

Arbeitsbericht NAB 20-09

**TBO Trüllikon-1-1:
Data Report**

**Dossier I
Drilling**

June 2021

**National Cooperative
for the Disposal of
Radioactive Waste**

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Dossier I Drilling

June 2021

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TRU1-1, Zürich Nordost, TBO, deep drilling campaign, drilling report, site construction, drilling process, drilling tools, sections, casing, cementing, mud system, coring system, hole opener, deviation, HSE, actual vs. planned, non-productive time

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This NAB aims at reporting drilling results at an early stage. Additional borehole-specific data will be published elsewhere.

In the event of inconsistencies between dossiers of this NAB, the dossier addressing the specific topic takes priority. In the event of discrepancies between Nagra reports, the chronologically later report is generally considered to be correct. Data sets and interpretations laid out in this NAB may be revised in subsequent reports. The reasoning leading to these revisions will be detailed there.

This Dossier was prepared by a project team consisting of:

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Editorial work: Geomecon and M. Unger

The Dossier has greatly benefitted from technical discussions with, and reviews by, external and internal experts. Their input and work are very much appreciated.

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Abbreviations

API	American Petroleum Institute
APS	Accelerator porosity sonde
Asl	Above mean sea level
ASLT	Array sonic logging tool
ASME	American Society of Mechanical Engineers
ATEX	EU directives describing the minimum safety requirements of the workplace and equipment used in an explosive atmosphere (Appareils destinés à être utilisés en ATmosphères EXplosives)
AWEL	Office of Waste, Water, Energy and Air (WWEA, Amt für Abfall, Wasser, Energie und Luft)
B/U	Bottom up
BA	Borehole azimuth/general purpose inclinometer tool
BGL	Blow ground level
BHA	Bottom hole assembly
BOP	Blow out preventer
BTC	Buttress connection
BU	Balled up
CAL	Caliper
CCL	Casing collar locator
CBL	Cement bond log
CE	CE marking certification, "Conformité Européen" = "European Conformity"
CHH	Casing head housing
CSG	Casing
DC	Drill collar
DETEC	Federal Department of the Environment, Transport, Energy and Communications
DEW	Döring/Ellert/Wilkens Wartungs und Reparatur GmbH
DF	Drilling fluid
DIN	German National Organisation for Standardisation (Deutsches Institut für Normung e.V.)
DLS	Dog leg severity
DM	Drilling manager
DMT	Deutsche Montan Technologie
DP	Drill pipe
DSA	Double studded adapter

DSV	Drilling supervisor
ECD	Equivalent circulation density
ECS	Elementary capture spectroscopy
EDTC	Enhanced digital telemetry cartridge
EGT	Expert Group on Nuclear Waste Disposal
EMS	Electronic multishot system
ENSI	Swiss Federal Nuclear Safety Inspectorate (Eidgenössisches Nuklearsicherheitsinspektorat)
EOWR	End of well report
EQMW	Equivalent mud weight
EVED	Department of Transport and Energy Economics (Eidgenössisches Verkehrs- und Energiewirtschaftsdepartement)
FAC	First aid cases
FEM	European materials handling federation
FIT	Formation integrity test
FMI	Formation micro imager tool
FOEN	Federal Office for the Environment
GGD	Generalised Gaussian density
GL	Ground level
GMT	Magnetometer temperature
GPCI	Geneva Petroleum Consultants International
GPIT	General purpose inclinometer tool
GR	Gamma ray
GR-INC	Gamma ray – inclination
GR-INC/AZ	Gamma ray – inclination/azimuth
GTA	Gesellschaft für technische Akustik mbH
GTS	General Tubular Services GmbH
HCR	High closing ratio hydraulic valve
HiVis	High viscosity
HLW	High-level waste
HMR	High magnesium resistant cement
HNGS	Hostile gamma ray neutron sonde
HPU	Hydraulic power unit
HRLA	High resolution laterolog array tool
HRLT	High resolution laterolog array tool
HSE	Health, safety & environment

HWDP	Heavyweight drill pipe
IADC	International Association of Drilling Contractors
IBC	Intermediate bulk container
IBOP	Inside blow out preventer
ID	Inner diameter
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
jts	Joints
KOP	Kick-off point
KSIL	Potassium silicate mud
L/D	Lay down
L/ILW	Low- and intermediate-level waste
LCM	Lost circulation material
LDT	Acronym from Semmlogging – service no longer available - Litho-density tool/log?
LEH.QT	Logging equipment head with tension
LIH	Left in hole
LSRV	Low-shear rate viscosity
LSS	Long spaced sonic
LTI	Lost time injuries
LTIF	Lost time injuries frequency
M/U	Make up
MAASP	Maximum allowable annulus surface pressure
MCFL	Micro-cylindrically focused log
MD	Measured depth
MDT	Multiple dynamic tester
MHF	Microhydraulic fracturing
MSIP	Modular sonic imaging platform
MT	Metric tons
MTC	Medical treatment cases
MTCF	Medical treatment cases frequency
NB	Near-Bit
NOV	National Oilwell Varco
NPT	Non-productive time
NSC	Federal Nuclear Safety Commission

NSG	Application for exploration permits (Nagra Sondiergesuch)
OD	Outer diameter
OH	Open hole
OPS	Operations
PAEI	Proactive effort indicator
PBR	Polished borehole receptacle
PDC	Polycrystalline diamond compact bit
POOH	Pull out of hole
PPC	Powered positioning device & caliper
PPE	Personal protective equipment
ppf	Pounds per foot
PT	Pressure test
P/U	Pick up
PUW	Pick up weight
Revs	Revolutions
RIH	Run in hole
RM	Rig manager
ROP	Rate of penetration
RPM	Revolutions per minute
RS	Rohrschuh (casing/liner shoe)
RW	Pumping test with constant flowrate ('rate withdrawal test')
RWC	Restricted work case
RWCF	Restricted work cases frequency
RWS	Pressure recovery after pumping test with constant flowrate (shut-in)
S/N	Serial number
SCR	Slow circulation rate
SFOE	Swiss Federal Office of Energy
SG	Specific gravity
SGT	Sectoral Plan for Deep Geological Repositories
SHO	Staged hole opener
SLB	Schlumberger N. V.
SOW	Slack off weight
SPA	Spontaneous potential apparent
TBO	Tiefbohrungen (deep boreholes)
TC	Tungsten carbide

TCI	Tungsten carbide inset
TD	Target depth of section or hole
TDS	Technical data sheet
TDS	Topdrive system
TLD	Three-detector lithology detector
TOC	Top of cement
TP	Tool pusher
TQ	Torque
TRC	Total recordable cases
TRS	Tubular running service
TT	Transit time
TVD	True vertical depth
UBI	Ultrasonic borehole imager
USIT	Ultrasonic imager tool
VA	Annular velocity
VDL	Variable density log
VS	Vertical section
VSP	Vertical seismic profile
W/O	Wash outs
WBM	water based mud
WEP	Well Engineering Partners BV
WL	Wireline
WOB	Weight on bit
WOC	Waiting on cement
XO	Crossover

1 Introduction

1.1 Context

To provide input for site selection and the safety case for deep geological repositories for radioactive waste, Nagra has drilled a series of deep boreholes in Northern Switzerland. The aim of the drilling campaign is to characterise the deep underground of the three remaining siting regions located at the edge of the Northern Alpine Molasse Basin (Fig. 1-1).

In this report, we present the results from the Trüllikon-1-1 borehole.

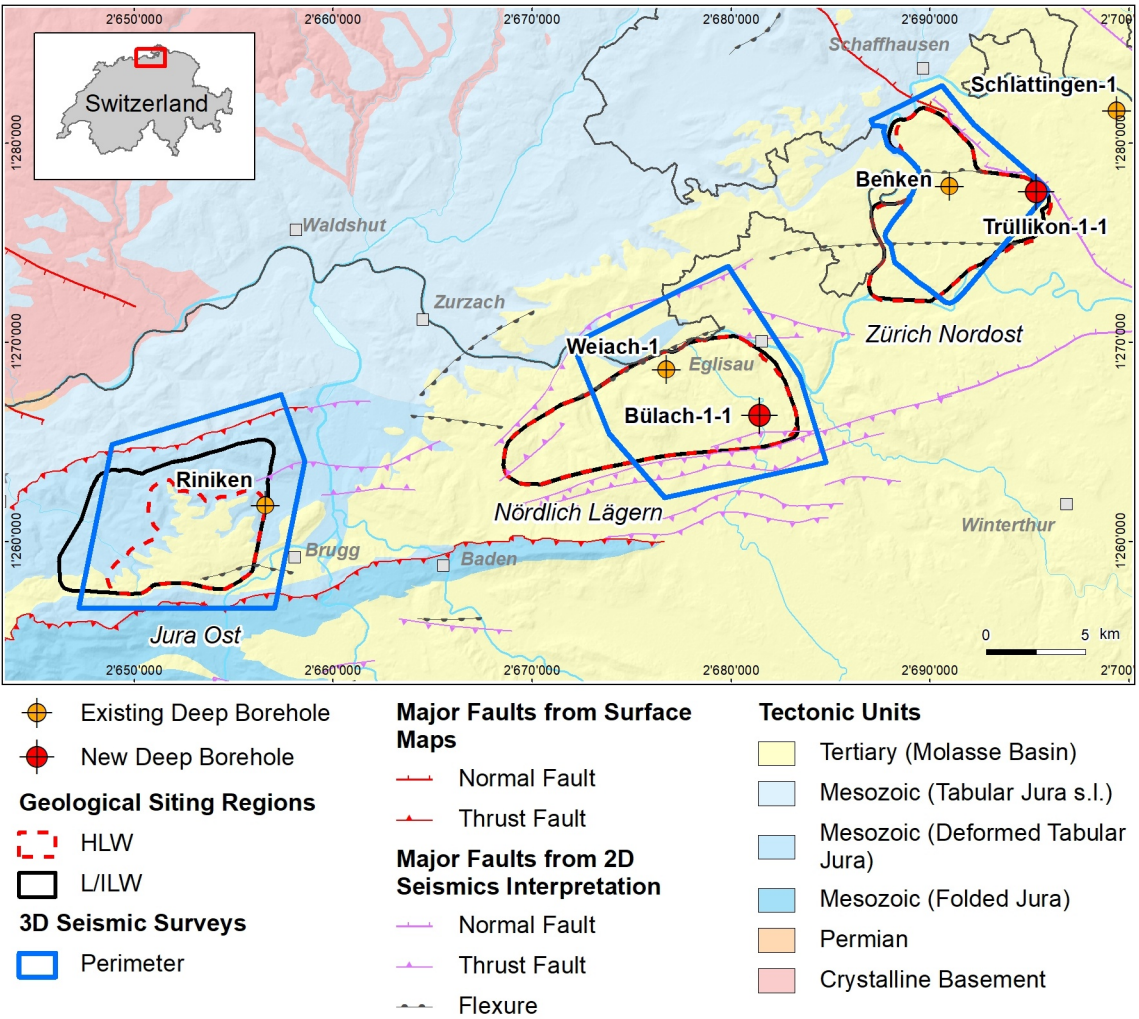


Fig. 1-1: Tectonic overview map with the three siting regions under investigation

1.2 Location and specifications of the borehole

The Trüllikon-1-1 (TRU1-1) exploratory borehole is the second borehole drilled within the framework of the TBO project. The drill site is located in the eastern part of the Zürich Nordost siting region (Fig. 1-2). The vertical borehole reached a final depth of 1'310 m (MD)¹. The borehole specifications are provided in Tab. 1-1.

Tab. 1-1: General information about the TRU1-1 borehole

Siting region	Zürich Nordost
Municipality	Trüllikon (Canton Zurich / ZH), Switzerland
Drill site	Trüllikon-1 (TRU1)
Borehole	Trüllikon-1-1 (TRU1-1)
Coordinates	LV95: 2'695'372.648 / 1'277'548.076
Elevation	Ground level = top of rig cellar: 475.07 m above sea level (asl)
Borehole depth	1'310.0 m measured depth (MD) below ground level (bgl)
Drilling period	15. August 2019 – 5. April 2020 (spud date to end of rig release)
Drilling company	PR Marriott Drilling Ltd.
Drilling rig	Rig-16 Drillmec HH102
Drilling fluid	Water-based mud with various amounts of different components such as ² : 46 – 712 m: Pure-Bore® 712 – 1'161 m: Potassium silicate 1'161 – 1'310 m: Sodium chloride brine
Application (Sondiergesuch)	NSG 16-11 (Nagra 2016) of 26. September 2016
Official permit	17. August 2018
Drill site construction period	22. October 2018 – 02. July 2019
Drill site civil engineer	SWR+, Schöneeggstrasse 30, 8953 Dietikon
Drill site executing company	Landolt + Co. AG Bauunternehmung, Schaffhauserstrasse 10, 8451 Kleinandelfingen
Drilling rig up	01. July 2019 – 15. August 2019

The lithostratigraphic profile and the casing scheme are shown in Fig. 1-3. The comparison of the core versus log depth³ of the main lithostratigraphic boundaries in the TRU1-1 borehole is shown in Tab. 1-2.

¹ Measured depth (MD) refers to the position along the borehole trajectory, starting at ground level, which for this borehole is the top of the rig cellar. For a perfectly vertical borehole, MD below ground level (bgl) and true vertical depth (TVD) are the same. In all Dossiers depth refers to MD unless stated otherwise.

² For detailed information see Chapter 5.

³ Core depth refers to the depth marked on the drill cores. Log depth results from the depth observed during geophysical wireline logging. Note that the petrophysical logs have not been shifted to core depth, hence log depth differs from core depth.

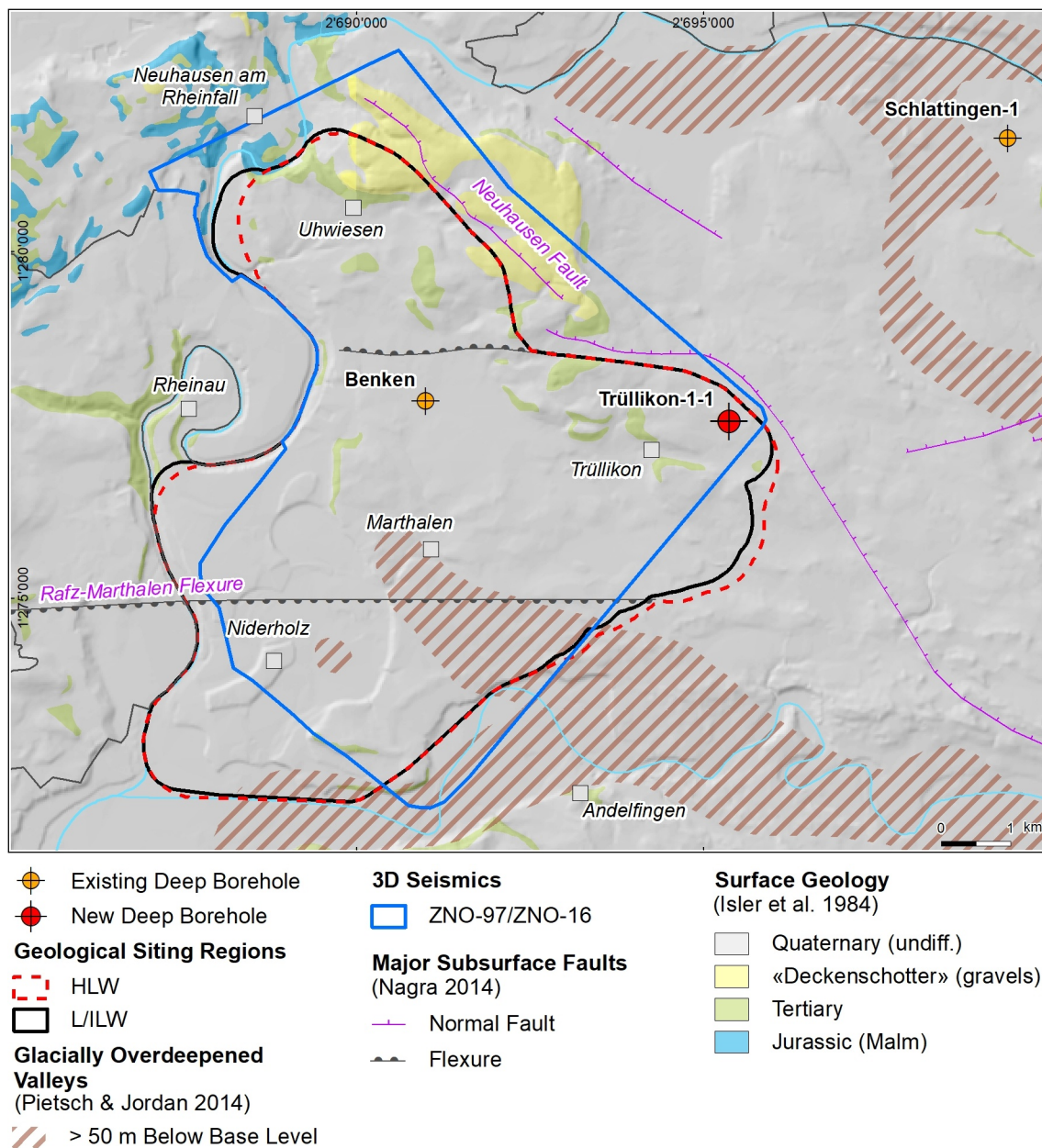


Fig. 1-2: Overview map of the investigation area in the Zürich Nordost siting region with the location of the TRU1-1 borehole in relation to the boreholes Benken and Schlattingen

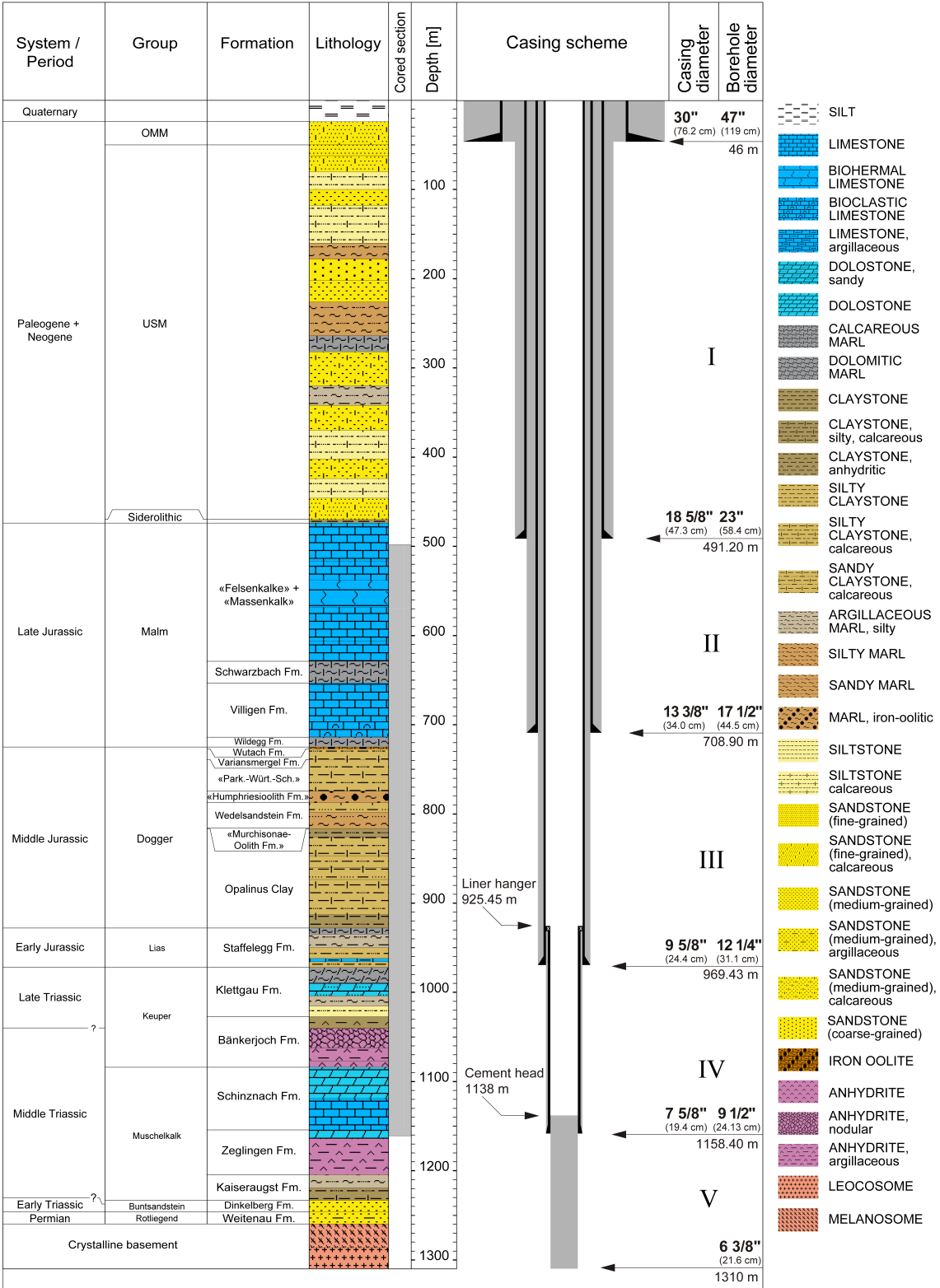


Fig. 1-3: Lithostratigraphic profile and casing scheme for the TRU1-1 borehole⁴

⁴ For detailed information see Dossier I and III.

Tab. 1-2: Core and log depth for the main lithostratigraphic boundaries in the TRU1-1 bore-hole⁵

System / Period	Group	Formation	Core depth in m (MD)	Log
Quaternary				
			24.0	—
Paleogene + Neogene	OMM		50.0	—
	USM		470.0	—
	Siderolithic		474.0	—
		«Felsenkalke» + «Massenkalk»		
	Malm	Schwarzbach Formation	628.87	628.75 —
		Villigen Formation	653.29	653.15 —
		Wildegge Formation	714.00	714.00 —
		Wutach Formation	724.85	725.03 —
		Wutach Formation	727.13	727.27 —
		Variansmergel Formation	738.97	739.06 —
Jurassic		«Parkinsoni-Württembergica-Schichten»	774.55	774.66 —
	Dogger	«Humphriesioolith Formation»	787.50	787.55 —
		Wedelsandstein Formation	815.51	815.50 —
		«Murchisonae-Oolith Formation»	816.42	816.43 —
		Opalinus Clay	927.91	927.87 —
	Lias	Staffelegg Formation	971.68	971.55 —
		Klettgau Formation	1027.22	1027.44 —
	Keuper	Bänkerjoch Formation	1084.01	1084.22 —
		Schinznach Formation	1154.25	1154.43 —
Triassic	Muschelkalk	Zeglingen Formation	1204.5	—
		Kaiseraugst Formation	1233.2	—
	Buntsandstein	Dinkelberg Formation	1246.1	—
Permian	Rotliegend	Weitenau Formation	1259.7	—
		Crystalline Basement	1310.0	final depth

⁵ For details regarding lithostratigraphic boundaries see Dossier III; for details about depth shifts (core goniometry) see Dossier V.

1.3 Documentation structure for the TRU1-1 borehole

NAB 20-09 documents the majority of the investigations carried out in the TRU1-1 borehole, including laboratory investigations on core material. The NAB comprises a series of stand-alone dossiers addressing individual topics and a final dossier with a summary composite plot (Tab. 1-3).

This documentation aims at early publication of the data collected in the TRU1-1 borehole. It includes most of the data available approximately one year after completion of the borehole. Some analyses are still ongoing (e.g. diffusion experiments, analysis of veins, hydrochemical interpretation of water samples) and results will be published in separate reports.

The current borehole report will provide an important basis for the integration of datasets from different boreholes. The integration and interpretation of the results in the wider geological context will be documented later in separate geoscientific reports.

Tab. 1-3: List of dossiers included in NAB 20-09

Black indicates the dossier at hand.

Dossier	Title	Authors
I	TBO Trüllikon-1-1: Drilling	M. Ammen & P.-J. Palten
II	TBO Trüllikon-1-1: Core Photography	D. Kaehr & M. Gysi
III	TBO Trüllikon-1-1: Lithostratigraphy	M. Schwarz, P. Jordan, P. Schürch, H. Naef, T. Ibele, R. Felber & M. Gysi
IV	TBO Trüllikon-1-1: Microfacies, Bio- and Chemostratigraphic Analyses	S. Wohlwend, H.R. Bläsi, S. Feist-Burkhardt, B. Hostettler, U. Menkveld-Gfeller, V. Dietze & G. Deplazes
V	TBO Trüllikon-1-1: Structural Geology	A. Ebert, S. Cioldi, L. Gregorczyk, S. Rust, D. Böhni & M. Gysi
VI	TBO Trüllikon-1-1: Wireline Logging and Microhydraulic Fracturing	J. Gonus, E. Bailey, J. Desroches & R. Garrard
VII	TBO Trüllikon-1-1: Hydraulic Packer Testing	R. Schwarz, L. Schlickenrieder, H.R. Müller, S. Köhler, A. Pechstein & T. Vogt
VIII	TBO Trüllikon-1-1: Rock Properties, Porewater Characterisation and Natural Tracer Profiles	L. Aschwanden, L. Camesi, T. Gimmi, A. Jenni, M. Kiczka, U. Mäder, M. Mazurek, D. Rufer, H.N. Waber, P. Wersin, C. Zwahlen & D. Traber
IX	TBO Trüllikon-1-1: Rock-mechanical and Geomechanical Laboratory Testing	E. Crisci, L. Laloui & S. Giger
X	TBO Trüllikon-1-1: Petrophysical Log Analysis	S. Marnat & J.K. Becker
	TBO Trüllikon-1-1: Summary Plot	Nagra

1.4 Scope and objectives of this dossier

The objective of this report is to provide a summary of the drilling operations, including rig site construction, casing tallies, cement bond quality, coring parameter and recovery.

