a barge fixed to the dredge.
- RTK differential GPS georeferenced shovel



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The end

- - -

obrigado pela vossa
gentil atenção