The report is organised as follows:

- Chapter 1 presents the general overview of the drilling campaign and the vertical borehole TRU1-1.
- Chapter 2 describes the construction phase (prior to spud)
- Chapter 3 is dedicated to drilling technology
- Chapter 4 describes drilling operations and its chronology.
- Chapter 5 describes further drilling-related topics
- Chapter 6 discusses the health, safety and environmental topic.
- Finally, this report includes a set of appendices, which present relevant general project information and further investigation details.

1.5 Involved companies

The following companies were involved in the drilling activities of borehole TRU-1-1:

- Nagra
 - Drilling manager: project management, coordination and organisation of the drilling of the borehole, definition of test aims, quality control, technical supervision of all the drilling, coring, casing running, cementing, logging and testing operations performed in the borehole
 - Drilling engineer: technical supervision of all the drilling, coring, casing running, cementing, logging and testing operations performed in the borehole
 - Health safety & environment (HSE) manager
- Marriott's drilling contractor
- GEO-data GmbH: Mud logging and core handling
- Sirius-Austria: Mud engineering
- Fangmann Energy Services: Cementing service
- National Oilwell Varco (NOV): Liner hanger / packer systems
- Schlumberger (SLB) and SEMM logging: Wireline logging and testing
- Solexperts and Intera: Hydraulic and gas testing
- Deutsche Montan Technologie (DMT) GmbH & Co KG and SLB: Seismic service
- Well Engineering Partners BV (WEP): Night and day drilling supervisors and HSE specialist

2 Drill site construction and conductor pipe

Start of implementation

Prior to the work preparation, extensive soil profiles were taken based on a survey by the landowner. Nagra believed these site investigations to be advisable and they were carried out simultaneously with the technical examination. The previous soil profiles had shown that the humus thicknesses were significantly greater than the expected values. Therefore, an additional space requirement was created. In order to optimise costs and minimise the disturbance of the soil, only part of the drill site area was covered with geotextile and gravel. The remaining gravel was poured directly onto the turf. Nagra reduced their requirements for the ME value to 30 Nm/m².

In accordance with the authorities, the building permit was released in two stages by ENSI: stage one involved earthworks and stage two the in situ concrete construction of the drilling cellar.

Work preparation

The layout of the drill site was planned and prepared by Nagra with the assistance of the mandated civil engineering company swrplus AG, Dietikon.

Construction of site and standpipe

The construction of the drill site started on 22.10.2018 (Landolt + Co. AG construction company, Kleinandelfingen). swrplus AG was asked to also run the surface standpipe in preparation for the subsequent deep drilling operations. To run the standpipe, a subcontractor (Strabag) was hired. Furthermore, the mousehole had to be drilled. The standpipe was not drilled to the correct depth, and therefore the distance between the standpipe and the mousehole was off by several centimetres. For this reason, the cellar was adapted slightly to bring the standpipe and the mousehole back into one axis. The basic design of the drill cellar was not very suitable for the sub-contractors and had to be expanded with a steel structure and covered with steel plates and gratings. Optimum construction of the drilling cellar was difficult due to the removal of moist soil in autumn and the covering installation during cold weather in March.



Fig. 2-1: Trüllikon drill site with rigged up Marriott's rig 16

See Appendix C for images of the construction phase and technical drawings.

3 Drilling technology

The drilling operation combined wireline coring operations with rotary drilling operations.

The wireline coring string was driven from surface by the topdrive. To pull the core to surface, the drill string was kept in the hole and the inner core tube was pulled to surface with a catcher connected to a slick line. Compared with conventional coring this is much faster and the hole experiences less stress. With this method, short core sections (3 m) can be obtained in better quality without losing much time. Also, the handling of the cores is easier in terms of weight and time required at the surface. In difficult sections of the borehole individual core runs of less than one metre were drilled to increase the core gain and core quality.

A topdrive guided on the drilling mast was used by the drilling rig. For ecological reasons, this system was operated electrically by providing a separate electro-hydraulic main drive unit. The mud pumps were operated by electric frequency adjustable motors.

3.1 Technical data of the drilling rig

The drilling rig of the contractor Marriott was a Drillmec HH102 (102 t operational hook load) semi-trailer with telescopic mast. The draw works had a power of 447 kW. The hydraulic Drillmec topdrive was equipped with 447 kW drive system power (22.5 kNm torque with 140 rpm); mud pumps were two triplex pumps BAMCO F-1000 with a 735 kW power rating for each pump. Three shakers were used. One centrifuge and one flocculation unit were provided by the mud service company. An overview of the general drilling rig data can be found in Tab. 3-1 and a detailed description of the equipment in Appendix D.

Tab. 3-1: General drilling rig data

Rig	Type	Drillmec HH102
	Year of construction	2012
	Owner	MARRIOTT
Mast	Type	Telescopic in compliance with API 4F
	Mast height from ground level (GL)	26.80 m
	Drill floor elevation from GL	4.9 m (false rotary table 5.0 m)
	Max. pull up weight	100 t
	Sheaves of crown block	4
Drilling floor	Height	4.90 m
	Dimensions	4.40 m × 2.10 m
	Clear height under rotary beams	4.39 m

Tab. 3-1: Cont.

Topdrive	Type	Drillmec
	Torque 1, 2, 3	22'500 Nm, 14'500 Nm, 9'000 Nm
	Speed 1, 2, 3	140 rpm, 225 rpm, 360 rpm
	Max. pull up	100 t
	Max. pull down	20 t
	Stroke	16"
Rotary table	Type	Drillmec
	Opening	20½"
	Max. torque	1'000 kgm
	Max. speed	60 rpm
Mud pump	Mud pump 1	6¾ × 10" F-1000 Bamco
	Power input	1'000 HP
	Pressure max.	176 bar with 6½" piston, 345 bar with 4" piston
	Pump rate max.	1'760 l/min with 6½" piston, 783 l/min with 4" piston
	Stroke	10"
	Stroke per minute max.	150
	Mud pump 2	6¾ × 10" F-1000 Bamco
	Power input	1'000 HP
	Pressure max.	176 bar with 6½" piston, 345 bar with 4" piston
	Pump rate max.	1'760 l/min with 6½" piston, 783 l/min with 4" piston
	Stroke	7"
	Stroke per minute max.	150
Drill pipe	DP wireline coring	97 × 5½" SK N80/P110 29 kg/m Nagra, 82 × 5" G105 premium G105 19.5 ppf, 55 jts 3½" DP, 15 × 5" HWDP 73.4 kg/m, 9 × 3½" HWDPs 37.7 kg/m
	DC	12 × 8", 12 × 6¾", 10 × 4¾"
Diesel consumption		80 – 120 €/1'000 HP/hr dependent upon drilling activities

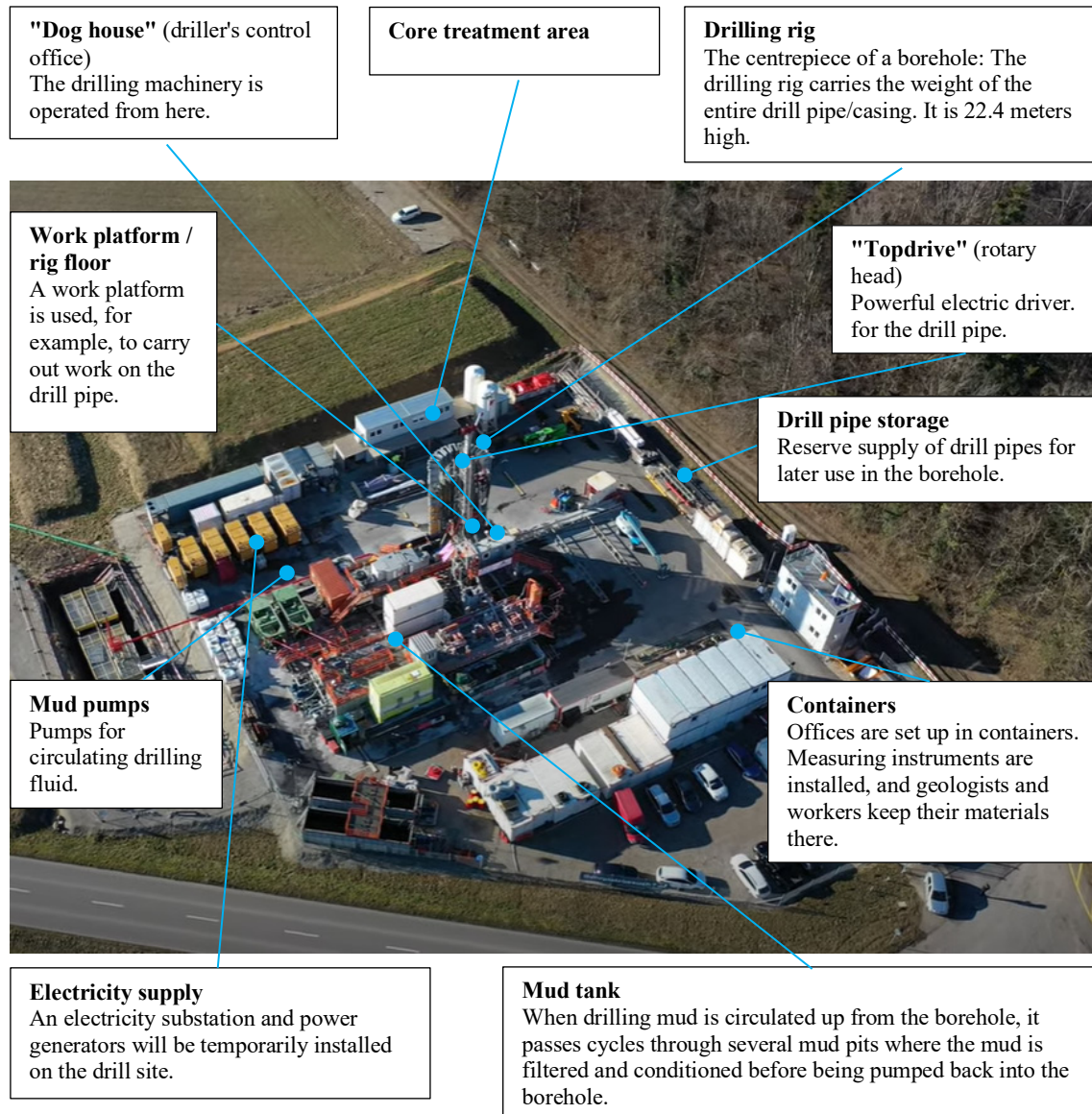


Fig. 3-1: Drilling rig

3.2 Drilling tools

3.2.1 Drill string and wireline coring string

Two different drill strings were used for the TRU1-1 borehole. A 5½" wireline coring string (SK 5½" B, N80) from the manufacturer MICON-Drilling GmbH was mainly used for coring operations (see Appendix H) and a 5" drill string (G105, #19.5) was mainly used for destructive drilling, hole opening and drilling out cement and float equipment.

Wireline core barrels were used to ensure complete recovery of the cores without pulling out the drill string. This technique speeds up core retrieval, reduces time-consuming drill rod handling and helps to maximise coring efficiency. The catching assembly is attached to a wireline winch system and lowered into the wireline drill string. The overshot securely interlocks with the latching head. Subsequently, the core-filled inner tube system can be hoisted out through the wireline drill string.

The wireline coring system used for the TRU1-1 borehole consisted of a core bit, inner and outer core barrels, core catcher, core pipes, stabilisers as well as crossovers and other spare parts and consumables. The drilling diameter was 6¾" (161.9 mm) resulting in a core diameter of 95 mm. All cores were drilled with plastic liners for protection and higher quality of the cores. These plastic liners allowed simplified handling of the cores, eliminating mechanical impacts such as hammering or pumping out the core from the inner core barrel. It enabled transport of the cores to the core handling table in one piece. The core was then removed from the plastic liner by pushing it out by hand or cutting the liner along the longitudinal axis. Core lengths up to 6 m could be reached with the wireline coring system, but to decrease the exposure time of the core in the drilling fluid and during sampling, the core length was set to 3 m.

Compared to conventional drill pipes, the wireline coring pipes with an average length of 9 m have slick tool joints, which means that the outer diameter of the pipe body and the tool joint are identical. Tool joints have no shoulders and the diameter of 5½" is the same along the entire drill string. This prevents flow restrictions and improves hole cleaning during coring within the small annulus between the formation and the coring string.

For drilling operations other than coring, conventional 5" drill pipes were used as they have standard connections which makes assembling the BHA much easier compared to the coring string, which has non-standard connections. The outer diameter of the tool joint is larger (168 mm) than the body of the 5" drill pipe to accommodate the threads. Furthermore, these shoulders provide stiffness to prevent bending and breaking. Due to the large diameter at the tool joint, the 5" drill pipes with an average length of 9.6 m did not fit into the 6¾" borehole.

3.2.2 Coring bits

The 5½" wireline coring string allows to use 6¾" (161.9 mm) core bits; the core barrel OD (outer diameter) is 152.4 mm with a core diameter of 95 mm. Three different types of core bits (see Fig. 3-2) were used in the TRU1-1 borehole:

- Thermally stable diamond (TSD) core bit, also called "Synset":

This type of core bit is designed for medium hard to hard and medium abrasive formations. TSD cutters consist of multiple layers of synthetic diamond fragments. This feature gives TSD cutters a self-sharpening property.

- Diamond-impregnated matrix core bit:

This type of core bit is designed for medium hard to extremely hard formations, but also for less abrasive to very abrasive rocks. Multiple layers of synthetic diamond fragments are sintered into a hard metal matrix. This compound has self-sharpening properties during progressive abrasion. Worn diamonds are released and replaced by new ones until the matrix compound is completely eroded. This core bit is available with different types of matrix.



Fig. 3-2: Synset core bit (left) and impregnated core bit (right)

Pictures including comments of selected bits after POOH are available in Appendix H.

3.2.3 Tricone bits

The tricone bit is by far the most common bit type used in rotary drilling operations. They are available with a large variety of tooth designs, bearing types and nozzle designs. They have three roller cutter cones with a series of teeth that crush the rock on the rock face as they roll across their face. Because of the bearings used for every cone, the revolutions for such a bit are limited. There are different types available with either longer or shorter teeth, and wider or closer placement of teeth for different levels of hardness of the drilled formation. Furthermore, the teeth can have milled teeth for softer formations or tungsten carbide insert teeth for harder formations. The teeth are cleaned by hydraulic nozzles.

The 23" section of TRU1-1 was drilled with two tricone bits.

The hard formations drilled in the upper hole section of TRU1-1 required short teeth, which needed sufficient weight to crush the rock. Because of the short drill string length below the rotary table, the weight exerted onto the drill bit by the drill collar was limited. In the beginning the drilling ROP (rate of penetration) was thus restricted by the available WOB (weight on bit).

The first bit had to be pulled at 229 m because of low ROP, was found balled up, cleaned and rerun. After 194 hours the lifetime of the bearings had already been reached and the bit was pulled because of bit revolutions. Back at the surface, the bit was graded with 0-1-WT-G-E-I-BT-HR (see Appendix J: IADC bit dull grading).

The second 23" bit managed to drill to the end of the section at 493 m and was pulled without any wear with 0-1-WT-G-E-I-BT-TD.

After cementing the different casings (18 $\frac{5}{8}$ ", 13 $\frac{3}{8}$ " and 9 $\frac{5}{8}$ "), the float valve and cement in the casing had to be drilled out. This was done with 17 $\frac{1}{2}$ ", 12 $\frac{1}{4}$ " and 8 $\frac{1}{2}$ " tricone bits.

To enlarge the hole from 6 $\frac{3}{8}$ " coring diameter to a size suitable to run the casing, the borehole was opened with hole openers guided by tricone bits to prevent a new wellbore path being cut when running the hole opener.

The last section of the well Trüllikon-1-1 was not cored, it was drilled with Rotary BHA and tricone bits. Because 6 $\frac{3}{8}$ " is not a standard drilling size, the stabilisers had to be grinded down and were not under-gauged causing the bit to hang up, creating cutting with the stabiliser, so that identification of the crystalline formation was not easy getting red cuttings from Rotliegend with stabiliser offset from bit on the shakers. The open hole section from 1'123 to 1'310 m was drilled with three tricone bits. First bit was tripped at 1'167 m because ROP was low. The bit grade was 8-2-LC3-LT3-F-1/16-NO-TD. Means the bit was already $\frac{1}{16}$ " under gauged with full gauged stabilisers above. The second bit drilled 113 m and was pulled with low penetration rate and graded 3-0-LT-N-8-F-I-RP. For the last two runs, a mud motor from MICON was picked up because without motor the string stalled out and with more than 60 rpm from surface stick slip occurred. With two runs the section was drilled to TD. The stabiliser has lost hard metal from the blade and was singled out for the last BHA.

3.2.4 Hole opening tools

Staged hole openers (SHO) were used to enlarge the existing borehole to the required diameter for casing running and cementing, mostly in steps from 6 $\frac{3}{8}$ " to 8 $\frac{1}{2}$ " and from 8 $\frac{1}{2}$ " to 12 $\frac{1}{4}$ ". By relieving stress from the formation with this intermediate stage, larger-hole drilling can be done at a more aggressive ROP. These SHO run with a bullnose or a pilot bit of the same size as the existing borehole at the bottom, which serves as guidance for the enlarged hole. The pilot section of the SHO itself (lower part of the SHO) consists of one or two rows of cuttings structures to recondition the pilot hole and remove any swelling clays or loose material. Gauge pads provide initial stabilisation as the SHO begins the staged reaming process to reduce stick / slip, whirling or off-centre tendencies. The lower cutters of the SHO are designed to minimise work rates on each cutter position for maximum durability. This part of the SHO recentralises the SHO on the given vertical borehole trajectory. The main body of the SHO completes the final hole diameter. With the formation being already stress-relieved, the reaming section remains aggressive even in more competent formations. Gauge trimmers and spiralled gauge pads ensure good hole quality. For examples of staged hole openers see Appendix H-3.

Besides the drilling and hole opening bits, a well-stocked supply of various stabilisers, drill collars, heavy weight drill pipes and other BHA (bottom hole assembly) components was kept on-site to be able to arrange suitable BHA setups for the planned work steps. Appropriate BHA designs are of great importance in drilling operations to effectively load and control the drill bit.

Tab. 3-2: Table with bit runs

Run Nr.	OD inch	Ser.Nr-	Type IADC code	Producer	Jets '1/32	Footage	Rotation	ROP	Date in	Depth			Date out	Total-footage	Total-hours	Depth	Condition	Remarks
						[m]	[hrs]	[m/h]		[in]	[out]	[m]						
1	23"	D 266286	435	NOV	3 × 20	189.00	129.45	1.46	15/08/2020	40.00	229.00	189.00	21/08/2019	189.00	129.45	229.00	01-WT-G-E-I-NO-PR	
2	23"	D 266286	435	NOV	3 × 20	103.40	65.00	1.59	21/08/2020	229.00	332.40	103.40	25/08/2020	292.40	194.45	332.40	0.1-WT-G-E-I-BT-HR	Change bit
3+4	23"	D 266120	435	NOV	3 × 18	160.6	118.3	1.36	25/08/2020	332.40	493.00	160.60	31.08.20219	160.60	118.30	493.00	0-1-WT-G-E-I-BT-TD	
5	17½ "	D 188410	115	NOV	3 × 22	19.00	6.5	2.92	09/09/2019	479.00	498.00	19.00	10/09/2019	19.00	6.50	498.00	2-2-WT-A123-E-I-NO-TD	Drill out cement shoe, collar
6	6¼"	67435	Ballas Set	MICON	N/A	6.00	3.75	1.60	12/09/2019	498.00	504.00	6.00	13/09/2019	6.00	3.75	504.80	1-1-WT-A-X-I-BHA	
6	6¼"	67435	Ballas Set	MICON	N/A	1.18	7.00	0.17	13/09/2019	504.00	505.18	1.18	13/09/2019	7.18	7.00	505.18	1-2-WT-A-X-I-RP	Side track
7	12¼"	D 263285	117	NOV	3 × 2	3.50	6	0.58	15/09/2019	498.00	501.50	3.50	16/09/2019	3.50	6.00	501.50	0-0-NO-E-I-NO-BHA	Hole opening 6¼" to 12.25"
8	8½"	32357	325	Reed hycalog	3 × 18	3.50	4	0.88	16/09/2019	501.50	505.00		16/09/2019	3.50	3.50	505.00	1-1-WT-A123-E-I-RP	Center hole punching
9			MAGNET															
10	8½"	32357	325	Reed hycalog	3 × 18	0.00	0	0.00	17/09/2019	505.00	505.00	0.00	17/09/2019	3.50	3.50	505.00	1-1-WT-A123-E-I-TD	Reaming and check trip
11	6¼"	67435	Ballas Set	MICON	N/A	7.82	22.5	0.35	19/09/2019	505.18	513.00	7.82	20/09/2019	15.00	29.50	513.00	2-3-WT-A-X-I-RP	
12	6¼"	67443	Imp. Gold	MICON	N/A	87.00	33.5	2.60	21/09/2020	513.00	600.00	87.00	24/09/2019	87.00	33.50	600.00	1-2-WT-A-X-I-BHA	
12	6¼"	67443	Imp. Gold	MICON	N/A	80.00	42.5	1.88	01/10/2019	600.00	680.00	80.00	05/10/2019	167.00	76.00	680.00	4-4-WT-A-X-I-RP	
13	6¼"	67435	Ballas Set	MICON	N/A	1.50	2.5	0.60	06/10/2019	680.00	681.50	1.50	06/10/2019	168.50	78.50	681.50	6-6-BT-A-X-I-RP	Segments broken
14	6¼"	67447	Imp. Gold	MICON	N/A	30.50	13.5	2.26	06/10/2019	681.50	712.00	30.50	07/10/2019	30.50	13.50	712.00	2-2-WT-A-X-I-TD	
	6¼"	226575	tricone	NOV	3 × 12	207.00	34.5	6.00	18/10/2019	505.00	712.00	207.00	19/10/2019	207.00	34.50	712.00	0-0-NO-E-I-NO-TD	Hole opening to 8½"
17	8½"	A1/A266713	Hole opener	NOV	5 × 13	206.00	34.5	5.97	18/10/2019	505.00	711.80	206.80	19/10/2019	206.00	34.50	712.00	OK	Hole opening to 8½"
	8¼"	261422	Tricone	NOV	3 × 18	210.30	37.5	1.00	19/10/2019	501.50	711.80	210.30	21/10/2019	210.30	37.50	712.00	1-1-NO-E-I-NO-TD	Pilot bit
18	12¼"	266794	Hole opener	NOV	5 × 14	209.20	37.5	1.00	19/10/2019	501.50	710.70	209.20	21/10/2019	209.20	37.50	712.00	OK	Hole opening from 8 ½" to 12 ¼"
	12¼"	D 263285	117	NOV	3 × 16	210.50	91.5	1.00	21/10/2019	501.50	712.00	210.50	25/10/2019	214.00	95	712.00	1-0-WT-A123-E-I-NO-TD	Pilot bit
19	17½"	IBH-19-175-1	Hole opener	NOV	3 × 20	212.65	91.5	1.00	21/10/2019	498.00	710.65	212.65	25/10/2019	212.65	91.5	710.65	Cutters broken crap	Hole opener 12¼" to 17½"
21	8½"	32357	325	Reed hycalog	3 × 18	23.20	12	1.93	14/11/2019	696.80	720.00	23.20	14/11/2019	26.70	16.00	720.00	2-2-WT-A123-E-I-NO-TD	Drill out shoe, collar and 5 m formation

Tab. 3-2: Cont.

Run Nr.	OD inch	Ser.Nr-	Type IADC code	Producer	Jets '1/32	Footage	Rotation	ROP	Date in	Depth			Date out	Total-footage	Total-hours	Depth	Condition	Remarks
22	6½"	67445	Imp. Gold	MICON	N/A	0.06	6.25	0.01	17/11/2019	720.00	720.06	0.06	17/11/2019	0.06	6.25	720.06	8-8-BT-A-X-1/16-WT-RP	Broken matrix
23+24	6½"	67439	Ballas Set	MICON	N/A	101.94	92	1.11	17/11/2019	720.06	822.00	101.94	25/11/2019	101.94	92.00	822.00	8-7-WT-A-X-I-CT-RP	
25+26	6½"	67437	Ballas Set	MICON	N/A	4.60	4	1.15	08/12/2019	822.00	826.60	4.60	08/12/2019	4.60	4.00	826.60	1-1-HC-A-X-I-CT-BHA	Burned matrix
27-30	6½"	67916	Ballas Set	MICON	N/A	147.40	108.5	1.36	09/12/2019	825.60	973.00	147.40	17/12/2019	147.40	108.50	973.00	5-7-WT-A-X-I-TD	
	6½"	226575	Tricone	NOV	3 × 12	253.00	45.2	5.60	12/01/2020	720.00	973.00	253.00	14/01/2020	207.00	79.70	973.00	1-1-WT-A123-E-I-NO-TD	Pilot bit
31	8½"	A1/A266713	Hole opener	NOV	5 × 13	253.00	45.2	5.60	12/01/2020	720.00	973.00	253.00	14/01/2020	459.00	79.70	973.00	2 PDC Cutters Chipped	Hole opener
	8½"	261422	Tricone	NOV	3 × 18	261.00	64.25	4.06	14/01/2020	712.00	973.00	261.00	17/01/2020	471.30	101.75	973.00	1-2-WT-A123-E-I-NO-TD	Pilot bit
32	12½"	266794	Hole opener	NOV	5 × 14	261.00	64.25	4.06	14/01/2020	712.00	973.00	261.00	17/01/2020	470.20	101.75	973.00	Cutters broken scrap	Hole opener 12½" to 17½ "
33	8½"	32357	325	Reed hycalog	3 × 18	58.00	16.25	3.57	23/01/2020	920.00	978.00	58.00	24/01/2020	84.70	32.25	978.00	3-2-WT-A123-E-CT-TD	Drill out cement shoe, collar
34	8½"	67447	Imp. Gold	MICON	N/A	1.50	6.5	0.23	26/01/2020	978.00	979.50	1.50	27/01/2020	37.00	20.00	979.50	5-7-CT-A-X-I-WT-RP	Broken matrix
35	6½"	67308	Ballas Set	MICON	N/A	13.20	20.75	0.64	27/01/2020	979.50	992.70	13.20	28/01/2020	13.20	20.75	992.70	5-8-WT-A-X-I-CT-RP	
36+37	6½"	67692	Surface set	MICON	N/A	42.30	48	0.88	29/01/2020	992.70	1035.00	42.30	02/02/2020	42.30	48.00	1035.00	4-4-WT-A-X-1/16-NO-RP	Flat diamond
38	6½"	67311	Imp. Gold	MICON	N/A	15.00	17	0.88	08/02/2020	1035.00	1050.00	15.00	09/02/2020	17.00	15.00	1050.00	2-1-WT-A-1/16-NO-BHA	Core under gage
39	6½"	67621	Ballas Set	MICON	N/A	24.00	32.5	0.74	10.02.2020	1050.00	1074.00	24.00	13/02/2020	24.00	32.50	1074.00	4-3-WT-A-X-I-CT-RP	Wrong bit
40+41	6½"	67623	Imp. Gold	MICON	N/A	87.00	57.25	1.52	13/02/2020	1074.00	1161.00	87.00	18/02/2020	87.00	57.25	1161.00	4-5-CT-A-X-I-WT-TD	OK
	6½"	226575	tricone	NOV	3 × 12	183.00	21	8.71	07/03/2020	978.00	1161.00	183.00	06/03/2020	390.00	100.70	1161.00	4-4-WT-A123-E-1/16-SD-TD	Pilot
42-45	8½"	A1/A266713	Hole opener	NOV	5 × 13	183.00	21	8.71	07/03/2020	978.00	1161.00	183.00	06/03/2020	642.00	100.70	1161.00	Some PDC cutters chipped	
47	6½"	733782	Tricone	Security	3 × 16	44.00	24	1.83	17/03/2020	1123.00	1167.00	44.00	21/03/2020	44.00	24.00	1167.00	8-2-LC3-LT3-F-1/16-NO-TD	Under gage
48	6½"	4378692/1	637	NOV	3 × 16	113.00	79.5	1.42	21/03/2020	1167.00	1280.00	113.00	26/03/2020	113.00	79.5	1280.00	3-0-LT-N-8-F-I-RP	
49	6½"	LP 7685	537	NOV	3 × 16	8.00	8	1.00	26/03/2020	1280.00	1288.00	8.00	27/03/2020	8.00	2.00	1286.00	1-1-WT-A123-E-I-RP	
50	6½"	LP 7685	537	NOV	3 × 16	22.00	20.4	1.08	27/03/2020	1288.00	1310.00	22.00	28/03/2020	30.00	22.40	1310.00	2-1-BT-M1-WT-A123-E - 3/16-TD	

4 Drilling operations

4.1 Overview

Drilling began on 15. August 2019 including the scientific investigations carried out in the borehole and continued until 05. April 2020. With a final depth of 1'310 m, the borehole passed through 1'259.7 m of sediments and 50.3 m of gneiss of the crystalline basement. The Opalinus Clay was found from 816.42 m to 927.91 m (111.49 m in thickness). Fig. 1-3 shows final casing schematics and formation tops. In Tab. 1-2 actual formation tops are represented. A detailed stratigraphy and lithology can be found in Dossier III (Lithostratigraphy).

The standpipe with 30" Outer Diameter (OD) to protect the ground water was run to 46 m and cemented during the rig site construction.

The borehole was drilled with three tricone bits (tooth bits) for the uppermost 493 m; the next two sections were continuously cored using wireline technique. Last section was drilled with 6 $\frac{3}{8}$ " Rotary BHA. The drilling rig used was a rotary drilling rig type Drillmec HH102 by Marriott's (Appendix D).

For the cored sections, core barrels with synthetic liners were almost exclusively used and core recovery was 99%. The main diameter drilled with core bit and the final diameter of the borehole were 6 $\frac{3}{8}$ " (161.9 mm). The cores have a diameter of 95 mm.

A total of three permanent casings and the anchor casing were installed in the borehole and the 18 $\frac{5}{8}$ " and 9 $\frac{5}{8}$ " casings were cemented up to ground level. The top of the cement behind the 13 $\frac{3}{8}$ " casing was found at 78 m (losses during cementation with cement density 1.88 SG). The 7 $\frac{5}{8}$ " liner was run with 45 m overlap to the 9 $\frac{5}{8}$ " casing and cemented successfully (see final casing schematics in the appendix E1).

The upper sections of the borehole down to the base of the Malm were drilled using a mixture of clay and freshwater as drilling fluid (Pure-Bore® mud system). Dogger till Keuper was drilled with potassium silicate mud, and the bottom section was drilled with a saturated brine for drilling through the salt horizon in the Muschelkalk and into the crystalline.

Once the final depth of 1'310.0 m was reached and the active borehole investigations were completed, the borehole was backfilled with cement approximately 20 m into the liner (shoe at 1'158.40 m) down to 1'138 m.

Work was completed in 234 $\frac{1}{2}$ working days (continuous 24 h operation) after spud-in followed by 22 days rig down. Scientific investigations in the borehole add up to 27.98% and the drilling activities including casing runs and cementation add up to 72.02% of the total time. The difference between the planned (175.25 days) and actual time equals 58.9 days. NPT (non-productive time) is in total 28.6 days, logging and hydraulic testing took 10.4 days and drilling 14.4 days longer than planned. Maximum amount of NPT was assigned to Marriott's equipment with 70% of NPT. Rig down took 12 days longer than planned.

Below the 18 $\frac{5}{8}$ " shoe, the well was unintentionally side-tracked, 135.5 h were spent to fix the problem zone below the shoe before coring was continued.

The welding of the wellhead after running the 13 $\frac{3}{8}$ " casing created 175.5 h NPT time.

While drilling the borehole in Malm, dynamic loss of 5.5 m³/h occurred. Losses stopped at 681 m during drilling with mud density 1.05 to 1.08 SG.

Stabilisers ordered for drilling the last section Rotary with 6³/₈" bit were not grinded proper to be under-gauged and caused hanging problems and even reamed the Rotliegend formation when drilling already into the crystalline basement.

Drilling chronology

The sequence of the work on the Trüllikon1-1 borehole is listed in Tab. 4-1 chronologically in keywords.

Tab. 4-1: Drilling chronology

Item	Start date	MD [m]	TVD [m]	Comments
Conductor		46	46	The 30" conductor was drilled and cemented prior to installing the rig
23" hole TD	15.08.2019	493	492.99	Drilled 23" hole to 493 m MD in three runs. Inclination of 0.57°
18 ⁵ / ₈ " casing	04.09.2019	491.2	491.71	Ran 18 ⁵ / ₈ " casing to 491.2 m MD. Landed casing with 55 t. Cemented casing to surface with a stab-in sub on 5" HWDP and 2 ⁷ / ₈ " tubing. Waiting on cement (WOC), install diverter system. Drill out cement to 501 m, formation integrity test (FIT), cement bond log (CBL)
6 ³ / ₈ " core section	12.09.2019	504.8	504.79	Cored with 6 ³ / ₈ " core bits to a depth of 504.8 m MD through a 7 ⁷ / ₈ " auxiliary casing set at 498 m MD. No rate of penetration (ROP)
12 ¹ / ₄ " drilling	15.09.2019	501.4	501.39	Laid down 7 ⁷ / ₈ " auxiliary casing and drilled 12 ¹ / ₄ " from 498 m to 501.5 m MD
8 ¹ / ₂ " drilling	16.09.2019	505	504.99	Drilled 8 ¹ / ₂ " from 501.5 m to 505 m MD, M/U and RIH 7" fishing magnet, RIH 8 ¹ / ₂ " BHA
6 ³ / ₈ " core section	19.09.2019	600	599.98	Cored with several 6 ³ / ₈ " core bits to a depth of 600 m MD through a 7 ⁷ / ₈ " auxiliary casing set at 498 m MD. Performed logging and hydraulic testing operations in open hole (OH)
6 ³ / ₈ " core section	01.10.2019	712	711.97	Cored with several 6 ³ / ₈ " core bits to a depth of 712 m MD through a 7 ⁷ / ₈ " auxiliary casing set at 498 m MD. Performed logging and hydraulic testing operations in OH. Pull out of hole (POOH) 7 ⁷ / ₈ " auxiliary casing
8 ¹ / ₂ " hole opening	17.10.2019	711.5	711.47	Opened 6 ³ / ₈ " hole to 8 ¹ / ₂ " hole
12 ¹ / ₄ " hole opening	19.10.2019	711.8	711.77	Opened 8 ¹ / ₂ " hole to 12 ¹ / ₄ " hole

Tab. 4-1: Cont.

Item	Start date	MD [m]	TVD [m]	Comments
17½" hole opening	21.10.2019	710.65	710.62	Opened 12¼" hole to 17½" hole
13⅜" casing	27.10.2019	708.9	708.87	Ran 13⅜" casing to 708.9 m MD. Cemented casing to surface with a stab-in sub on 5" HWDP and 2⅞" tubing. WOC, install CHH and blow out preventer (BOP). CBL log, run wireline (WL) VSP, welding wellhead, drill out shoe to 717 m MD, FIT, WL logs, mud exchange
6⅜" core section	17.11.2019	822	821.93	Cored with several 6⅜" core bits to a depth of 822 m MD through a 7⅞" auxiliary casing set at 719 m MD. Performed logging and hydraulic testing operations in OH
6⅜" core section	08.12.2019	973.2	972.04	Cored with several 6⅜" core bits to a depth of 973 m MD through a 7⅞" auxiliary casing set at 719 m MD. Performed logging and hydraulic testing operations in OH. POOH 7⅞" auxiliary casing
8½" hole opening	12.01.2020	973	972.86	Opened 6⅜" hole to 8½" hole
12¼" hole opening	14.01.2020	971.85	972.71	Opened 8½" hole to 12¼" hole. Inclination 1.97°
9⅝" casing	20.01.2020	969.43	969.29	Ran 9⅝" casing to 969.43 m MD. Cemented casing to surface with a two-stage cementing system, WOC, installed extra casing spool
6⅜" core section	26.01.2020	1'035	1'034.81	Cored with several 6⅜" core bits from 978 m to 1'035 m MD through a 7⅞" auxiliary casing set at 976.9 m MD. Performed logging and hydraulic testing operations in OH
6⅜" core section	07.02.2020	1'161	1'160.68	Cored with several 6⅜" core bits from 1'035 m to 1'161 m MD through a 7⅞" auxiliary casing set at 976.9 m MD. Performed logging and hydraulic testing operations in OH
8½" hole opening	27.02.2020	1'161	1'160.68	POOH auxiliary casing, pressurised the BOP. Opened hole from 6⅜" to 8½" from 978 m to 1'122 m MD. Wire line MDT tests, wiper trip. Wire line MDT tests and caliper log. Opened hole from 6⅜" to 8½" from 1'122 m to 1'161 m MD
8½" hole section	07.03.2020	1'161	1'160.68	9⅝" scraper run prior to ultrasonic imager tool (USIT) logging and running 7⅞" liner. Caliper run, tight hole. Check trip to bottom. Awaiting arrival of under reamer
8½" hole section	11.03.2020	1'161	1'160.68	Under reamed 8½" hole to 9½" hole and performed wireline caliper log, and check trip to bottom with 9½"

Tab. 4-1: Cont.

Item	Start date	MD [m]	TVD [m]	Comments
7½" liner	15.03.2020	1'158.40	1'158.08	Ran 7½" liner to 1'158.40 m MD (TOL 925.45 m). Cemented liner, WOC
6¾" section	28.03.2020	1'310	1'309.51	Drilled 6¾" hole to 1'310 m MD in three runs (two with motor)

4.2 Casing and sectional overview

The initially planned casing schematic was realised with a 9½" casing and no 7½" liner planned.

Appendix E shows the initially planned casing schematics. The 13¾" casing shoe depth changed from 885 m to 725 m MD. The 9½" shoe depth was moved from 1'195 m to 1000 m MD. By that it was possible to have the potential loss zone in Malm behind the 13¾" casing when drilling and testing Dogger and Lias. The mud window for breakouts and losses improved enabling to use higher mud weight and increase core quality in Dogger and Lias.

Tab. 4-2: Actual casing list

Diameter	Weight [ppf]	Connection	Depth from [m MD]	Depth to [m MD]	Length [m]
30" CSG S355	137.95	Welded	0	46.00	46.00
18½" CSG K55	94.5	BTC	0.00	491.2	491.2
13¾" CSG K55	68	BTC	0.00	708.90	708.90
9½" CSG K55	40	BTC	0.0	969.43	969.43
7½" Liner K55	29.7	BTC	925.45	1'158.40	232.95

Tab. 4-3 Actual borehole list

Diameter	Depth from [m MD]	Depth to [m MD]	rpm	Torque [daN·m]
23"	0	493.0	80 – 120	420 – 620
17½"	493.0	710.7	65 – 75	720 – 1'025
12¼"	709.0	973.0	70 – 80	520 – 1'100
8½"	973.0	1'122.0	70 – 90	350 – 1'300
6¾"	973.0	1'161.0	130 – 185	400 – 720
6¾"	1'158.4	1'310	30 – 250	370 – 1'300

The borehole was drilled almost vertically. The maximum measured inclination is 3.1° at 1'310 m MD.

4.3 Drilling by sections

Of the total time required to drill the borehole of around 234 days, approximately 69 days were spent for scientific research work.

4.3.1 Conductor

The conductor section has been drilled and completed during the well site building process.

4.3.2 Section I: 23" drilling to 493 m and 18½" anchor casing to 491.2 m

The 23" hole was drilled with BHA #1 with a roller cone bit (IADC 435) after drilling out the cement in the 30" conductor from 44 m to 46.5 m MD. A Pure-Bore® mud system with a density of 1.04 SG to 1.10 SG was used. The section was drilled with a progress of 25 m to 50 m per day. The following parameters were applied until the depth of 229 m MD was reached: 3 t to 7 t weight on bit (WOB), 80 rpm to 100 rpm, 550 daNm to 700 daNm torque (TQ), 1'700 lpm to 2'100 lpm, 30 bar to 47 bar. A check trip was performed, and the same bit was used again on BHA #2 to drill to a depth of 332.4 m MD with the same drilling parameters. During trip out and back in, no abnormalities were observed. A multishot survey showed an inclination of 0.39°.

BHA #3, with a new roller cone bit (IADC 435), was then made up and RIH until 313 m MD, washed down to 332.4 m MD. Drilling continued with the same parameters as before until 493 m MD. Mud density was increased from 1.10 SG to 1.18 SG and a progress variation of 24 m to 38 m per day was seen. It was difficult to achieve higher ROP because the available weight of the string was limited while drilling the top hole, and because the formations are very hard. Hole inclination was measured with 0.57°. During the trip out, no abnormalities were observed.

No major issues were recorded during the drilling operations for this section. However, the crew had to manage blockage in the flow line towards the shakers when the drilling mud carrying cuttings returned to surface. This blockage occurred because of the smaller size of the flow line which was unable to carry the cuttings. Therefore, for the umbilical setup for future rigs, the drilling contractor will ensure that the appropriate size of flow line is fitted.

The section to 493 m MD was drilled through the Aquitanian and the Chattian formations into the «Felsenkalk» + «Massenkalk» where the 18½" casing was set and cemented to surface.

On 19.08.2020, the suction line between the active and mix tank failed and mud spilled onto the drill site because the wrong gate valve was operated. The connection between active and mix tank moved out of position due to hydraulic thrust created from the closed valve (see Fig. 4-1).

Apart from this, the shakers overflowed with 1'200 lpm during drilling the 23" section.



Fig. 4-1 Connection between active and mix tank

4.3.3 Section II: 6 $\frac{3}{8}$ " Wireline coring to 712 m

Coring was carried out in 3 m sections and cores were retrieved with a wireline winch.

After waiting on cement (WOC) and cutting off the conductor and the 18 $\frac{5}{8}$ " casing, the casing head housing (CHH) was installed. The 21 $\frac{1}{4}$ " diverter system was then installed as well as the wear bushing set.

BHA #5 (17 $\frac{1}{2}$ " bit tricone IADC 115) was made up and RIH until 337 m MD. A pressure test was done on the 18 $\frac{5}{8}$ " casing to 40 bar. The BHA was continued to RIH till 450 m, washed down and tagged hard cement at 479 m. Hard cement was drilled from 479 m to 479.8 m MD with 3 t WOB, 100 rpm, 1'440 l/min and a drilled out float collar. Hard cement was drilled from 480 m to 491.2 m MD (18 $\frac{5}{8}$ " shoe).

The 18 $\frac{5}{8}$ " shoe at 491.2 m was drilled with erratic torque and tendencies to stall the TDS. Drilling parameters were varied to optimise progress. Pocket below 18 $\frac{5}{8}$ " shoe was drilled out to 493 m MD. New formation was drilled from 493 m to 498 m MD with 1'450 lpm, 35 bar, 50 rpm and 5 t to 8 t WOB. The mud system was changed to fresh Pure-Bore® mud with 1.09 SG. A formation integrity test (FIT) was performed at 491.2 m MD, pumped in steps up to 20 bar (80 l). The pressure was held for 10 min. The test was OK resulting in an equivalent mud weight (EQMW) of 1.51 kg/l.

After pull out of hole (POOH), BHA #5, Schlumberger performed the cement bond log (CBL). The wear bushing was then removed and the open-ended 7 $\frac{5}{8}$ " (29.7 lbs/ft K55 BTC) auxiliary casing was RIH and spaced out setting the 7 $\frac{5}{8}$ " shoe at 492.79 m. A 5 $\frac{1}{2}$ " SKB coring string BHA #6 with 6 $\frac{3}{8}$ " core bit was made up and RIH to 493 m. During the makeup of the coring string, the connections of the coring string were made up twice because they were new. Circulated bottom up, with 300 lpm and 14 bar to 17 bar. Conditioned mud tagged bottom at 498 m MD.

Cored from 489 m, in sections of 3 m and cores were retrieved with a wireline winch till drilled to 504.8 m. No progress was made because core jammed. Core #3 was pulled and laid down (total recovery approx. 6.5 m). It was observed that the borehole had been side-tracked. After some discussions, it was decided to make a centrepunch hole. POOH core BHA #6. In the attempt to engage the running tool to pull out the 7 $\frac{5}{8}$ " auxiliary casing, we had an NPT of 8 h. After finally engaging the running tool with the casing, it was pulled out to surface.

The wear bushing was set, and the 12 $\frac{1}{4}$ " BHA #7 was made up, RIH to 492 m MD and washed down to 498 m MD. A 12 $\frac{1}{4}$ " hole was drilled from 498 m to 501.5 m MD with 2.5 t to 3 t WOB, 1'600 lpm, 40 bar to 42 bar, 60 rpm to 70 rpm, TQ 330 daNm to 370 daNm. The 12 $\frac{1}{4}$ " BHA #7 was POOH with bit grading 0-0-0-A-E-I-NO-BHA. Then the 8 $\frac{1}{2}$ " BHA #8 (centre punch assembly) was made up and RIH to 495 m MD. It was washed down to 501.5 m MD without problems. A 8 $\frac{1}{2}$ " hole was drilled from 501.5 m to 505 m MD with 2 t to 3 t WOB, 1'390 lpm, 46 bar, 50 rpm. POOH BHA #8 without problems. Because it was mentioned by the drilling contractor that they had lost a 10 cm piece of centraliser while pulling out the 7 $\frac{5}{8}$ " auxiliary casing, it was decided to do a magnet run down the hole.

The 7" fishing magnet was made up and RIH, taking weight at 502.8 m in run #1. Circulation was established and the fishing magnet was washed down to bottom at 505 m MD, no fill. POOH 7" fishing magnet with no result. A 8 $\frac{1}{2}$ " bit on slick BHA #10 was made up and RIH until resistance was found (1.5 t) at 502.8 m MD. It was washed down to 505 m MD with 900 lpm, 15 bar, without resistance. The area between 501.5 m and 505 m MD was washed and reamed and POOH BHA #10. The wear bushing was retrieved and the 7 $\frac{5}{8}$ " auxiliary casing was RIH until shoe at 504.2 m MD.

BHA #11, a 5 $\frac{1}{2}$ " SKB coring string with a 6 $\frac{3}{8}$ " core bit, was made up and RIH to 498 m MD and washed down to 505 m MD. A 6 $\frac{3}{8}$ " hole was cored from 505 m to 513 m MD, the BHA was racked back to 495 m MD, and noise measurements were performed.

POOH BHA #11. The bit was changed and proper latch of inner core barrel was checked, all OK. BHA #12 was RIH to 505 m MD and washed to bottom at 513 m MD. Cored from 513 m to 600 m MD. After seeing some losses starting at 591.5 m MD, the borehole was observed for a while, and the BHA was pulled to surface. While preparing for the hydraulic testing, the borehole was observed via the trip tank and a static loss of 870 l in 7 hours was recorded.

A hydraulic testing programme was performed by Intera in the open hole section. The testing lasted for 121.6 h including RIH and POOH.

After the testing, BHA #13, a 5 $\frac{1}{2}$ " SKB coring string with a 6 $\frac{3}{8}$ " core bit was made up and RIH to 505 m MD and washed down to 600 m MD. No mud losses were observed.

A 6 $\frac{3}{8}$ " hole was cored from 600 m to 680 m MD, some small dynamic losses were observed in this section. POOH BHA #13, 50% wear and two cutters/segments sheared off the core bit were observed.

Made up and RIH coring BHA #14 to 655 m MD and washed to bottom at 680 m MD. No hole problems were observed. A 6 $\frac{3}{8}$ " hole was cored from 680 m MD to section TD at 712 m MD. POOH BHA #14 and prepared for logging.

Schlumberger performed wireline logging as per programme, the mud then was exchanged for freshwater, and Intera performed fluid logging as per programme. The borehole was stable during these operations.

Hole opening 8 $\frac{1}{2}$ ", 12 $\frac{1}{4}$ " and 17 $\frac{1}{2}$ " and 13 $\frac{3}{8}$ " casing to 708.87 m

This section was already cored to depth with a diameter of 6 $\frac{3}{8}$ " as in Section 3.2.3 and, after the testing of this section, the 7 $\frac{5}{8}$ " auxiliary casing was POOH and the wear bushing put in place. Note: No gas was observed/trapped underneath the hanger.

The coring BHA #16 was made up and RIH to 712 m MD, no restriction noticed. The borehole changed from freshwater to Pure-Bore® mud with specific gravity 1.04 SG, no gas readings were observed. POOH BHA #16.

The 8 $\frac{1}{2}$ " hole opener BHA #18 (6 $\frac{1}{8}$ " bit, 8 $\frac{1}{2}$ " hole opener, 6 $\frac{1}{4}$ " pony DC, 8 $\frac{1}{2}$ " stabiliser) was made up and RIH to 499 m MD bit depth. The existing 8 $\frac{1}{2}$ " hole was reamed from 498 m to 505 m MD. The 6 $\frac{3}{8}$ " hole was opened to a 8 $\frac{1}{2}$ " hole with 2070 lpm/52 bar, 75 rpm, 420 daNm TQ from 505 m till 711.15 m MD. POOH BHA #18.

The 12 $\frac{1}{4}$ " hole opener BHA #19 (8 $\frac{3}{8}$ " bit, 12 $\frac{1}{4}$ " hole opener, 6 $\frac{1}{4}$ " pony DC, 12 $\frac{1}{4}$ " stabiliser) was made up and RIH to 496 m MD bit depth, washed and rotated to 498 m MD. The 8 $\frac{1}{2}$ " hole was opened to a 12 $\frac{1}{4}$ " hole with 1 t to 2.5 t WOB, 2'260 lpm/36 bar, 60 rpm to 90 rpm, 650 daNm to 940 daNm TQ, from 498 m to 711.8 m MD (bit depth, hole opener at 710.7 m MD). POOH BHA #19.

The 17 $\frac{1}{2}$ " hole opener BHA #20 (12 $\frac{1}{4}$ " bit, 17 $\frac{1}{2}$ " hole opener, 6 $\frac{1}{4}$ " pony DC, 17 $\frac{1}{2}$ " stabiliser) was made up and RIH to 496 m MD bit depth, washed and rotated to 498 m MD. The 12 $\frac{1}{4}$ " hole was opened to a 17 $\frac{1}{2}$ " hole with 1.5 t to 3 t WOB, 2'600 lpm/49 bar, 55 rpm to 65 rpm, 500 daNm to 700 daNm TQ, from 498 m to 712 m MD (hole opener at 710.65 m MD). POOH BHA #20.

The borehole was stable during these operations.

4.3.4 Section III: 6 $\frac{3}{8}$ " wireline coring to 973 m

Coring was carried out in 3 m sections and cores were retrieved with a wireline winch.

After the 13 $\frac{3}{8}$ " casing was run, set and cemented, the well head and the 13 $\frac{5}{8}$ " blow out preventer (BOP) were installed and tested, the shoe was drilled out and virgin formation was drilled to 717 m MD with the 12 $\frac{1}{4}$ " BHA #21. A FIT was performed, and the Schlumberger logging was completed with EQMW = 1.7 kg/l.

The 8 $\frac{1}{2}$ " BHA #22 was RIH to 711 m MD, washed and rotated down to 717 m MD. The mud then was changed from Pure-Bore® to KSIL (potassium silicate mud). POOH BHA #22.

The wear bushing was then removed and the open-ended 7 $\frac{5}{8}$ " auxiliary casing (29.7 lbs/ft K55 BTC) was RIH, spaced out and hung off, setting the 7 $\frac{5}{8}$ " shoe at 719 m MD.

BHA #23, a 5½" SKB coring string with a 6¾" core bit was made up and RIH to 706 m MD and washed down 719.8 m MD. A 6¾" hole was cored from 720 m to 822 m MD (Top Opalinus Clay found at 816.42 m MD).

BHA #23 was POOH from 822 m MD to surface without any problems. Logging was performed by Schlumberger and the hydraulic testing programme was performed by Intera in the open hole section. Together, this lasted for 107.5 hours including RIH and POOH.

A check trip BHA (BHA #24) with a 6¾" core bit was made up and RIH to 785.5 m MD and washed down to 822 m MD. The mud was conditioned and the BHA was pulled out of hole again.

The Intera test assembly was then made up again and RIH to 805.67 m MD. Testing including assembly and disassembly took 130 h and, once the test assembly was out of the hole, Schlumberger performed a caliper run and the BOP was pressure tested.

A 6¾" core bit was made up and RIH to 813 m MD and washed down to 822 m MD. No hole fill was observed. The mud weight was increased from 1.13 SG to 1.20 SG and the open hole section was displaced to 1.20 SG. A 6¾" hole was cored from 720 m to 822 m MD. It was attempted to seat the inner barrel, with no success, because it was not possible to connect the wireline to pull out the core barrel. POOH BHA #29 solved the problem on the latching head. The core bit was changed because some cutters were damaged.

The BHA #30 (with preinstalled inner core barrel) was made up and RIH to 713 m MD. Circulation was broken and BHA washed down from 713 m to 822 m MD. No hole problems. Bit was bedded in and cored from 822 m to 825.6 m MD. The string was stalling out, stuck at the bottom. The string was worked, unable to rotate or circulate. (Note: because of this stuck pipe event, the bleed-off valve was inadvertently left open). Rotation was established, the string freed. Unable to regain circulation, the string was plugged. The BHA #30 was POOH and some burned cutters were found on the core bit, inner and outer gauge were OK.

A new core bit was made up on BHA #31 with pre-installed inner core barrel to 713 m MD, washed down to 825.6 m MD. The bit was bedded in and cored from 825.6 m to 826.8 m MD. Due to a core jam, the inner core barrel was POOH and a new one dropped. A 6¾" hole was cored from 826.8 m to 903 m MD. It was not possible to retrieve the core barrel with the wireline winch, the inner barrel was found tight. BHA #31 was POOH to surface and the core barrel retrieved. The core catcher was found stuck by a shackle nut inside the outer core barrel.

The BHA #31 was RIH with a pre-installed inner core barrel to 903 m MD. A 6¾" hole was cored from 903 m to section TD at 973 m MD. The BHA #31 was pulled out, Schlumberger performed logging operations and the Intera test string, BHA #32, was RIH to perform a hydraulic test on the formations. After the test string was removed from the borehole, Schlumberger performed their next programme of logging and sampling operations. Due to the length of time, a BOP p-test came in the middle of the tests and a check trip was performed with a 6¾" bit as BHA #33. The hole was in good shape and the mud was conditioned (potassium silicate) prior to POOH.

The Intera test string, BHA #34, was RIH. Intera continued with the hydraulic tests on the formations and the BHA was POOH after completion of the tests.

Again, a check trip BHA (#35) was made up and RIH to 720 m MD, washed down to 777 m MD and observed a tight hole. The hole was washed and reamed from 777 m to 973 m MD and tight spots were worked. On the way out some tight spots needed some attention.

After the string was removed from the hole, Schlumberger performed a short programme of logging and operations and, after finishing, the Intera test string, BHA #36 was RIH. Intera continued with the hydraulic tests on the formations and POOH after completion of the tests. The 7 $\frac{5}{8}$ " auxiliary casing was then pulled out to surface.

Note: No gas was observed/trapped underneath hanger.

8 $\frac{1}{2}$ " and 12 $\frac{1}{4}$ " hole opening and 9 $\frac{5}{8}$ " casing till 969.43 m

The 8 $\frac{1}{2}$ " hole opener BHA #37 (6 $\frac{1}{8}$ " bit, 8 $\frac{1}{2}$ " hole opener, 6 $\frac{1}{4}$ " DC, 8 $\frac{1}{2}$ " stabiliser) was made up and RIH to 707 m MD, washed and reamed to 720 m MD. The 6 $\frac{3}{8}$ " hole was opened to a 8 $\frac{1}{2}$ " hole with 1500 lpm to 1945 lpm, 35 bar to 57 bar, 80 rpm to 90 rpm, 520 daNm to 950 daNm TQ from 720 m to 973.2 m MD (bit depth). POOH BHA #37.

Made up 12 $\frac{1}{4}$ " hole opener BHA #38 (8 $\frac{1}{2}$ " bit, 12 $\frac{1}{4}$ " hole opener, 6 $\frac{1}{4}$ " DC, 12 $\frac{1}{4}$ " stabiliser) and RIH till 703 m end washed and reamed to 719 m and tagged bottom. Open 8 $\frac{1}{2}$ " hole to 12 $\frac{1}{4}$ " hole with 1'600 – 1'945 lpm, 35 – 48 bar, 40 – 50 rpm, TQ, 520 – 900 daNm from 719 m till 973 m (bit depth).

BHA #38 was POOH without any abnormalities. A BOP p-test and a scraper/brush run were performed in the 13 $\frac{3}{8}$ " casing in preparation for logging.

Schlumberger performed isolation scanner logging on the 13 $\frac{3}{8}$ " casing. A check trip was performed with BHA #40 (8 $\frac{1}{2}$ " bit, 12 $\frac{1}{4}$ " hole opener, 6 $\frac{1}{4}$ " DC, 12 $\frac{1}{4}$ " stabiliser) prior to run the 9 $\frac{5}{8}$ " casing.

4.3.5 Section IV: 6 $\frac{3}{8}$ " wireline coring to 1'161 m

Coring was carried out in 3 m sections and cores were retrieved with a wireline winch.

After the 9 $\frac{5}{8}$ " casing was run, set and cemented, the BOP was lifted and a 13 $\frac{3}{8}$ " $\times$ 7" 5M casing spool was installed and p-tested. Wear bushing was installed and, after waiting for the cement to become hard, the 8 $\frac{1}{2}$ " BHA #41 was made up and RIH to 588 m MD and washed down to 920.1 m MD (top of cement plug). Cement and shoe track were drilled out (shoe at 969.43 m MD). The rathole was cleaned out to 973 m MD and the new formation was drilled to 978 m MD.

A FIT was performed to 480 psi (33 bar) with 1.17 SG in the hole, EQMW 1.50 SG. BHA #41 was POOH and rigged up for logging. Schlumberger performed CBL logging on 9 $\frac{5}{8}$ " casing. The open-ended 7 $\frac{5}{8}$ " auxiliary casing (29.7lbs/ft K55 BTC) was RIH, spaced out and hung off, setting the 7 $\frac{5}{8}$ " shoe at 976.9 m MD.

BHA #42, a 5 $\frac{1}{2}$ " SKB coring string with a 6 $\frac{3}{8}$ " core bit, was made up and RIH to 884 m MD and washed down to 978 m MD. Cored from 978 m to 978.5 m MD. No progress was made, the core broke without overpull and the inner core barrel was retrieved. In core #171, 0.3 m core and two parts aluminium from the 9 $\frac{5}{8}$ " casing shoe were observed. A new inner barrel and catcher were prepared and pumped down.

Cored from 978.5 m to 979 m MD. No progress was made, the core broke without overpull and the inner core barrel was retrieved. In core #172, 0.54 m core and 10 smaller parts of aluminium from the 9⁵/₈" casing shoe were observed. A new inner barrel and catcher were prepared and pumped down.

Cored from 979 m to 979.54 m MD. No progress was made, the core broke without overpull and the inner core barrel was retrieved empty.

The 6³/₈" core BHA #42 was POOH from 979 m MD to surface and the core bit was renewed.

BHA #43 was RIH to 978 m MD and washed down to 978.5 m MD. A 6³/₈" hole was cored from 978.5 m to 992.7 m MD, with low ROP. The 6³/₈" core BHA #43 was POOH, the bit changed and the core BHA #44 was RIH.

A 6³/₈" hole was cored from 992.7 m to 1'008 m MD. A drill off test was performed with different parameters. It was attempted twice to retrieve the inner core barrel without success. The 6³/₈" core BHA #44 was POOH. A piece of core was found stuck in the core bit. The same core head was made up and the inner core barrel placed. BHA #45 was RIH to 974 m MD and washed down to 1'008 m MD. A 6³/₈" hole was cored from 1'008 m to 1'035 m MD. The 6³/₈" core BHA #45 was POOH to surface.

Schlumberger performed logging operations. The Intera test string BHA #46 was RIH and Intera performed a hydraulic test on the formations. After the test string was removed from the hole, a three-week BOP pressure test was performed. Coring was continued with 6³/₈" coring BHA #47 after it was RIH till 973 m MD and reamed down to 1'035 m MD.

A 6³/₈" hole was cored from 1'035 m to 1'050 m MD. Due to the incorrect diameter of the core, the core bit was pulled out on BHA #47. Some metal parts were found stuck in the bit, causing the incorrect diameter of the core. The operations were shut down for a while because of high winds.

The 6³/₈" BHA #48 was RIH with a new core bit to 975 m MD and reamed down to 1'050 m MD, 0.8 m fill were observed. A 6³/₈" hole was cored from 1'050 m to 1'074 m MD. No progress.

The 6³/₈" core BHA #48 was POOH to surface, the bit and the bottom stabiliser were changed.

The 6³/₈" BHA #49 was RIH to 973 m MD and reamed down to 1'074 m MD. A 6³/₈" hole was cored from 1'074 m to 1'161 m MD.

Seven petrophysical logging runs were performed by SLB. A wiper trip was performed with the coring BHA before the Intera test string BHA #51 was RIH. Intera continued with the hydraulic tests on the formations. The BHA was POOH because the upper packer was no longer sealing before all planned tests were completed. The surface reservoir for the upper packer ran out of fluid and nitrogen was pumped into the line. At the surface, the packer was leaking when pumping up with approximately 1 bar with a hand pump. The stick up of the 2⁷/₈" tubing with 1.5 m was too high to safely install the motor on the sucker rods. On future jobs the stick up needs to be adjusted to between 0.5 m and 1.0 m with the available pup-joints.

8½" / 9½" hole opening and 7⅝" liner to 1'158.40 m

The coring pipe was singled out, then the 7⅝" auxiliary casing was POOH. Pulling was only possible after circulation had been established; without circulation, the casing did not move with 88 t hook-load. BOP was pressure tested and Marriott 5" DP picked up to RIH BHA #52 with a 6⅜" bit (3 × 15) and a 8½" hole opener (5 × 13), 1 × DC and a 8⅜" string stabiliser. The BHA opened the hole from 978 m to 1'122 m MD. An initial SLB image log was performed, then the MHF tests with the MDT tool were performed. The tests showed that pressure was not released to zero bar and the string had to be pulled and was cleaned/maintained, resulting in 8.25 h NPT. After RIH, the priority was on the upper intervals to be tested. Overpull of 9'600 lbs was necessary at 1'107 m to 1'109 m MD to pull the string free. Somewhat later, the control valve to release pressure on the packer no longer functioned before the tests in the Lower Keuper could be performed and the string was POOH to surface, resulting in 4.25 h NPT. A wiper trip was performed without any indications of TQ or overpull. The SLB caliper log after the wiper trip showed no restrictions. Meanwhile, the MDT tools were double-checked, maintained and tested at surface before RIH again. Due to some problems with the tools, it was decided to perform a check trip while testing the wireline tools. BHA #53 was RIH with a 6⅜" bit (3 × 15) and an 8½" hole opener (5 × 13), 1 × DC and a 8⅜" string stabiliser. No resistance found in open hole. After this, a caliper log and an MDT run were performed.

BHA #54 was RIH with a 6⅜" bit (3 × 15) and a 8½" hole opener (5 × 13), 1 × DC and an 8⅜" string stabiliser. The BHA opened the hole from 1'122 m to 1'161 m MD.

BHA #55 (9⅝" scraper) was then RIH run prior to USIT and OH caliper logging and running 7⅝" liner. The caliper log showed that the hole was unstable under gauge (210 mm to 207 mm). A check trip with BHA #56, with a 6⅜" bit (3 × 15) and a 8½" hole opener (5 × 13), 1 × DC and an 8⅜" string stabiliser was performed while waiting on the arrival of the underreamer. The 8½" open hole was underreamed to 9½" with BHA #57, with an 8½" bit, a 9½" under-reamer, a 6½" DC, a 8½" string stabiliser, 11 × 6½" DC, 7 × HWDP. After this, the OH caliper log again showed some problem spots. The section was reamed again, BHA #58 (9½" under-reamer) was POOH and the 7⅝" liner was run to bottom without any major problems.

The 29.7 ppf, K-55 BTC 7⅝" casing was made up to 220.45 m MD, the liner hanger was installed and RIH without any issues to 1'153 m MD and washed down to 1'158.40 m MD. It was circulated while preparing for the cementation with 700 lpm/25 bar. The liner hanger was then set according to NOV operator advice. The liner set was confirmed, and the running tool released. The shoe depth was 1'158.40 m MD and the top of the PBR was at 925.45 m MD.

The liner was cemented with 3.5 m³ spacer (1.45 SG) and 4.1 m³ cement slurry (1.83 SG). The dart was released and displaced with 1 m³ freshwater spacer and 3.2 m³ mud (1.2 SG). The dart was sheared, and the bump was seen as calculated. P-test liner to 100 bar 7/20 min. The test was good. The packer was set with clear indications (2 shears). The cement head was removed, and the excess cement and spacer were circulated out. Setting tool was POOH.

4.3.6 Section V: 6⅜" open hole to 1'310 m and cement plug

After WOC, including working on the BOP, a 6⅜" TCI bit with IADC 537 was RIH with NB and two string stabilisers. The shoe track was drilled to 1'165 m MD and the hole was circulated clean. The drilling of the landing collar from 1'137 m to 1'137.7 m MD on 17.03.2020 took 10 hours. When the bit was at surface, it was found to be damaged – possibly from M/U or B/U without breaker plate or by drilling out the casing shoe. The potassium silicate mud was changed to brine (Pure-Bore®) mud. A formation integrity test (FIT) with 41 bar and EQMW 1.57 SG was

performed successfully, but after drilling the 6 $\frac{3}{8}$ " from 1'165 m to 1'167 m MD, the BHA was POOH due to low ROP. At surface, the bit was under gauge by $\frac{5}{32}$ " and the NB stabiliser showed that it already drilled formation. The next BHA was RIH with a new 6 $\frac{3}{8}$ " bit IADC code 637 and drilled from 1'167 m to 1'280.04 m MD. The reason to pull the bit was bit revs reached with 340 krevs. In the next BHA, the bit was changed to IADC 537, and a slick and straight 4 $\frac{3}{4}$ " motor was RIH with two stabilisers above. The motor was picked up to enable a wider range of surface rpm to reduce lateral vibrations. The BHA was RIH with a 4 $\frac{3}{4}$ " mud motor and drilled to 1'290.2 m MD. There was no longer any weight transfer (no differential pressure from the motor) and therefore no ROP. The BHA was pulled and all stabiliser L/D. The bit was under gauge by approximately $\frac{1}{8}$ ". The bit and motor were rerun and drilled to 1'310 m MD, the hole was circulated clean while a HiVis pill was swept around and L/D motor and bit ($\frac{3}{16}$ " under gauge) were POOH. Schlumberger performed an FMI and repeated pass 1'150 m to 1'309 m MD. VSP was performed as per programme and followed by petrophysical measurements, then an MDT and post MHF FMI log were run, before finally a USIT and CBL were run.

The hole was cemented back into the 7 $\frac{5}{8}$ " liner. TOC is 2.4 m above shoe at 1'138 m MD.

4.4 Time analysis

The project was initially planned for a duration of 175 days without rig down/up (see Appendix A). The project finally extended over 230 days and took 55 days longer than initially planned (see Appendix B). Non-productive time (NPT) accounted for 28.5 days, while 26.5 days were due to deviations from the plan. One reason, that the actual days were more than planned is the casing set – 9 $\frac{1}{2}$ " hole opening, but as well drilling 23" took 10.1 days longer than planned. Hydraulic tests lasted 8.5 days longer than planned. Drilling 6 $\frac{3}{8}$ " with Rotary BHA was slow because 6 $\frac{3}{8}$ " is an unusual hole size, and therefore the stabilisers were grinded down. The BHA hang up on the stabilisers and possible rate of penetration was decreased as well as one roundtrip was done to drop one stabiliser.

The total operational time for Trüllikon-1-1 was 5'620 h, with 1'572.75 h for logging and testing and 4'047.25 h for drilling, casing runs and cementation. Therefore, 72.02% of the operational time were spent on drilling, and 27.98% on testing and logging.

Total non-productive time (NPT) accounts for 685.25 h, which is 12.2% relative to the total project time; 70% of NPT was assigned to Marriott, 10% to SLB, 9% to Nagra, and 8% to Intera.

The main reason for NPT by Marriott were wellhead issues. Sidetracking accounted for 28% of NPT, coring equipment accounted for 17%.

5 Drilling related topics

5.1 Borehole deviation

The maximum measured inclination is 3.153° at 1'310 m MD (TD). The maximum dog leg severity (DLS) with $3.00^\circ/30$ m at 1'310 m MD was caused by a large turn of the WL tool with sag. At 1'290 m MD, the measured DLS was $1.7^\circ/30$ m. The definitive survey listing can be found in Appendix F of this report. Plan and section view showing deviation are shown in Figs. 5-1 and 5-2.



Fig. 5-1: Plan view TRU1-1

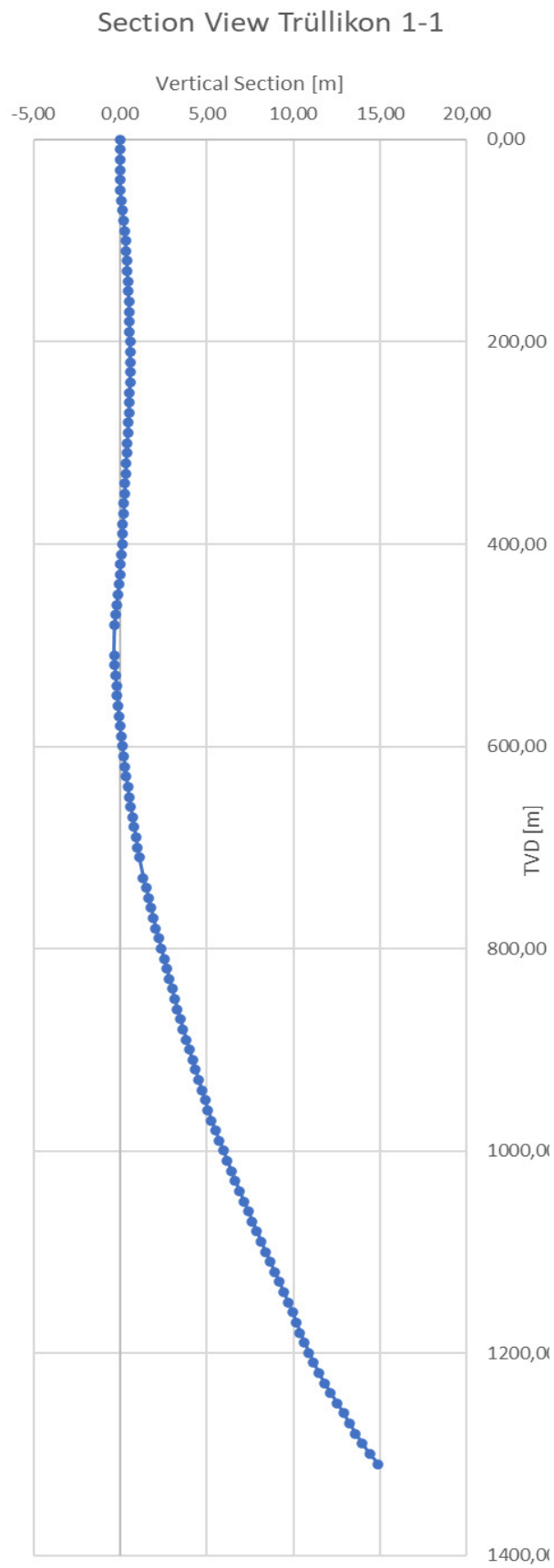


Fig. 5-2: Section view TRU1-1

5.2 Drilling fluids

The borehole consists of five sections. Sections III to IV were completely cored. In Section I and II a Pure-Bore® mud system was used; sections III and IV were completed using a highly inhibitive potassium silicate system. The performance of the systems met with expectations and operations were completed successfully, avoiding numerous issues encountered in the offset well. The last section was drilled with brine.

Pure-Bore® mud

- Freshwater as drilling fluid with polymers to maintain plastic viscosity and yield point.
- Pure-Bore® is a newly developed polymer, which supports the drilling fluid performance with viscosity, enhances inhibition and controls the API fluid loss.
- Pure-Bore® is a natural, biodegradable drilling agent approved for regions with water supply regulations.
- It provides exceptional clay and shale inhibition and as well acts as fluid loss agent, has a water hazard class = 0 and provides an enhanced borehole stability.
- It reduces the dilution factor and consequently the waste volume. Technically Pure-Bore® DF has in comparison to Bentonite DF an easy controlled viscosity (no necessity for dilution during drilling clay formations), enhanced hole stability (even in dispersed clay formations) and highly efficient hole cleaning in reduced circulation rates. The reason is the very high "Low-Shear Rate Viscosity" (LSRV).
- pH control by soda ash

Potassium silicate mud

- Silicate mud remains very stable, and in comparison with conventional WBM mud systems requires only sporadic treatments to maintain properties.
- Strong inhibitive properties of silicate ensured that even during drilling clay formations with very high content of reactive minerals cuttings did not stick to shaker screens. This enabled the use of extremely fine mesh (53 microns in case of API 270 screens), resulting in mud with minuscule content of drill solids.
- During routine tests, no bacteria presence was observed in the mud.
- Extra care must be taken to avoid contact of silicate mud with cement. Barite used as a spacer in front of cement works fine, however, there is place to improve considering separation of the tail part of the cement and mud; freshwater only seems insufficient to remove all residues and a wiper foam ball is insufficient if, for example, circulation has to be reversed. In each and every case surface piping needs to be thoroughly flushed with water with sufficient pressure to remove any cement residues.
- In case the formation is drilled containing gypsum and anhydrite, these formations are providing calcium ions to the potassium silicate mud. This leads to a faster depletion and precipitation of silicate providing the rheology and Low-Shear Rate Viscosity (LSRV) increasing, due to the active drilling fluid which has to be conditioned with freshwater and K-silicate to keep the mud rheology in proper range. To keep the proper mud rheology active, mud has to be treated continuously with water and silicate while anhydrite formation as well.

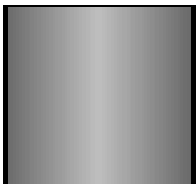
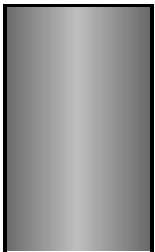
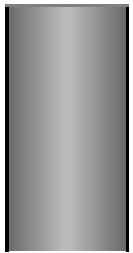
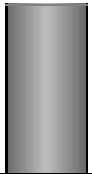
Salt saturated sodium chloride mud system

- Same polymers used as in the potassium silicate mud and Pure-Bore® to maintain plastic viscosity and yield point. Used when drilling salt sections to prevent creating caverns due to salt being dissolved in the mud fluid.

Tab. 5-1 and 5-2 show the different mud systems used for the different sections, mud density and planned/actual days per section.

Calcium carbonate in different particle size distributions is used as lost circulation material (LCM) to stop losses. The usage of different grain sizes and different concentrations of calcium carbonates will create a stable filter cake, which seals the bore wall and reduces/stops losses. H₂S might be a drilling hazard, and the drilling fluid needs to be tested on H₂S. In case of any traces of H₂S, at first stage the pH value should be raised to > 11 and, in agreement with the operator, H₂S scavenger shall be added to the fluid system.

Tab. 5-1: Mud properties by section

Hole size [in]	Casing size [in] Depth [m MD]	Casing programme	Planned depth [m MD] ([m TVD])	Actual depth [m MD] ([m TVD])	Length drilled [m]	Incl. [°]	Mud system density [SG]	Planned days	Actual days
23	18 ⁵ / ₈ 491.2		540	493	448	0.7	Pure-Bore® 1.01 – 1.1 0	20	28
17 ½	13 ³ / ₈ 708.90		885	709 (709)	219	1.0	Pure-Bore® 1.01 – 1.1 0	40	67
12 ¼	9 ⁵ / ₈ 969.43		1'195	973	261	2.7	K-silicate	30	69
8 ½	7 (liner) 1158.4		1'220	1'161	188	2.8	K-silicate	10	54
6 ³ / ₈	Open hole		1'161	1'310	149	3.2	NaCl brine	13	16

Tab. 5-2: Planned borehole design

Section	Mud type	Hole size [in]	Section start [m MD]	Section end [m MD]	Section TVD [m]	Section length [m]	Capacity [m ³ /m]	OH volume [m ³]
I	Pure-Bore®	23	0	540	540	540	0.2680	144.7
II	Pure-Bore®	17½	540	885	885	345	0.1552	53.5
III	Polymer DF	12¼	885	1'195	1'195	310	0.0760	23.6
IV	Pure-Bore®	8½	1'195	1'360	1'360	165	0.0366	6.0
Total length [m]						1'360	Total volume [m ³]	227.9

The initial design was planned without silicate mud. After getting a lot of cavings in the cores drilling Opalinus Clay in BUL1-1 and BUL1-1B, it was decided to add an additional section and use silicate mud for Section III and IV instead of Pure-Bore® (Tab. 5-3).

Tab. 5-3: Actual borehole design

Section	Mud type	Hole size [in]	Section start [m MD]	Section end [m MD]	Section TVD [m]	Section length [m]	Capacity [m ³ /m]	Open hole volume [m ³]
I	Pure-Bore®	23	0	493	493	493	0.2680	132.1
II	Pure-Bore®	17½	493	712	712	219	0.1552	34.0
III	K-silicate DF	12¼	712	973	973	261	0.0760	19.8
IV	K-silicate DF	8½	973	1'161	1'161	188	0.0366	6.9
V	NaCl polymer	6⅜	1'161	1'310	1'310	149	0.0206	3.2
Total length [m]						1'310	Total volume [m ³]	195.9

Planned and actual section lengths are different. The mud system was changed to silicate mud in sections III and IV; in section V brine was used to drill the salt in the Muschelkalk.

The planned and actual borehole volumes are represented in Tabs. 5-4 and 5-5.

Tab. 5-4: Planned borehole volumes

TD: total depth; Vol.: volume, W/O: wash outs, OH: open hole, CSG: casing, ID: inner diameter, TVD: true vertical depth, TOL: top of liner

Section	Vol. at TD [m ³]	W/O size [%]	W/O vol. [m ³]	CSG size [in]	CSG ID [in]	CSG TD [m MD]	CSG TVD [m]	TOL	CSG length [m]	Capacity [m ³ /m]	Vol. 1 [m ³]	Vol. 2 [m ³]	CSG vol. [m ³]
I	144.7	7.00	10.1	18 $\frac{3}{8}$	17 19/29	540	540		540	0.1579	85.3	0.000	85.3
II	138.8	5.00	2.7	13 $\frac{3}{8}$	12 1/3	885	885		885	0.0770	68.2	0.000	68.2
III	91.7	2.00	0.5	9 $\frac{3}{8}$	8 3/4	1'195	1'195		1'195	0.0388	46.4	0.000	46.4
IV	52.4	1.00	0.1	7	6 9/50	1'360	1'360		1'360	0.0194	26.3	0.000	26.3
Total volume W/O			13.3										

Tab. 5-5: Actual borehole volumes

TD: total depth; Vol.: volume, W/O: wash outs, OH: open hole, CSG: casing, ID: inner diameter, TOL: top of liner

Section	Vol. at TD [m ³]	W/O Size [%]	W/O vol. [m ³]	CSG size [in]	CSG ID [in]	CSG TD [m MD]	CSG TVD [m MD]	TOL	CSG length [m]	Capacity [m ³ /m]	Vol. 1 [m ³]	Vol. 2 [m ³]	CSG vol. [m ³]
I	132.1	13.40	17.7	18 $\frac{3}{8}$	17 19/29	491	491	0	491	0.1579	77.5	0.000	77.5
II	111.5	41.00	13.9	13 $\frac{3}{8}$	12 26/51	708.5	708.5		708.5	0.0793	56.2	0.000	56.2
III	76.0	7.00	1.4	9 $\frac{3}{8}$	8 3/4	969.4	969.4		969.4	0.0388	37.6	35.924	37.6
IV	44.5	6.00	0.4	7 $\frac{3}{8}$	6 7/8	1'159		926	233	0.0239	5.6	0.000	41.5
V	44.6	6.00	0.2						0	0	0.0	0.000	0.0
Total volume W/O			33.6										

In Section I, the borehole was drilled to the depth of 493 m MD (TD) in two bit runs and without any technical problems. TD was set earlier due to geological conditions. The Pure-Bore® mud system performed as predicted and provided stable viscosity, good hole cleaning and borehole stability. The final caliper log showed a total washout of 13% and good borehole conditions. Borehole logging was completed and 18 $\frac{3}{8}$ " casing was set without any issues. The cementation of the surface casing was as planned: 5.0 m³ water spacer, 62.0 m³ lead cement, 8.0 m³ tail cement and 1.5 m³ freshwater were pumped. A volume of 6.0 m³ cement-contaminated mud and 4.0 m³ clean cement of 1.70 SG was disposed of.

The rig was equipped with three shale shakers. One was additionally fitted with a desander/desilter unit. Initially, two shakers processed the active mud, while the third shaker was intended to operate only as a mud cleaner. While drilling this section, an additional flow connection was prepared, and the third shaker was connected to the flow line as well to increase the solids control treatment capacity.

All shakers were initially dressed with API 80 and API 100 screens, which were gradually swapped with API 120 and API 140 as the drilling operation progressed.

In addition to the equipment mentioned, two Sirius-ES high performance centrifuges (type Flottweg Z3E and Z4E) with a floc unit processed the drilling fluid system and were applied as required to maintain the proposed mud parameters.

Cuttings were loaded into specially constructed skips that were transported from the location for further treatment. Each transport/loading was documented in the data management system with the corresponding weights. The coordination of the drilling waste transportation was performed in a timely, accurate and safe way.

Tab. 5-6: 23" interval – Section I – mud properties

Parameter	Unit	Min.	Max.	Average
Mud weight	SG	1.03	1.12	1.08
PV	cp	8	20	13
YP	kg/100 ft ²	11	22	18
10 s gel	kg/100 ft ²	4	12	7
10 m gel	kg/100 ft ²	5	26	17
FL	ml	6.0	9.4	7.4
Cake	mm	0.4	1.0	0.5
Solids	%	1	4	3
Sand	%	0.0	0.8	0.3
MBT	kg/m ³	0	35	22
pH		9.4	10.8	9.9

Section II started with drilling the cement and conducting the FIT as planned. Contaminated drilling fluid was disposed of and replaced with fresh mixed Pure-Bore® mud.

The next phase was coring. After some initial difficulties related to the placement of the 7⁵/₈" auxiliary casing and the selection of the 6³/₈" core bit, coring was successfully conducted to a depth of 600 m MD, which was defined operationally as the appropriate depth for hydraulic testing (geological features).

At the depth of 591 m MD, partial losses occurred. Initially 4.0 m³/h were detected with a decreasing tendency. During the last circulation, dynamic losses with 1.0 m³/h were recorded.

After coring, hydraulic tests were conducted. While testing, the borehole was filled through the trip tank. Static losses were determined to be between 1.5 m³/day to 2.0 m³/day.

After concluding the hydraulic tests, 6³/₈" coring was resumed. Minor losses up to 4.0 m³/day were encountered but stopped later on. Coring was completed up to 712 m MD and next test sequences started.

During fluid logging, all drilling fluid had to be displaced with tap water. After completion of the aforementioned tests, the water was exchanged back with the drilling fluid at surface. During this time, the drilling fluid parameters went out of specification due to dilution with water, which occurred up to a certain degree during each displacement.

The next operational step was the hole opening, first to 8½", then to 12¼" and finally to 17½". The drilling fluid was conditioned by treatment with Pure-Bore® and S-ES Bio XG to achieve the desired viscosity. A minor amount of S-ES Bio XG was used in this phase to achieve a synergy with Pure-Bore® to create higher rheological properties, as no further testing was planned and the influence on the formation properties was not as relevant as before.

During routine testing, bacterial contamination was also observed, leading to quicker degradation of the polymers. A possible source of contaminant were the vacuum trucks (these were used during displacements) that normally transport sewage and faeces. This contamination is unavoidable – although trucks are cleaned, they are not sterile – but was easy to handle using Sirius Stab XL, Grotan OX and controlling the pH with soda ash.

No losses occurred during hole opening and this operation was completed without any problems. The 13⅜" casing was run to 708 m MD. During the cement job, 6.5 m³ freshwater spacer were pumped and switched to lead cement with 1.7 SG. After pumping a volume of 54 m³, no returns were observed at the surface. A volume of 9.3 m³ tail cement with 1.88 SG was pumped, followed by 2.1 m³ water as spacer and as flush for the lines. Measurements conducted later on showed that top of cement (TOC) in the annulus was at a depth < 100 m MD, therefore no remedial action was necessary.

During WOC and operations associated with the wellhead, excess Pure-Bore® drilling fluid was disposed of. The surface drilling fluid system was restricted to the sand trap and one suction tank only. The rest of the pits were cleaned, and new K-silicate mud was mixed.

In total, 233 m³ of additional fluids were used to build and treat the mud to finish this section.

Tab. 5-7: 17½" interval – Section II – mud properties

Parameter	Unit	Min.	Max.	Average
Mud weight	SG	1.04	1.10	1.05
PV	cp	3	18	10
YP	kg/100 ft²	4	23	12
10 s gel	kg/100 ft²	1	8	3
10 m gel	kg/100 ft²	2	18	6
FL	ml	6.8	10.8	8.3
Cake	mm	0.5	0.7	0.5
Solids	%	2	4	2
Sand	%	0.0	0.3	0.1
MBT	kg/m³	14	21	16
pH		8.2	11.4	9.8

Before starting the 12¼" interval, cement and formation were drilled to perform a FIT using Pure-Bore® mud. The mud was then displaced using K-silicate mud mixed during WOC. The K-silicate used to mix the mud was initially 2.6 SG, however, the latter one was a 2.0 SG mud. The mud proved to be exceptionally stable and barely needed any maintenance treatment.

The auxiliary casing was run in, and the hole was cored to 822 m MD, i.e. Top Opalinus Clay, where operations were paused to conduct wireline measurements and hydraulic testing. Based on the acquired information, the operator decided to increase the mud weight from 1.13 SG to 1.20 SG, using 2.0 SG silicate as weighting material. Coring was continued to 973 m MD, where additional logging and testing were conducted.

As a next step, the hole was opened to 12¼". The mud properties remained stable during the test and hole opening. Fluid loss increased slightly after hole opening; however, it still remained well within specifications and no maintenance treatment was considered necessary. Some surface foaming was successfully cured using Defoamer ST.

The casing was run without difficulties and the borehole was cemented in two stages. During pilot testing before the job, it became clear that silicate mud reacts strongly with the cement and solidifies quickly. Additional spacers were thus introduced in the cementing programme, and the volume of spacer was increased for a maximum safety margin. The volumes pumped during cement job were:

First stage: 3 m³ freshwater spacer, 7 m³ saltwater spacer (1.15 SG), 16.3 m³ cement (1.88 SG), 5 m³ freshwater spacer, 5.1 m³ mud (1.2 SG), 5 m³ spacer, 2.6 m³ mud, 0.5 m³ freshwater

Second stage: 3 m³ freshwater spacer, 3.2 m³ saltwater spacer (1.15 SG), 23.5 m³ cement (1.88 SG), 5 m³ freshwater spacer, 20.98 m³ mud (1.20 SG), 0.5 m³ freshwater

The cement job was completed successfully. Due to the mentioned strong reaction between cement and drilling fluid, strongly contaminated mud was dumped and disposed of.

Tab. 5-8: 12¼" interval – Section III – mud properties

Parameter	Unit	Min.	Max.	Average
Mud weight	SG	1.10	1.20	1.17
PV	cp	7	12	9
YP	kg/100 ft ²	7	17	11
10 s gel	kg/100 ft ²	1	6	2
10 m gel	kg/100 ft ²	2	8	3
FL	ml	0.00	7.60	3.23
Cake	mm	0.00	0.20	0.10
Solids	%	0	2	2
Sand	%	0.00	0.12	0.10
MBT	kg/m ³	0	3	0
pH		11.2	12.8	12.2

In the 8½" interval, the formation was drilled using silicate mud, the same mud system as used for the previous section. Mud weight was SG 1.20, achieved through increasing the silicate content. The cement job, drilling off the cement and contamination with spacers negatively influenced the mud parameters to a degree, necessitating some mud treatment, mainly to improve fluid loss.

The coring operations from 978 m to 1'035 m MD were completed without problems. A series of tests that followed was also completed successfully. Coring the underlying formation of clay – anhydrite was slightly problematic, with lower-than-expected ROP. A few additional trips to replace the core bit were necessary.

Hole opening was conducted in two stages, first to 1'122 m MD, then to 1'161 m MD. At 1'122 m MD, a series of logging runs were conducted, and some problems were encountered, hence a wiper trip was conducted but without any problems. It was assumed that the problems were not related to the hole conditions.

The hole was opened to a depth of 1'161 m MD and additional logging and measurements were conducted. Caliper showed an under-gauge hole, partially with a diameter of 8". Although a check trip performed with a reaming assembly encountered neither resistance nor overpull, and although no formation material was observed during circulation, the decision was made to under-ream the hole to 9½". After this, logging was run, and the under-reamer was then used to reach the bottom without problems. Following this, the 7⅝" liner was RIH.

The cement job was performed as per programme: 3.5 m³ spacer (SG 1.45); 4.1 m³ cement (SG 1.83; checked before) and together 3.0 m³ of freshwater spacer. A volume of 11.0 m³ mix zone with a maximum SG of 1.37 was dumped. After WOC, RIH to 1'123 m MD to the top of cement and the shoe track was drilled out to 1'165 m MD and 4 m new formation. After circulation, the well clean POOH and start supported with the vacuum trucks cleaning the pits.

The mud was then changed to a NaCl polymer system. A volume of approximately 5.0 m³ spacer was pumped from suction pit 2. The silicate mud in suction pit 1 was displaced with new salt polymer mud. The old silicate mud was transferred to mix 2 and the diverter pit. The flowrate was adjusted between 1'100 l/min and 1'300 l/min. A volume of approximately 35 m³ of silicate mud was displaced in mix 2 and the diverter pit. A volume of approximately 13.0 m³ of spacer and mix zone were dumped, followed by cleaning of the sand trap and mix 2. A volume of approximately 85 m³ of silicate mud was sent for storage to the warehouse.

Tab. 5-9: 8½" interval – Section IV – mud properties

Parameter	Unit	Min.	Max.	Average
Mud weight	SG	1.17	1.20	1.20
PV	cp	7	22	12
YP	kg/100 ft ²	10	31	18
10 s gel	kg/100 ft ²	2	16	6
10 m gel	kg/100 ft ²	4	24	8
FL	ml	5.60	8.70	6.73
Cake	mm	0.20	0.30	0.21
Solids	%	2	2.6	2
Sand	%	0.10	1.00	0.10
MBT	kg/m ³	0	0	0
pH		11.8	12.7	12.3

In the 6 $\frac{3}{8}$ " interval, after cleaning the pit and circulating the borehole, the FIT with 41 bar to EQMW 1.57 SG was performed. Uranine was added for tracer tests, first samples were taken, and the hole was drilled from 1'165 m to 1'167 m MD. After POOH, the bit was changed, RIH, then washed and reamed down from 1'137 m to 1'167 m MD. The hole was drilled from 1'266 m to 1'280 m MD and, after circulation, two HiVis pills were pumped, and the hole was cleaned. POOH. The system was changed to a small active system including the sand trap and the suction pit.

A motor BHA was RIH, drilled to 1'290 m MD and POOH because of high torque readings. RIH again and drilled the rest to 1'310 m MD. A 3.0 m³ HiVis pill was pumped, and the borehole circulated until shakers were clean. POOH and logging was started, while partial pit cleaning was performed. Schlumberger wireline equipment was rigged down, and a cement stinger RIH to 1'309.4 m MD. After circulation, cementing was carried out with Fangmann service from 1'310 m MD up to the 7 $\frac{5}{8}$ " liner (1'138 m MD = 20 m into liner). After 2.7 m³ spacer (SG 1.36), 5.0 m³ cement slurry (SG 1.88) were pumped and followed by a 0.3 m³ spacer (SG 1.36). Thereafter, POOH to 1'126 m MD, left circulation (through annulus up the string) and 9 m³ of cement, spacer, and mud mix zone were dumped.

The cement stinger was POOH to surface, L/D 2 $\frac{7}{8}$ " tubing. A 6 $\frac{3}{8}$ " BHA was RIH to 1'122 m MD, cement was drilled out to 1'138 m MD. A volume of 5 m³ spacer and 60 m³ anticorrosive fluid was mixed. Circulation was initiated after a pressure test to 50 bar.

After pumping, the spacer with the anticorrosive fluid (140 kg Grotan OX, 100 kg caustic soda and 75 kg S-ES Bio XG) displacement of the mud was done.

Including the cellar volume, 91 m³ NaCl polymer mud was disposed of in total, which increased the planned quantity in this section.

The 6 $\frac{3}{8}$ " BHA was POOH to surface and L/D, rigging down the rig started.

Tab. 5-10: 6 $\frac{3}{8}$ " interval – Section V – mud properties

Parameter	Unit	Min.	Max.	Average
Mud weight	SG	1.21	1.22	1.21
PV	cp	20	25	23
YP	kg/100 ft ²	11	17	14
10 s gel	kg/100 ft ²	2	3	2
10 m gel	kg/100 ft ²	3	4	4
FL	ml	4.50	5.50	4.77
Cake	mm	0.10	0.10	0.10
Solids	%	2.3	2.4	2
Sand	%	0.00	0.10	0.09
MBT	kg/m ³	0	0	0
pH		10.1	10.6	10.3

6 Health, safety and environment (HSE)

6.1 Health and safety

The health and safety of employees, contractors and subcontractors of Nagra is of vital importance. Therefore, several measures were taken during the planning and operation of the drilling campaign to reduce hazards to a minimum and to create safe working conditions.

The site was fenced to protect workers from external influences and to define a clear boundary for people and animals which are not allowed to access the drill site. Additionally, the drill site was permanently guarded by a security service during the entire drilling phase. The security guards were also responsible for performing detailed access controls.

To respect the different ATEX zones around the drilling rig, the drill site was divided into a restricted area and a non-restricted area. Access to the restricted area was allowed only with the correct personal protective equipment (PPE), consisting of:

- overall/jacket
 - anti-flammable
 - anti-static
 - high visibility
- safety shoes
 - S3
 - mid height
- safety helmet
- safety glasses
- safety gloves

Within the restricted area, it was not permitted to carry any non-explosion-proof electrical devices to prevent hazardous sparks within the ATEX zone.

A firefighting and rescue plan with specific procedures for emergency situations was in place for the drill site. Furthermore, the drill site was equipped with emergency exits, muster points, fire-extinguishers, first aid kits and alarm signals. Evacuation drills and trainings were carried out with the onsite personnel on a weekly basis to practice correct behaviour in emergency situations.

Daily changes of shifts always started with pre-job safety meetings to make the rig crew aware of potential hazards on location. Special jobs such as cementing required additional safety meetings together with subcontractors to address all planned work steps and further safety instructions.

Life-saving rules were implemented which everyone who was visiting or working at the drill site had to follow. These rules set the minimum requirements for controlling the risk of serious injury from common activities.

The drilling contractor had a STOP card system in place that allowed all persons on-site to address positive and/or negative observations at the drill site related to HSE. These STOP cards were collected and analysed to pinpoint problems that needed to be addressed and improved for the future. Good cards served as feedback and motivation on excellent performance.

Throughout the drilling phase of TRU1-1, one restricted work case and three first-aid cases were reported. The restricted work case happened on 26.01.2020: RWC and was a foot injury. The first-aid cases happened on 25.08.2019: with bruised thumb of the left hand, on 14.12.2019 with chemical burn to eye from silica mud and on 25.02.2020 with chemical burns on body due to exposure to potassium silicate.

6.2 Environment

6.2.1 Environmental supervision and monitoring

Due to official regulations, the entire project had to be accompanied by an environmental supervisor. This supervisor was responsible for advising and informing Nagra on environmental aspects and for consulting external experts if necessary.

The tasks of the environmental supervisor during the drilling phase were:

- the communication of transport routes
- verifying whether environmental requirements and protective measures were respected for transporting and drilling activities
- to check if the drainage concept was respected and working correctly
- to check if the lighting concept was respected and whether further measures were necessary
- to check the machinery list and particle filters of all vehicles and machines
- to check the storage of hazardous substances
- the conduction of leakage tests of wastewater and sewage pipes
- to check the storage, separation and disposal of waste at the drill site
- to check if legal noise limits were complied with

The drill site was inspected on a regular basis. No major findings were identified, and official regulations were all fulfilled.

6.2.2 Wastewater

A dewatering concept was prepared according to official regulations and approved by the cantonal authorities. The water collected on the drill site within the asphalted area was originally collected over a roof pitch, passed through a scum collector, an oil separator, decantation pits and finally seeped away in a seepage pit. The collected solids in the decantation pits were disposed of on a regular basis by suction trucks. It was agreed with AWEL (Office for Waste, Water, Energy and Air) that the collected water from the rig site can be discharged into the nearest public water via the rainwater sewer system instead of being moved to a wastewater facility by truck.

6.2.3 Noise measurements

During the entire drilling phase, the legal limits of the Noise Abatement Ordinance had to be complied with at the nearest residential properties to the drill site. Because drilling operations were carried out without any interruptions, it was important to stay within the legal limits for day and night. The limit during daytime was 60 dB(A) and 50 dB(A) during the night. For the TRU1-1 borehole, several noise measurements were performed by a specialised company at the nearest house to evaluate the average noise emissions of the work carried out. Noise measurements showed no excess of noise, so that no additional noise protection walls were built.

6.2.4 Lighting

Besides noise emissions, light emissions were also relevant for the drill site, especially during the night. Proper lighting at the workspace is indispensable in terms of safety for the crew but must not affect the surrounding environment. Therefore, warm-white LED lamps were installed at the site to reduce the harmful blue content in the emitted spectrum, being more environmentally friendly for wildlife and people.

6.2.5 Waste management

Waste material from the drilling process was categorised and disposed of according to the regulations of the Federal Office for the Environment (FOEN).

In every section of the borehole, a detailed analysis of the cuttings and drilling fluid was performed at a specified laboratory to classify the waste materials. For each analysis two samples were taken: first to determine the texture and mechanical modularity and second for eluate investigations.

6.2.6 Mud losses

At the TRU1-1 borehole no significant mud quantities were lost into the formations. 5.5 m³ of Pure-Bore® mud were lost in the Malm formation starting at 591.5 m without influence on drilling operations or environment. Losses stopped at 681 m during drilling with mud density 1.05 to 1.08 SG.

7 References

Isler, A., Pasquier, F. & Huber, M. (1984): Geologische Karte der zentralen Nordschweiz 1:100'000. Herausgegeben von der Nagra und der Schweiz. Geol. Komm.

MICON Mining Bits (2016):

https://www.micon-drilling.de/Download/Catalog_Mining%20Bits_EN_170131.pdf

MICON Wireline Core Barrels (2019):

https://www.micon-drilling.de/Download/Catalog_WirelineCoreBarrels-short_EN_190111.pdf

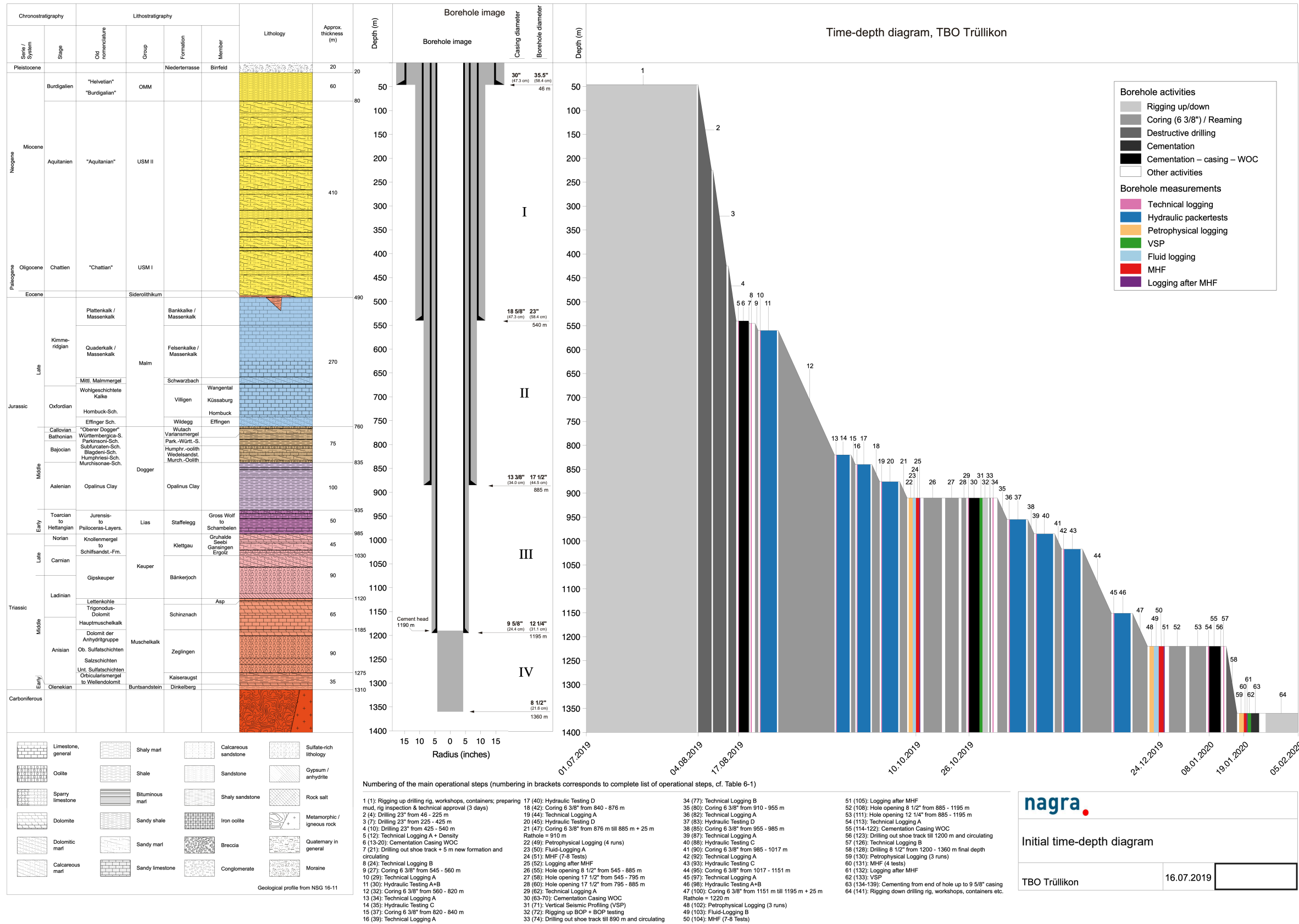
Nagra (2014): SGT Etappe 2: Vorschlag weiter zu untersuchender geologischer Standortgebiete mit zugehörigen Standortarealen für die Oberflächenanlage. Geologische Grundlagen. Dossier II: Sedimentologische und tektonische Verhältnisse. Nagra Technischer Bericht NTB 14-02.

Nagra (2016): Gesuch um Erteilung einer Bewilligung für erdwissenschaftliche Untersuchungen im Standortgebiet Zürich Nordost (ZNO) – Sondierbohrungen Trüllikon 1. Nagra Sondiergesuch NSG 16-11.

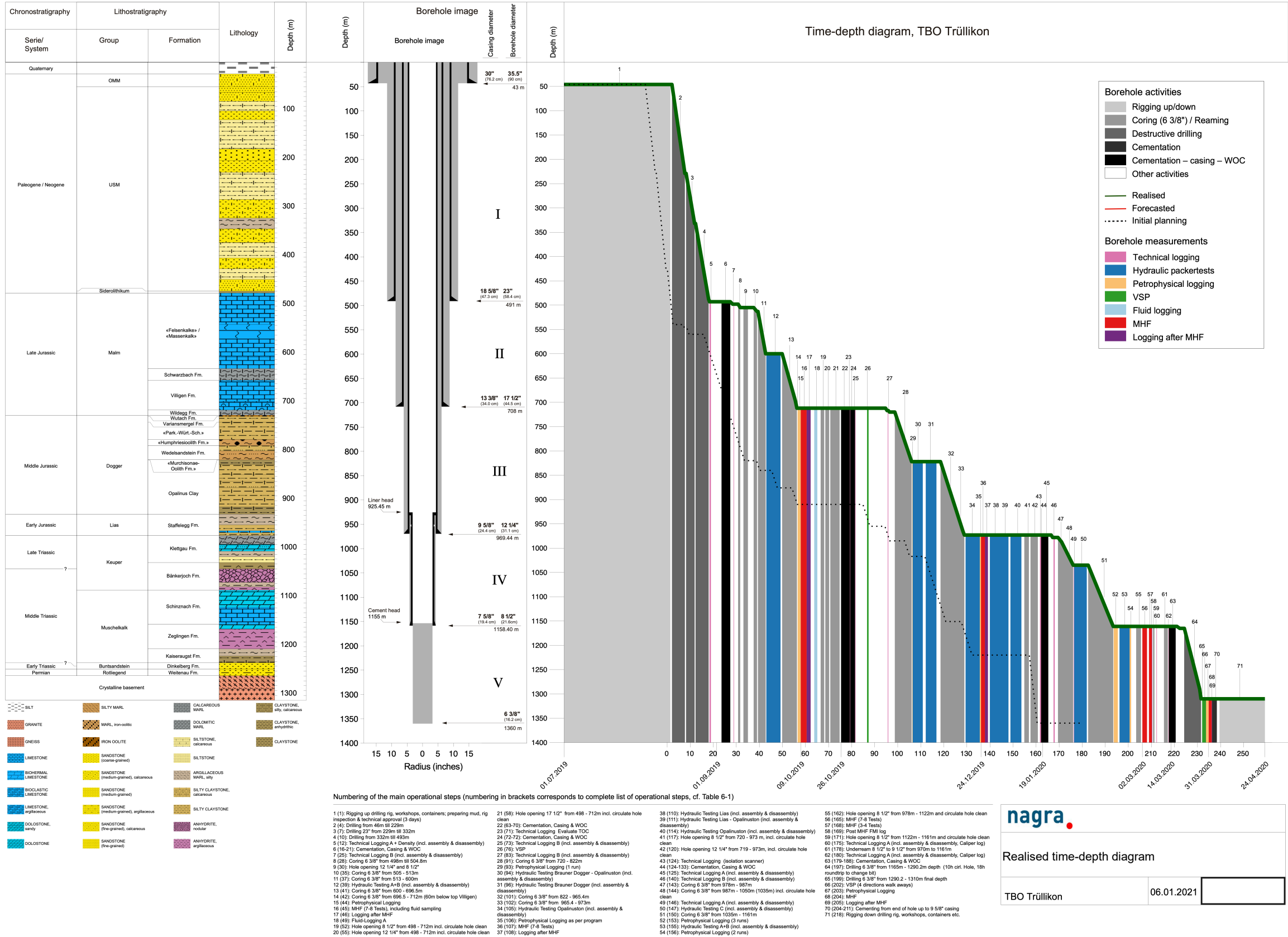
Nagra (2019): Arbeitsprogramm für Tiefbohrungen – Spezifisches Untersuchungsprogramm der Tiefbohrung Trüllikon-1-1. Nagra Sondiergesuch NSG 16-11 AP1, Rev. 1.

Pietsch, J. & Jordan, P. (2014): Digitales Höhenmodell Basis Quartär der Nordschweiz – Version 2013 (SGT E2) und ausgewählte Auswertungen. Nagra Arbeitsbericht NAB 14-02.

Appendix A: Initial time – depth diagram



Appendix B: Realised time – depth diagram



Appendix C: Drill site pictures and plan

C.1 Drill site pictures

Video drill site Trüllikon-1-1:

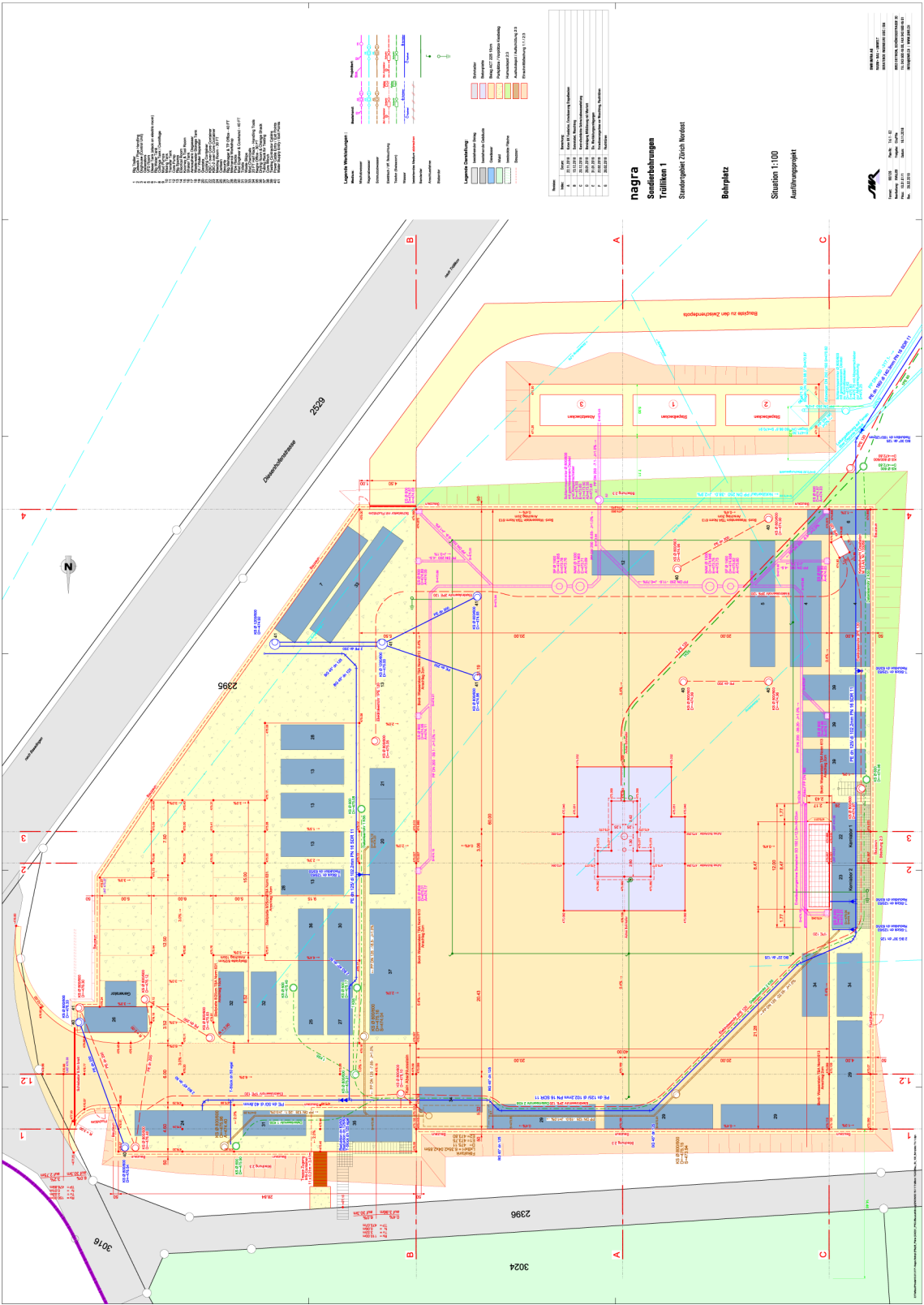
<https://www.youtube.com/watch?v=KeaOerXMnoE&feature=youtu.be>



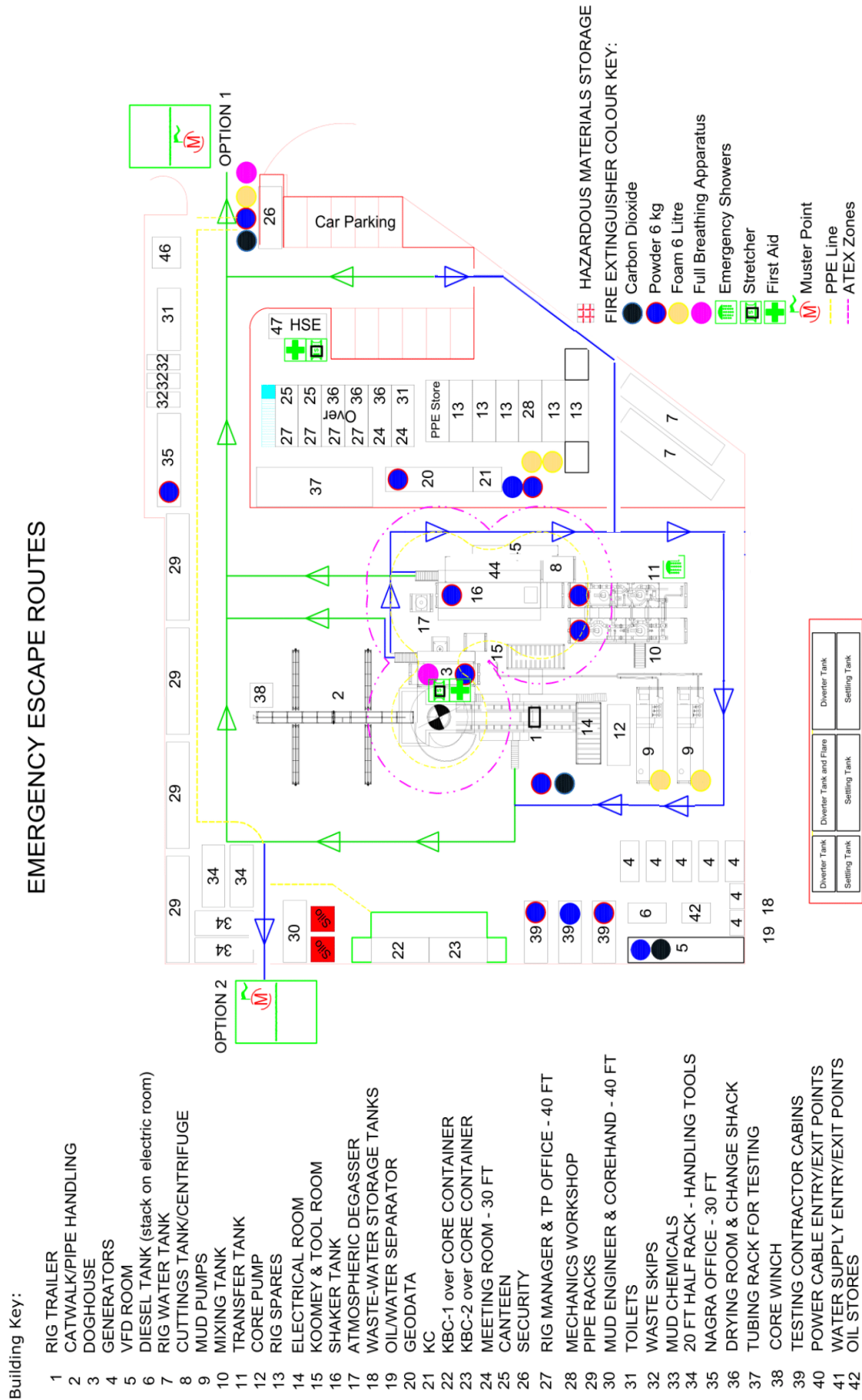




C.2 Site plan



EMERGENCY ESCAPE ROUTES



Appendix D Technical data of the rig

Tab. D-1: Derrick / mast, substructure, draw works and associated equipment

A 1 Derrick / mast

Manufacturer		Drillmec
Type		Telescopic HH102
Year of construction		2012
Free height	m	16 (topdrive stroke)
Nominal gross capacity at least (with 8 lines)	kN	978.61 (100 metric tons)
Nominal hook load (with 8 lines)	kN	Not applicable
Crown block		
Gross capacity	kN	978.61
Nominal capacity	kN	978.61
Racking capacity		
5" string incl. DC	m	1'767
3½" string incl. DC	m	2'356
Casing stabbing board	Yes / no	Not applicable
Derrickman windbreaks height	m	Not applicable
Derrick camera system	Yes / no	Not applicable

A 2 Substructure

Manufacturer		Drillmec
Type		2.9
Year of construction		
Width	m	
Clear height below rotary table beams up to	m	4.87
Setback capacity up to	kN	978.61
Casing / rotary capacity	kN	978.61
Setback capacity at max. rotary capacity	kN	978.61
BOP installation equipment		Yes

A 2.1 Drill floor

Size	m ²	35
Drill floor wind breaks height	m	2.5
Drainage system		Yes
Kelly hole	Yes / no	Not applicable
Mousehole	Yes / no	Yes / with hydraulic clamp

A 3 Draw works

Manufacturer		Drillmec
Type		Hydraulic RAM
Year of construction		2012
Number of electric motors		1
Drive system power	kW	447
Max. cable tension, 2 nd layer	kN	Not applicable
Auxiliary brake		Drillmec hydraulic
Automatic feed system		
Manufacturer		Drillmec
Type		Pipe handler

A 4 Drilling and coring lines**A 4.1 Drilling line**

Diameter	mm	34
Type		Diepa AF 2371C
Minimum breaking load	kN	652

A 4.2 Coring wireline

		Millenium wireline
Diameter	mm	8
Length	m	2'000

A 5 Dead line anchor

Manufacturer		Drillmec
Type		Yoke pinned

A 6 Crown block and hook**A 6.1 Crown block**

Manufacturer		Drillmec
Type		Fixed to mast telescopic section
Year of construction		2012
Capacity	kN	978.16
Crown block safety device		Drillmec Kinetic

A 6.2 Hook

Manufacturer		Drillmec
Type		Ouble hook
Year of construction		2012
Capacity	kN	978.61

A 7 Swivel

Manufacturer		Drillmec
Type		
Year of construction		2012
Static capacity	kN	978.61
Pressure rating	bar	344.7

A 8 Auxiliary winches

Number		1
Type		Hydraulic
Maximum cable load, 1 st layer	kN	49.82

B 1 Rotary table

Manufacturer		Drillmec
Type		Independent hydraulic driven
Maximum opening		20.5
Static capacity	inch	978.61
Number of electric motors		2 × hydraulic motors
Drive system power	kN	447
	kW	
Maximum rotary speed	min ⁻¹	60

B 2 Topdrive

(Electric / hydraulic)		hydraulic
Manufacturer		Drillmec
Model		HH 102
Drive system power	kW	447
Static capacity	kN	978.61
Dynamic capacity	kN	
Maximum torque	Nm	32'330
Continuous torque	Nm	1'129

	Maximum rotary speed	min ⁻¹	154
	Rotary speed at continuous torque	min ⁻¹	53
C 1	Mud pumps		
	Number		2
	Manufacturer		Baoji
	Model		MP-1000
	Drive system (electric)		Motor
	Power rating	kW	746
	Maximum pressure	psi/bar	5'000/350
	with liner		
	Size	inch	4"
	Maximum flowrate	l/min (140 spm)	2'484 × 2
	with liner		
	Size	inch	6¾"
	Stroke length	inch	10"
C 2	Standpipe(s)		
	Number		1
	ID	inch	3¼"
	Working pressure	psi/bar	5'000/350
C 3	Rotary hose		
	Number		1
	ID	inch	3½"
	Working pressure	psi/bar	7'500/517
C 4	Circulation head	4½" IF × Fig 1502	
C 5	Wash lines		Not applicable
	ID	inch	
D 1	Active tanks		
	Total capacity	m ³	82.83
D 1.1	Shaker tank		
	Capacity	m ³	46

	Number of chambers		4
	Sand trap	m ³	11.5
	Agitators		
	Number		
	Power	kW	14.91
	Mud guns		
	Number		
D 1.2	Intermediate tank		
	Number		1
	Capacity	m ³	51
	Number of chambers		3 (22 m ³ , 15 m ³)
	Agitators		
	Number		2
	Power	kW	14.91
	Mud guns		
	Number		4
D 1.3	Suction tank		
	Number		1
	Capacity	m ³	37.36
	Number of chambers		2
	Agitators		
	Number		2
	Power	kW	14.91
	Mud guns		
	Number		2
D 2	Mixing system		
D 2.1	Mix tank		
	Capacity	m ³	45.47
	Pill tank capacity	m ³	3.97
	Agitators		
	Number		2
	Power	kW	14.91

D 2.2 Mix funnels

Number	1
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D 2.3 Mix pumps

Number	21
Manufacturer	Baker
Type	electric
Power rating	kW 75

D 3 Chemical mixing tank

Capacity	m ³ 0.23
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D 4 Mud treatment equipment**D 4.1 Shale shakers**

Number	3
Manufacturer	Swaco
Type	Mongoose
Drive system	Electric motors
Power rating	kW
Screen area	m ² 4.065

D 4.2 Desander

Number	1
Manufacturer	Swaco
Type	2-12T 6T4
Number of cyclones	2
Diameter of cyclones	inch 12"
Cyclone capacity	l/min 3785

Feed pump

Number	1
Manufacturer	Forum
Type	8" × 6" × 14"
Drive system (electric)	Electric driven
Power rating	kW 75
Rotary speed control	Yes/no No

D 4.3 Desilter

Number		1
Manufacturer		Swaco
Type		2-12T 6T4
Number of cyclones		12
Diameter of cyclones	inch	4"
Cyclone capacity	l/min	3'406
Feed pump		
Number		1
Manufacturer		Forum
Type		8" × 6" × 14"
Drive system (electric)		Electric driven
Power rating	kW	75
Rotary speed control	Yes / no	No

D 4.4 (Vacuum) degasser

Number		1/atm
Manufacturer		MISwaco
Type		Mechanical
Capacity	l/min	3785

D 4.5 Flowline magnets

Number

D 5 Additional tanks and silos**D 5.1 Reserve tanks**

Number		1
Type		Bulk tank
Total capacity	m ³	47
Agitators		
Number		2
Power	kW	14.91

D 5.2 Drinking-water tanks

Number		Not applicable
Total capacity	m ³	

D 5.3 Drilling water tanks

Number		1 (or as needed), max. 3
Total capacity	m ³	45

D 5.4 Dry material silos

Number		2
Total capacity	m ³	100

E 1 Drive system (electric)

Hydraulic-electrically driven

E 1.1 Power requirement

kVA 447

E 1.2 Diesel engines

Number		Not applicable see E 1.5
Manufacturer		
Type		
Power rating	kW	
At revs	min ⁻¹	

E 1.3 Torque converter

(only for diesel-mechanical rigs)

Number		Not applicable
Power rating	kW	

E 1.4 Generators

(only for diesel-electric rigs)

Number		5
Manufacturer		Caterpillar
Power rating	kVA	500 each

E 1.5 SCR system

(only for diesel-electric rigs)

Manufacturer		Bauer
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E 2 Auxiliary power supply (400 V / 50 Hz)

Number		2
Manufacturer		Caterpillar
Power rating	kVA	180

E 3 Fuel tanks

Number		1
Capacity	m ³	20.892
With EX-protection	Yes / no	Yes
Leak detection	CMR electrical	Type: ODS2-2

E 4 Rig service air system

Number		2
Volume	m ³ /min	3.6
Working pressure	bar	10.34
Storage capacity	l	Yes
Air dryer unit		Yes

F 1 Diverter system

Manufacturer		Drilltech
Type		R73
Size	inch	21¼"
Side outlets quantity		2
Side outlets size	inch	9"
H ₂ S rating	Yes / no	No

Diverter lines

Length	m	57
Nominal ID		10"

Manual valves

Number		2
Working pressure	psi/bar	580/40

Hydraulically actuated valves

Number		1
Working pressure	psi/bar	Max. 2'000/140

F 2 Annular preventer

Number		1
Manufacturer		
Type		Hydril
Size	inch	13⅝"
Pressure rating	psi	5'000
H ₂ S-rating	Yes / no	Yes

F 3 Ram type preventer

Number		1
Manufacturer		Shanghai Shenkai
Type		Double Gate
Size	inch	13 $\frac{5}{8}$ "
Pressure rating	psi	5'000
H ₂ S rating	Yes / no	Yes
Side outlets quantity		2
Side outlets size	inch	4 $\frac{1}{16}$ "

F 4 Ram types**F 4.1 Pipe rams**

Number	sets	2
Size	inch	3 $\frac{1}{2}$ " – 5" (variable)

F 4.2 Blind / shear rams

sets	1 (kit) each
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F 4.3 Variable bore rams

Number	sets	2 (depending on the well control programme)
Size (from – to)	inch	2 $\frac{7}{8}$ " to 5"

F 5 Drilling spools

Side outlets quantity	2
Side outlets size	4 $\frac{1}{16}$ "
Spacer Spools	2 × 13 $\frac{5}{8}$ "

F 6 BOP control system

Manufacturer		Shaffer
Type		5 stage T20120-35
Total capacity	l	1'059
Bottle working pressure	psi/bar	3'000/210
Annular pressure control valve	Yes / no	Yes

Electric pumps

Number		1
Capacity	l/min	15.52

Air pumps

Number		2
Capacity	l/min	227

Remote control panels

Number		2
Locations	(driller/tool pusher etc.)	driller and toolpusher

F 7 Choke/kill lines

H ₂ S rating	Yes / no	Yes
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F 7.1 Choke manifold

Nominal ID	inch	3 1/8"
Working pressure inlet	psi/bar	5'000/350
Working pressure outlet	psi//bar	5'000/350
Flanges with wear plugs	Yes / no	No

Manual choke

Number		1
Nominal ID	inch	2"

Remote choke

Number		1
Nominal ID	inch	2"
Automatic control	Yes / no	Yes

F 7.2 Choke lines

Number		
Type		
Nominal ID	inch	
Length	m	
Working pressure	psi	

Manual valves

Number		
Working pressure	psi/bar	5'000/350

Hydraulically actuated valves

Number		
Working pressure	psi/bar	5'000/350

F 7.3 Kill lines

Number

Type

Nominal ID inch

Length m

Working pressure check valve psi/bar 5'000/350

Manual valves

Number

Working pressure psi/bar 5'000/350

Hydraulically actuated valves

Number

Working pressure psi/bar 5'000/350

F 7.4 Poor boy degasser / mud gas separatorCapacity m³/min 3.78

Volume l 3'418

F 7.5 Flare line

Length m On demand/as needed

Nominal ID inch

Working pressure psi/bar

F 7.6 Flare

Height m On demand

OD inch

Ignition system

F 8 BOP test equipment**F 8.1 Test unit / test pump**

Working pressure psi/bar High pressure pump 10'000/700

Pressure recorder Yes / no Yes

F 8.2 Cup type tester

As per casing program Yes / no Yes

F 9 Kelly cocks

Number		1
Connection type		Drill pipe fitted
Working pressure	psi/bar	5'000/350
H ₂ S rating	Yes / no	Yes

F 10 Drop-in valves

Number		1
OD	inch	Depending on drill pipe size See above
ID	inch	5'000/350
Working pressure	psi/bar	
Landing nipple		
OD	inch	Depending on drill pipe size
ID	inch	See above
Connection type		Depending on drill pipe connection

F 11 IBOP / gray valve

Number		1
Connection type		Connected to the topdrive
Working pressure	psi/bar	5'000/350

G 1 Drill string

OD	inch	5" – 3½"
Total length	m	3'000
Nominal weight	lbs/ft	19.5/15.5 and/or 13.3
Range		R 2
Grade		G105
Class		Premium
Connection type		NC 50/NC 38
Tool joint OD	inch	6½" – 5 IEU
Tool joint ID	inch	3" – 2⅞"
Hard facing	Yes/no/type	Yes
Internal coating	Yes/no/type	No

G 1.1 Coring string

OD	inch	5 $\frac{5}{8}$ "
Inner barrel OD	inch	4 $\frac{5}{8}$ "
Total length	m	1'500
Nominal weight	lbs/ft	13.5
Joint length	m	9
Grade		
Class		N/P
Connection type		CSK / NSK
Tool joint OD	inch	5 $\frac{1}{2}$ "
Tool joint ID	inch	4 $\frac{7}{8}$ "
Hard facing	Yes/no/type	No
Internal coating	Yes/no/type	No

G 2 Pup joints

Number/length	m	3 × 1 m
Number/length	m	3 × 2 m
Number/length	m	3 × 3 m
		Other lengths available on request

G 3 HW drill pipe

Number		
OD	inch	
Nominal weight	lbs/ft	
Range		
Grade class		
Connection type		
Tool joint OD	inch	
Tool joint ID	inch	
Hard facing	Yes/no/type	
Internal coating	Yes/no/type	

G 4 Drill collars

Number		As needed
OD	inch	8¼" – ¾",
ID	inch	2 ¹³ / ₁₆ "
Nominal weight	lbs/ft	150 – 99
Range		R2
Connection type		6 ⁵ / ₈ " reg/NC-46
Spiral	Yes / no	Yes
Handling / slip reces	Yes / no	As needed

G 5 Bit and string stabilisers

As required for the drilling programme

G 6 Drilling jar

As required for the drilling programme

G 7 Drilling accelerator

As required for the drilling programme

G 8 Bumper sub

As required for the drilling programme

G 9 Crossovers

As required for the drilling programme

G 10 Bits

Drilling: As required for the drilling programme

Coring: As required for the drilling programme

H Handling tools

Elevator links		In sufficient quantities to perform the work scope for all strings (DP, casing, stinger etc.)
Elevators		
Rotary tongs		
Slips		
DC safety clamps		
Drill pipe wipers		
Bit breakers		
Automatic slips	Yes / no	Yes, hydraulically operated

I 1 Catheads

Number	Yes / no	All functions by power swivel
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[illegible]

K 2	Drilling recorder		
	Manufacturer		Drillmec
	Type		advance drillers
	Recording all parameters as shown at drilling console as minimum	Yes / no	No
K 3	Pit volume totaliser		
	Number of sensors		7
	Loss/gain indicators and alarm	Yes / no	Yes
K 4	Trip tank		
	Capacity	m ³	5
K 5	Tong torque / line pull indicators		
	Line pull range (maximum)	kN	40.67
K 6	General measuring equipment		
	Ring gauges	In adequate quantities for contractor's string and drilling programme	
	DP / DC drifts		
	Casing drifts		
	Bit calipers / gauges		
	Internal / external calipers		
	Derrick tapes (steel)		
K 7	Pressure gauges		
	Standpipe manifold	Number	3
	Choke manifold	Number	3
K 8	Flowline gas sensor		
	Total gas	Yes / no	Yes
	H ₂ S sensor	Yes / no	Yes
	Measurement range (C1 – Cx)		
	Alarm	Yes / no	Yes
K 9	Soft torque drilling system	Yes / no	Yes
K 10	Internal telephone system	Yes / no	No

K 11 Mud laboratory

Fully equipped mud laboratory as required to keep mud within programme parameters

K 12 Direction measuring system

Totco/Gyro Surehot 0 – 7 deg available

L 1 General personnel safety equipment

Fire fighting equipment	In adequate quantities
Personal protective equipment	In adequate quantities
First aid equipment	In adequate quantities
Eye washing stations	In adequate quantities
Emergency lights	In adequate quantities

L 2 Derrick safety equipment

Derrick escape line	In adequate quantities
Manufacturer	
Type	
Derrick safety belts	In adequate quantities
Derrick safety devices	In adequate quantities
Derrick climbing assistant	In adequate quantities

L 3 Gas / fire/smoke detection

H ₂ S monitoring system	Yes / no	Yes, on request
H ₂ S / CO ₂ detectors (portable)	Yes / no	Yes, on request
Explosimeters	Yes / no	Yes, on request

N 1 Phone and internet connection

Yes / no	No
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N 2 Pipe racks

Capacity	M	3000
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N 3 Cutting and welding equipment

Yes / no	Yes
----------	-----

N 4 High pressure cleaner

Yes / no	Yes
----------	-----

N 5 Cellar pump

Manufacturer

KSB

Type

ATEX

Power

kW

1.5

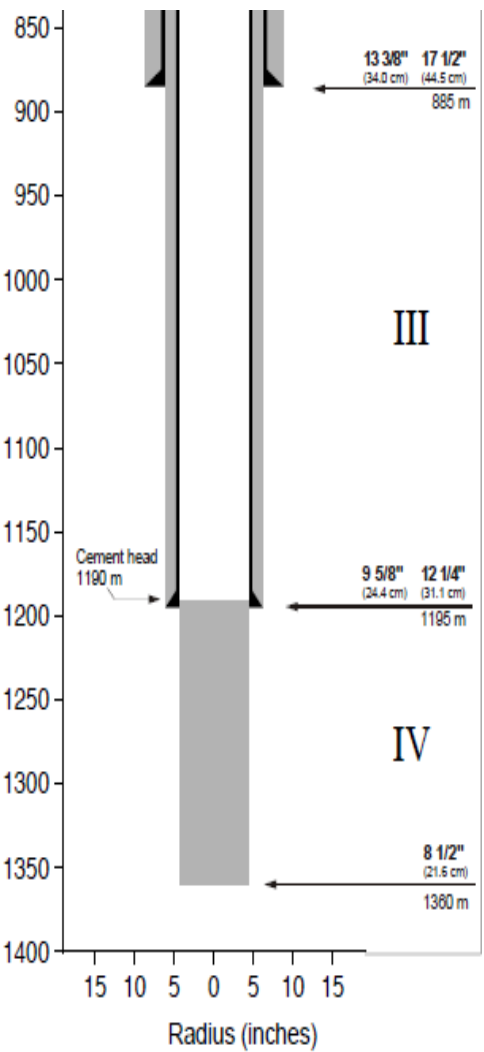
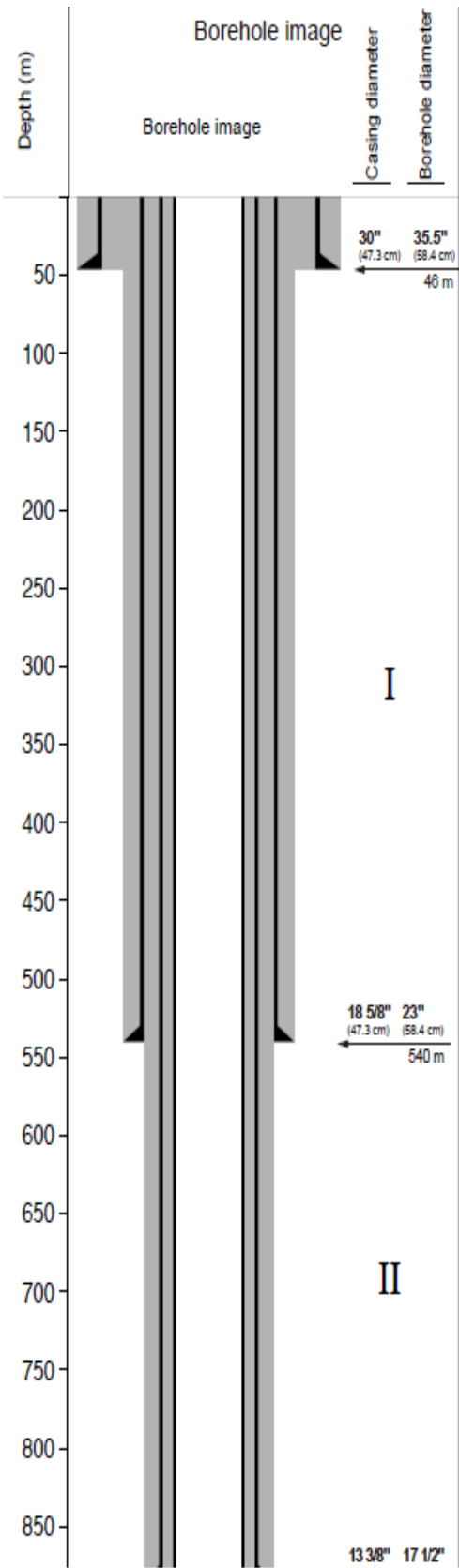
N 6 Forklift

Capacity

kN

120 and 25

Appendix E: Planned casing scheme



Appendix F: Survey report

The borehole is almost vertical. Maximum inclination measured is 3.153 deg inclination at 1'310 m. Maximum DLS with 3.00 deg/30 m at 1'310 m caused by large turn of the WL tool with sag. At 1'290 m DLS was measured with 1.7 deg/30 m.

Tab. F-1: Borehole deviation

MD [m]	Inclination [°]	Azimuth [°]	TVD [m]	Easting [m]	Northing [m]	VS [m]	DLS [°/30 m]
0	0	0	0.00	0.00	0.00	0.00	0.00
10	0	0	10.00	0.00	0.00	0.00	0.00
20	0	0	20.00	0.00	0.00	0.00	0.00
30	0	0	30.00	0.00	0.00	0.00	0.00
40	0	0	40.00	0.00	0.00	0.00	0.00
50	0.37	74.56	50.00	0.03	0.01	0.01	1.11
60	0.47	30.1	60.00	0.08	0.05	0.06	0.99
70	0.46	34.11	70.00	0.13	0.12	0.13	0.10
80	0.4	33.91	80.00	0.17	0.18	0.20	0.18
90	0.35	28.85	90.00	0.20	0.24	0.26	0.18
100	0.22	11.45	100.00	0.22	0.28	0.30	0.46
110	0.28	23.91	110.00	0.23	0.33	0.35	0.24
120	0.18	10.44	120.00	0.25	0.36	0.38	0.34
130	0.19	350.67	130.00	0.25	0.40	0.42	0.19
140	0.18	332.78	140.00	0.24	0.43	0.45	0.18
150	0.17	355.73	150.00	0.23	0.45	0.47	0.21
160	0.18	329.49	160.00	0.22	0.48	0.50	0.24
170	0.16	322.29	170.00	0.20	0.51	0.52	0.09
180	0.15	343.65	180.00	0.19	0.53	0.55	0.17
190	0.23	289.93	190.00	0.17	0.55	0.56	0.56
200	0.25	283.75	200.00	0.13	0.56	0.57	0.10
210	0.28	272.47	210.00	0.08	0.57	0.57	0.18
220	0.27	268.91	220.00	0.04	0.57	0.57	0.06
230	0.26	276.49	230.00	-0.01	0.57	0.57	0.11
240	0.31	272.11	240.00	-0.06	0.58	0.57	0.16
250	0.39	253.59	250.00	-0.12	0.57	0.55	0.41
260	0.35	248.11	260.00	-0.18	0.55	0.53	0.16
270	0.38	254.4	270.00	-0.24	0.53	0.50	0.15

Tab. F-1: Cont.

MD [m]	Inclination [°]	Azimuth [°]	TVD [m]	Easting [m]	Northing [m]	VS [m]	DLS [°/30 m]
280	0.45	252.38	280.00	-0.31	0.50	0.48	0.21
290	0.48	258.07	290.00	-0.39	0.48	0.45	0.17
300	0.52	254.33	300.00	-0.47	0.46	0.42	0.15
310	0.56	258.78	310.00	-0.57	0.44	0.39	0.17
320	0.55	257.75	320.00	-0.66	0.42	0.36	0.04
330	0.52	253.45	329.99	-0.75	0.40	0.33	0.15
340	0.58	257.38	339.99	-0.84	0.37	0.30	0.21
350	0.56	255.33	349.99	-0.94	0.35	0.27	0.09
360	0.59	254.55	359.99	-1.04	0.32	0.23	0.09
370	0.56	256.22	369.99	-1.13	0.30	0.20	0.10
380	0.55	257.7	379.99	-1.23	0.28	0.17	0.05
390	0.55	257.22	389.99	-1.32	0.26	0.14	0.01
400	0.59	256.79	399.99	-1.42	0.23	0.11	0.12
410	0.57	248.29	409.99	-1.52	0.20	0.07	0.26
420	0.6	249.62	419.99	-1.61	0.17	0.03	0.10
430	0.6	240.69	429.99	-1.71	0.12	-0.03	0.28
440	0.53	241.21	439.99	-1.79	0.08	-0.08	0.21
450	0.41	239.1	449.99	-1.86	0.04	-0.13	0.36
460	0.58	228.77	459.99	-1.93	-0.02	-0.18	0.57
470	0.5	229.12	469.99	-2.00	-0.08	-0.25	0.24
480	0.54	225.72	479.99	-2.07	-0.14	-0.32	0.15
510	0.74	297.13	509.99	-2.34	-0.15	-0.35	0.76
520	0.7	298.98	519.99	-2.45	-0.09	-0.30	0.14
530	0.69	299.45	529.98	-2.56	-0.03	-0.25	0.03
540	0.65	298.47	539.98	-2.66	0.02	-0.21	0.12
550	0.6	301.22	549.98	-2.76	0.08	-0.16	0.17
560	0.58	296.06	559.98	-2.85	0.13	-0.12	0.17
570	0.65	303.18	569.98	-2.94	0.18	-0.08	0.31
580	0.69	308.08	579.98	-3.04	0.25	-0.02	0.21
590	0.73	309.22	589.98	-3.13	0.33	0.05	0.13
600	0.74	310.87	599.98	-3.23	0.41	0.13	0.07
610	0.76	312.16	609.98	-3.33	0.50	0.20	0.08
620	0.78	310.66	619.98	-3.43	0.59	0.28	0.09
630	0.79	306.86	629.98	-3.54	0.67	0.36	0.16
640	0.86	307.25	639.98	-3.65	0.76	0.44	0.21

Tab. F-1: Cont.

MD [m]	Inclination [°]	Azimuth [°]	TVD [m]	Easting [m]	Northing [m]	VS [m]	DLS [°/30 m]
650	0.95	309.59	649.98	-3.77	0.86	0.52	0.29
660	0.96	308.43	659.97	-3.90	0.96	0.62	0.07
670	0.98	309.45	669.97	-4.04	1.07	0.71	0.08
680	1	310.6	679.97	-4.17	1.18	0.81	0.08
690	1.03	309.71	689.97	-4.30	1.29	0.91	0.10
700	1.02	309.55	699.97	-4.44	1.41	1.01	0.03
710	1.01	302.99	709.97	-4.58	1.51	1.11	0.35
730	1.6	309.38	729.96	-4.95	1.78	1.35	0.91
740	1.55	307.97	739.96	-5.16	1.96	1.50	0.19
750	1.49	307.07	749.95	-5.37	2.12	1.64	0.19
760	1.46	308.11	759.95	-5.58	2.27	1.78	0.12
770	1.44	309.87	769.95	-5.77	2.43	1.92	0.15
780	1.49	310.76	779.94	-5.97	2.60	2.07	0.16
790	1.51	311.08	789.94	-6.17	2.77	2.22	0.07
800	1.56	310.46	799.94	-6.37	2.95	2.38	0.16
810	1.59	309.82	809.93	-6.58	3.12	2.54	0.10
820	1.62	308.3	819.93	-6.80	3.30	2.69	0.16
830	1.62	307.42	829.93	-7.02	3.47	2.85	0.07
840	1.6	307.86	839.92	-7.24	3.64	3.00	0.07
850	1.58	308.71	849.92	-7.46	3.82	3.15	0.09
860	1.57	310.55	859.91	-7.67	3.99	3.31	0.15
870	1.62	311.32	869.91	-7.88	4.17	3.47	0.16
880	1.66	311.41	879.91	-8.10	4.36	3.64	0.12
890	1.74	310.64	889.90	-8.32	4.56	3.82	0.25
900	1.81	309.58	899.90	-8.56	4.76	3.99	0.23
910	1.84	309.24	909.89	-8.80	4.96	4.17	0.10
920	1.86	308.72	919.89	-9.05	5.16	4.35	0.08
930	1.85	308.59	929.88	-9.31	5.36	4.53	0.03
940	1.81	308.76	939.88	-9.56	5.56	4.71	0.12
950	1.83	309.57	949.87	-9.80	5.77	4.89	0.10
960	1.87	310.51	959.87	-10.05	5.97	5.07	0.15
970	1.98	309.96	969.86	-10.31	6.19	5.27	0.33
980	2.37	309.29	979.85	-10.60	6.43	5.48	1.17
990	2.44	310.16	989.84	-10.92	6.70	5.72	0.24
1'000	2.35	308.68	999.83	-11.24	6.97	5.96	0.33

Tab. F-1: Cont.

MD [m]	Inclination [°]	Azimuth [°]	TVD [m]	Easting [m]	Northing [m]	VS [m]	DLS [°/30 m]
1'010	2.39	307.89	1'009.83	-11.57	7.22	6.19	0.15
1'020	2.37	309.15	1'019.82	-11.89	7.48	6.41	0.17
1'030	2.42	309.61	1'029.81	-12.22	7.75	6.65	0.16
1'040	2.41	310.22	1'039.80	-12.54	8.02	6.89	0.08
1'050	2.4	311.18	1'049.79	-12.86	8.29	7.14	0.12
1'060	2.44	311.06	1'059.78	-13.18	8.57	7.39	0.12
1'070	2.5	310.73	1'069.77	-13.50	8.85	7.64	0.18
1'080	2.55	308.96	1'079.76	-13.84	9.13	7.89	0.28
1'090	2.56	308.84	1'089.75	-14.19	9.41	8.14	0.03
1'100	2.55	309.47	1'099.74	-14.53	9.69	8.39	0.09
1'110	2.59	310.81	1'109.73	-14.87	9.98	8.65	0.22
1'120	2.65	310.07	1'119.72	-15.22	10.28	8.91	0.21
1'130	2.69	308.92	1'129.71	-15.58	10.57	9.18	0.20
1'140	2.71	307.76	1'139.70	-15.95	10.87	9.43	0.17
1'150	2.7	306.88	1'149.69	-16.33	11.15	9.69	0.13
1'160	2.64	306.97	1'159.68	-16.70	11.43	9.93	0.18
1'170	2.32	307.2	1'169.67	-17.04	11.69	10.16	0.96
1'180	2.38	310.01	1'179.66	-17.36	11.95	10.39	0.39
1'190	2.61	309.69	1'189.65	-17.70	12.23	10.64	0.69
1'200	2.74	307.96	1'199.64	-18.06	12.52	10.90	0.46
1'210	2.73	309.39	1'209.63	-18.44	12.82	11.16	0.21
1'220	2.8	313.77	1'219.62	-18.80	13.14	11.45	0.67
1'230	2.95	318.39	1'229.61	-19.14	13.50	11.78	0.83
1'240	3.04	320.91	1'239.59	-19.48	13.90	12.15	0.48
1'250	2.97	321.41	1'249.58	-19.81	14.31	12.53	0.22
1'260	2.69	321.6	1'259.57	-20.12	14.69	12.88	0.84
1'270	2.66	322.97	1'269.55	-20.40	15.06	13.23	0.21
1'280	2.68	325.55	1'279.54	-20.67	15.44	13.58	0.37
1'290	2.64	337.85	1'289.53	-20.89	15.85	13.97	1.71
1'300	2.73	343.68	1'299.52	-21.05	16.29	14.39	0.86
1'310 (TD)	3.15	1.48	1'309.51	-21.11	16.79	14.89	3.00

Appendix G: Casing / liner tally lists

Tab. G-1: 18 $\frac{5}{8}$ " tally list

Casing List

Nagra Trullikon-1

18 5/8" Casing

Stabilizer

Joint #	Length	Total	Drifted	23" x 18 5/8"	30" x 18 5/8"	remarks
Shoe	0.75	0.75	X			
1	11.56	12.31	X	1		
Float Collar	0.4	12.71	X			
2	11.56	24.27	X	2		
3	11.51	35.78	X			
4	11.55	47.33	X	3		
5	11.4	58.73	X			
6	11.4	70.13	X	4		
7	11.51	81.64	X			
8	11.59	93.23	X	5		
9	11.62	104.85	X			
10	11.55	116.40	X	6		
11	11.6	128.00	X			
12	11.28	139.28	X	7		
13	11.61	150.89	X			
14	11.37	162.26	X	8		
15	11.6	173.86	X			
16	11.43	185.29	X	9		
17	11.53	196.82	X			
18	11.47	208.29	X	10		
19	11.56	219.85	X			
20	11.47	231.32	X	11		
21	11.56	242.88	X			
22	11.41	254.29	X	12		
23	11.54	265.83	X			
24	11.53	277.36	X	13		
25	11.55	288.91	X			
26	11.58	300.49	X	14		
27	11.2	311.69	X			
28	11.59	323.28	X	15		
29	11.47	334.75	X			
30	11.37	346.12	X	16		
31	11.55	357.67	X			
32	11.62	369.29	X	17		
33	11.62	380.91	X			
34	11.62	392.53	X	18		
35	11.61	404.14	X			
36	11.48	415.62	X	19		
37	11.62	427.24	X			
38	11.55	438.79	X	20		
39	11.62	450.41	X			
40	11.45	461.86	X		1	
41	11.53	473.39	X			
42	11.62	485.01	X		2	
43	11.61	496.62	X			last casing to run
44	11.62	508.24	X			
45	11.45	519.69	X			
46	11.38	531.07	X			
47	11.57	542.64	X			
48	11.61	554.25	X			
49	11.62	565.87	X			
50	11.61	577.48	X			
51	11.51	588.99	X			

Total Length of Casing String:

496.62 m

Total Length of Casing above RT:

1.00 m

Total Casing BGL:

491.2 m

above Bottom: **2.28 m**

Tab. G-2: 13³/₈" tally list

Date: 26/10/2019

Marriott Rig # 16

Nagra Well: Trullikon-1

Casing Tally List

Centralizer

Casing: 13 3/8" , 68 lb/ft K 55 BTC

Bow Centralizer Ridgid Centralizer

Joint #	Length	Total	Drifted	17 1/2" x 13 3/8"	18 5/8" 13 3/8"	Remarks
Float Shoe	0.50	0.50				
1	11.48	11.98	X	1		tack welding
Float Collar	0.48	12.46				tack welding
2	11.46	23.92	X	2		tack welding
3	11.32	35.24	X			tack welding
4	11.58	46.82	X	3		tack welding
5	11.30	58.12	X			
6	11.60	69.71	X	4		
7	11.60	81.31	X			
8	11.47	92.78	X	5		
9	11.56	104.34	X			
10	11.60	115.94	X	6		
11	11.36	127.29	X			
12	11.56	138.85	X	7		
13	11.58	150.43	X			
14	11.58	162.01	X	8		
15	11.51	173.52	X			
16	11.49	185.00	X	9		
17	11.46	196.47	X			
18	11.27	207.73	X	10		
19	11.60	219.33	X			
20	11.57	230.89	X	11		
21	11.60	242.49	X			
22	11.29	253.78	X	12		
23	11.22	265.01	X			
24	11.60	276.60	X	13		
25	11.60	288.20	X			
26	11.24	299.44	X	14		
27	11.58	311.02	X			
28	11.58	322.60	X	15		
29	11.59	334.19	X			
30	11.45	345.64	X	16		
31	11.18	356.82	X			
32	11.47	368.29	X	17		
33	11.60	379.89	X			
34	11.60	391.49	X	18		
35	11.57	403.05	X			
36	11.56	414.61	X	19		
37	11.49	426.10	X			
38	11.47	437.57	X	20		
39	11.49	449.06	X			
40	11.55	460.61	X	21		
41	11.56	472.17	X			
42	11.48	483.64	X	22		
43	11.43	495.07	X			
44	11.60	506.67	X	23		
45	11.34	518.01	X			
46	11.34	529.35	X	24		
47	11.61	540.96	X			
48	8.93	549.89	X			pup joint Nr. 3
49	11.52	561.41	X	25		
50	11.59	573.00	X			
51	11.60	584.60	X	26		
52	11.60	596.20	X			
53	11.56	607.76	X	27		
54	11.58	619.34	X			
55	11.60	630.93	X	28		
56	11.61	642.54	X			
57	11.53	654.07	X	29		
58	11.32	665.39	X			
59	11.60	676.99	X	30		
60	11.56	688.55	X			
61	11.54	700.09	X		1	
62	11.28	711.37	X			
5	2.92	714.29	X			pup joint Nr. 5
Stay out of hole						
48	10.77	10.89	X			
63	11.58	11.70	X			
64	11.61	11.73	X			
65	11.56	11.68	X			
Pup 1	5.91	6.03	X			Pup 1
Pup 2	8.91	9.03	X			Pup 2
Pup 4	5.91	6.03	X			Pup 4

Total Length of Casing String:

714.29 m

Total Casing BGL:

708.90 m

above Bottom:

3.10 m

Total Length of Casing above RT:

0.49 m

hole depth 12 1/4"

712.00 m

hole depth 17 1/2"

710.65 m

Setting depth 13 3/8"

1.35 m above 17 1/2" depth

GL to RT

4.90 m

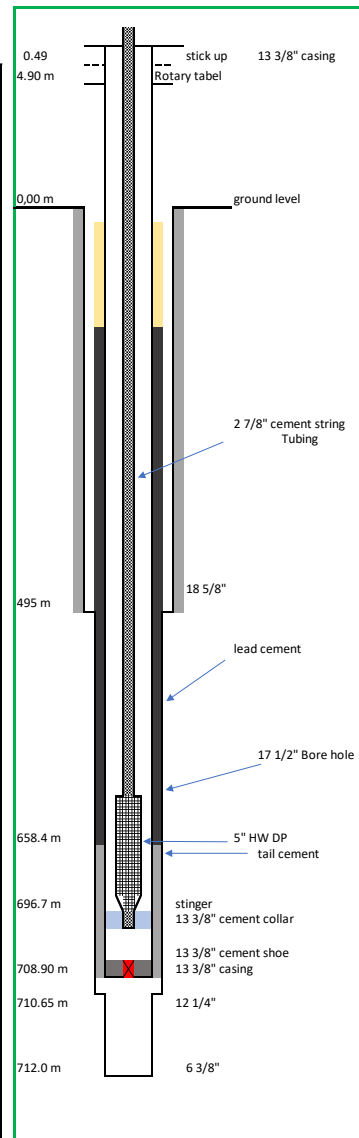
stick up RT

0.49 m

Total length casing required

714.69 m

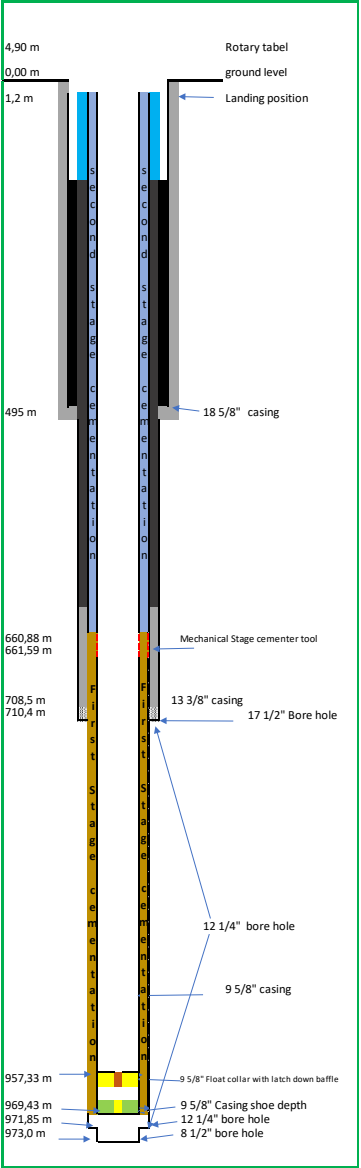
required



Tab. G-3: 9 5/8" tally list

Date: 20/01/2020
Casing Tally List
Casing: 9 5/8" 40 lb/ft
Marriott Rig # 16
hole depth 973.20 m
12 1/4" depth 971.85 m
Shoe depth 969.43 m
Nagra Well: Trullikon-1

Joint #	Length	Total	Final position in hole BGL		Centralizer	Remarks
			from	to		
Float shoe	0.5	0.5	969.43 m BGL	968.93 m BGL		
1	11.25	11.75	968.93 m BGL	957.68 m BGL	x	stop collar tack welding
Float collar	0.35	12.10	957.68 m BGL	957.33 m BGL		tack welding
2	11.35	23.45	957.33 m BGL	945.98 m BGL	x	stop collar tack welding
3	11.48	34.93	945.98 m BGL	934.50 m BGL		tack welding
4	10.79	45.72	934.50 m BGL	923.71 m BGL	x	
5	11.07	56.79	923.71 m BGL	912.64 m BGL		
6	11.12	67.91	912.64 m BGL	901.52 m BGL	x	
7	11.53	79.44	901.52 m BGL	889.99 m BGL		
8	11.42	90.86	889.99 m BGL	878.57 m BGL	x	
9	11.48	102.34	878.57 m BGL	867.09 m BGL		
10	11.39	113.73	867.09 m BGL	855.70 m BGL	x	
11	11.46	125.19	855.70 m BGL	844.24 m BGL		
12	11.41	136.60	844.24 m BGL	832.83 m BGL	x	
13	11.25	147.85	832.83 m BGL	821.58 m BGL		
14	11.12	158.97	821.58 m BGL	810.46 m BGL	x	
15	11.48	170.45	810.46 m BGL	798.98 m BGL		
16	11.35	181.80	798.98 m BGL	787.63 m BGL	x	
17	11.42	193.22	787.63 m BGL	776.21 m BGL		
18	11.29	204.51	776.21 m BGL	764.92 m BGL	x	
19	11.69	216.20	764.92 m BGL	753.23 m BGL		
20	11.62	227.82	753.23 m BGL	741.61 m BGL	x	
21	10.96	238.78	741.61 m BGL	730.65 m BGL		
22	11.17	249.95	730.65 m BGL	719.48 m BGL	x	
23	11.63	261.58	719.48 m BGL	707.85 m BGL		
24	11.51	273.09	707.85 m BGL	696.34 m BGL	x	
25	11.48	284.57	696.34 m BGL	684.86 m BGL		
26	11.65	296.22	684.86 m BGL	673.21 m BGL	x	
27	11.62	307.84	673.21 m BGL	661.59 m BGL		
Stage tool	0.71	308.55	661.59 m BGL	660.88 m BGL		
28	11.36	319.91	660.88 m BGL	649.52 m BGL	x	
29	11.37	331.28	649.52 m BGL	638.15 m BGL		
30	11.38	342.66	638.15 m BGL	626.77 m BGL	x	
31	11.10	353.76	626.77 m BGL	615.67 m BGL		
32	11.37	365.13	615.67 m BGL	604.30 m BGL	x	
33	11.35	376.48	604.30 m BGL	592.95 m BGL		
34	11.26	387.74	592.95 m BGL	581.69 m BGL	x	
35	11.06	398.80	581.69 m BGL	570.63 m BGL		
36	10.90	409.70	570.63 m BGL	559.73 m BGL	x	
37	11.28	420.98	559.73 m BGL	548.45 m BGL		
38	11.36	432.34	548.45 m BGL	537.08 m BGL	x	
39	11.39	443.73	537.08 m BGL	525.70 m BGL		
40	11.26	454.99	525.70 m BGL	514.44 m BGL	x	
41	11.43	466.42	514.44 m BGL	503.01 m BGL		
42	11.09	477.51	503.01 m BGL	491.92 m BGL	x	
43	11.33	488.84	491.92 m BGL	480.59 m BGL		
44	11.48	500.32	480.59 m BGL	469.11 m BGL	x	
45	11.51	511.83	469.11 m BGL	457.60 m BGL		
46	11.23	523.06	457.60 m BGL	446.37 m BGL	x	
47	11.07	534.13	446.37 m BGL	435.30 m BGL		
48	11.21	545.34	435.30 m BGL	424.09 m BGL	x	
49	11.11	556.45	424.09 m BGL	412.98 m BGL		
50	11.24	567.69	412.98 m BGL	401.74 m BGL	x	
51	11.59	579.28	401.74 m BGL	390.15 m BGL		
52	11.25	590.53	390.15 m BGL	378.30 m BGL	x	
53	11.41	601.94	378.30 m BGL	367.49 m BGL		
54	11.60	613.54	367.49 m BGL	355.89 m BGL	x	
55	11.61	625.15	355.89 m BGL	344.28 m BGL		
56	11.49	636.64	344.28 m BGL	332.79 m BGL	x	
57	11.51	648.15	332.79 m BGL	321.28 m BGL		
58	11.49	659.64	321.28 m BGL	309.79 m BGL	x	
59	11.43	671.07	309.79 m BGL	298.36 m BGL		
60	11.49	682.56	298.36 m BGL	286.87 m BGL	x	
61	11.58	694.14	286.87 m BGL	275.29 m BGL		
62	11.51	705.65	275.29 m BGL	263.78 m BGL	x	
63	11.44	717.09	263.78 m BGL	252.34 m BGL		
64	11.29	728.38	252.34 m BGL	241.05 m BGL	x	
65	11.39	739.77	241.05 m BGL	229.66 m BGL		
66	11.43	751.20	229.66 m BGL	218.23 m BGL	x	
67	11.15	762.35	218.23 m BGL	207.08 m BGL		
68	11.44	773.79	207.08 m BGL	195.64 m BGL	x	
69	11.42	785.21	195.64 m BGL	184.22 m BGL		
70	11.37	796.58	184.22 m BGL	172.85 m BGL	x	
71	11.49	808.07	172.85 m BGL	161.36 m BGL		
72	11.22	819.29	161.36 m BGL	150.14 m BGL	x	
73	11.24	830.53	150.14 m BGL	138.90 m BGL		
74	11.26	841.79	138.90 m BGL	127.64 m BGL	x	
75	11.44	853.23	127.64 m BGL	116.20 m BGL		
76	11.21	864.44	116.20 m BGL	104.99 m BGL	x	
77	11.63	876.07	104.99 m BGL	93.36 m BGL		
78	11.62	887.69	93.36 m BGL	81.74 m BGL	x	
79	11.49	899.18	81.74 m BGL	70.25 m BGL		
80	11.39	910.57	70.25 m BGL	58.86 m BGL	x	
81	11.37	921.94	58.86 m BGL	47.49 m BGL		
82	11.42	933.36	47.49 m BGL	36.07 m BGL	x	
83	11.58	944.94	36.07 m BGL	24.49 m BGL		
84	11.71	956.65	24.49 m BGL	12.78 m BGL		
85	11.58	968.23	12.78 m BGL	1.20 m BGL		
Casing Hanger for well head						
Stay out of hole						
86	11.28					
87	11.06					
88	11.13					
89	11.16					
90	11.05					
91	11.02					
92	11.40					



Tab. G-4: 7⁵/₈" liner tally list

[illegible]

Date 16.03.2020

Signature NOV

Appendix H: Core drilling system, selected bits and staged hole opener

H.1 MICON slickline core drilling system (see references)

The 5½" coring drill pipe SK 5½" B is owned by Nagra and is part of the coring equipment ordered from MICON Drilling in Celle/Nienhagen. The core diameter for this system is 95 mm, drilled with 6¾" (161.9 mm) core bits. The information shown in this Appendix was taken from MICON brochures (see references).

Tab. H-1: Coring drill pipe technical data

Technical data	
Hole size	161.9 mm
Core diameter without liner	101.4 mm
Core diameter with liner	95.0 mm
Outer tube	
Outside diameter	152.4 mm
Inside diameter	124.0 mm
Inner tube	
Outside diameter	115.0 mm
Inside diameter	107.0 mm
Drill pipe	
Outside diameter	141.0 mm
Inside diameter	124.0 mm
Weight	29 kg/m
Operational limits	
Torque to yield	185.4 kNm
Tension to yield	2'200 kN
Make-up torque (new tool joints)	11.0 kNm
Depth range (safety factor 2)	3'000 m

Wireline core barrels (double / triple tube core barrels with wireline connection) were used for reliable, complete recovery of the core without pulling out the drill string. This technique speeds up core retrieval, reduces time-consuming drill rod handling and helps to maximise coring efficiency.

All further explanations are made with the parts of the MICON CSK 146 system, which has the same technical systems as the SK 5½" B-System.

Core recovery (Fig. H-1): the catching assembly (A) was attached to a wireline winch system and lowered into the wireline drill string (B). The overshot securely interlocked with the latching head (C). Subsequently, the core-filled inner tube system could be hoisted out (D) through the wireline drill string.

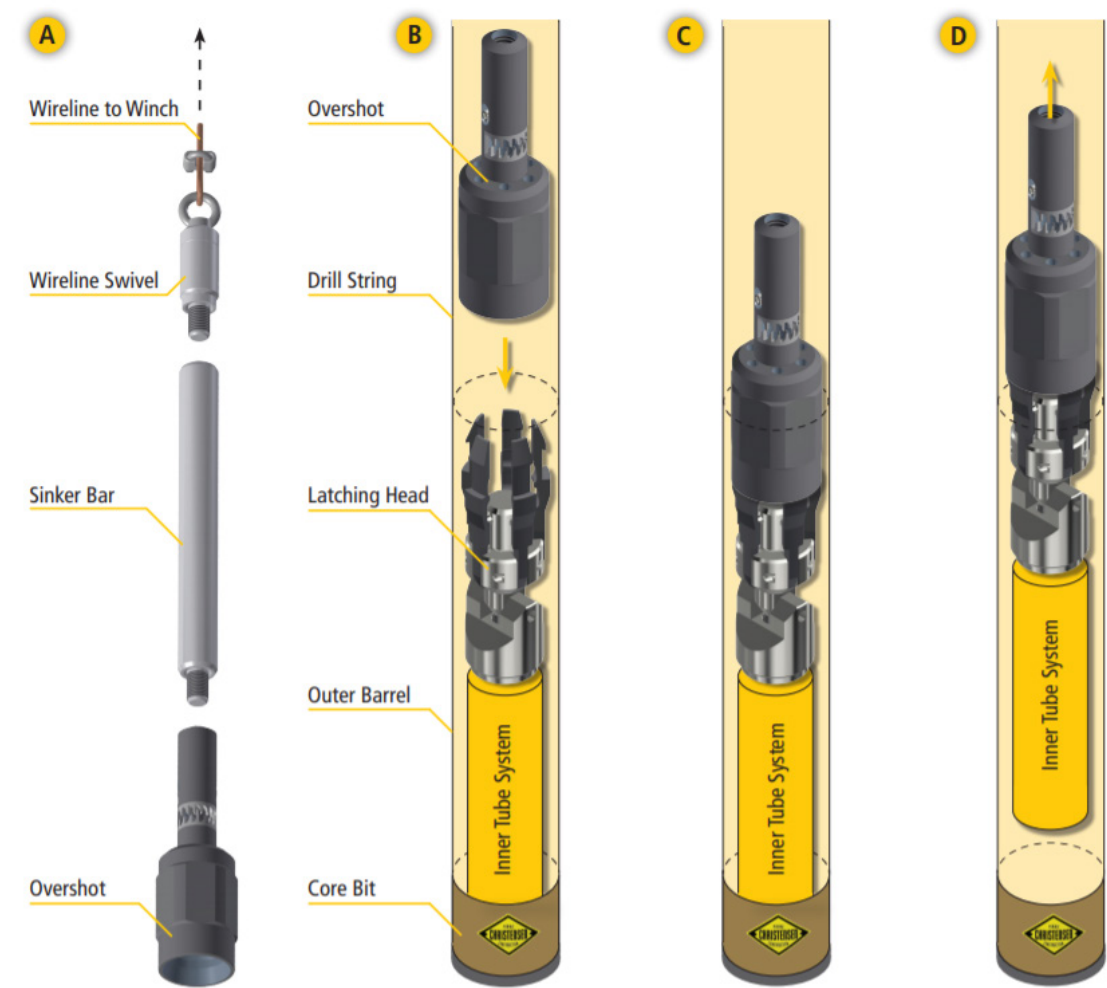


Fig. H-1: Core retrieval

Latching head

All Christensen wireline core barrels are equipped with the unique Christensen latching head (Fig. H-2), providing more latching surface than any other wireline system. The robust Christensen latching system minimises the number of moving parts to achieve a new level of dependable performance and long service life. The Christensen design ensures reliable latching for trouble-free operation while coring and during core retrieval.

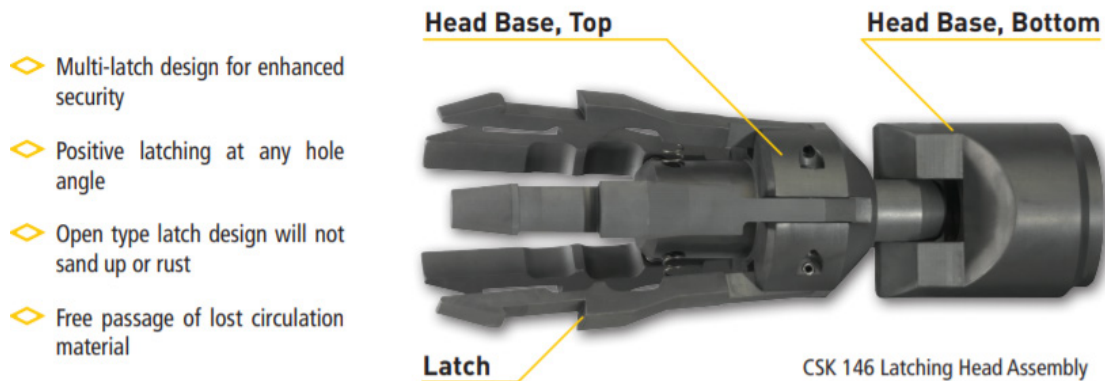


Fig. H-2: Latching head

Overshot

Complementing the reliable operation of the core barrel, the Christensen overshoot (Fig. H-3) works without external triggering hardware. Using a step ratch spring release mechanism, the overshoot is activated by repeated short raising and lowering of the wireline cable. After a pre-determined number of steps, the latching head is unblocked. This safety design prevents premature release of the inner tube. Inner tube retrieval is simply handled by pre-setting the step ratch spring before the overshoot is lowered to pick up the inner tube.

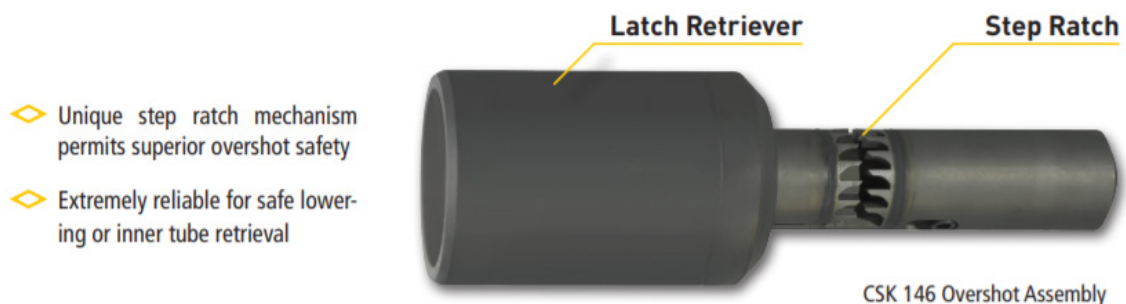


Fig. H-3: Overshot

Multidrill systems

The Christensen wireline systems can be equipped with a full hole drilling inner tube system. This multidrill system (Fig. H-4) allows to drill ahead in those areas where a core sample is not required. Like all other Christensen inner tube systems, it can be lowered without pulling out the wireline drill string.



Fig. H-4: Multidrill systems

Core lifting systems

Christensen provides a wide variety of different core lifter types (Fig. H-5). They are available with fine- and coarse-toothed profiles for less abrasive rocks. For hard, compact and abrasive rocks, Christensen core lifters can be equipped with a tungsten carbide grit. Additional short/long springs improve the core recovery rate in fractured or soft formations. Generally, all core lifters with additional springs are equipped with a profiled inner surface to ensure maximum reliability even in interbedded formations of loose and solid rocks. For homogeneous, loose formations, closed spring cage core lifters without profile can also be supplied. Additionally, special core lifters such as rubber traps or double core lifters are available.

Core Lifter Selection Chart		Additional Springs				
		No Springs	Short Springs	Long Springs	Open Spring Cage	Closed Spring Cage*
Core Lifter Profile Type	Toothed Profile, Coarse					
	Toothed Profile, Fine					
	Tungsten Carbide Grit					

*Special versions with flat core lifter profile available.



CSK 146 Core Lifter
Toothed Profile



CSK 146 Core Lifter
Tungsten Carbide Grit



CSK 146 Core Lifter
Rubber Trap



CSK 146 Core Lifter
Toothed Profile, Long Springs



CSK 146 Core Lifter
Toothed Profile, Long Springs,
Closed Spring Cage



CSK 146 Core Lifter
Flat Profile, Long Springs,
Closed Spring Cage

Fig. H-5: Core lifter systems

Core drill bits

A selection of cutter types based on formation properties and formation hardness is shown in Figs. H-6 and H-7, respectively.

Formation Properties*				Cutter Types					
Moh's Hardness	UCS [MPa]	Rock Examples	Hardness	TC	PDC	TSD	Surface Set [st/ct]		Diamond Impreg.
							6 - 15	15 - 30	
1	10	Soil, Soft Clay, Quartz-poor Sand, Marl, Sandy Limestone, Gypsum	Very Soft						
2									
3									
4	50	Hard Clay, Sand, Soft Limestone, Soft Sandstone, Soft Shale, Salt, Anhydrite	Soft						
5									
6	100	Sandstone, Siltstone, Claystone, Conglomerate, Shale, Weathered Hard Rock	Medium Hard						
7									
		Dolomite, Hard Shist, Marble, Granite, Greenstone, Andesite	Hard						
		Porphyry, Pegmatite, Diabase, Gabbro, Andesite, Gneiss	Very Hard						
		Chert, Taconite, Banded Ironstone, Quartzite	Extremely Hard						

* Specifications can differ according to geological variations.

Fig. H-6: Selection of cutter types based on rock type

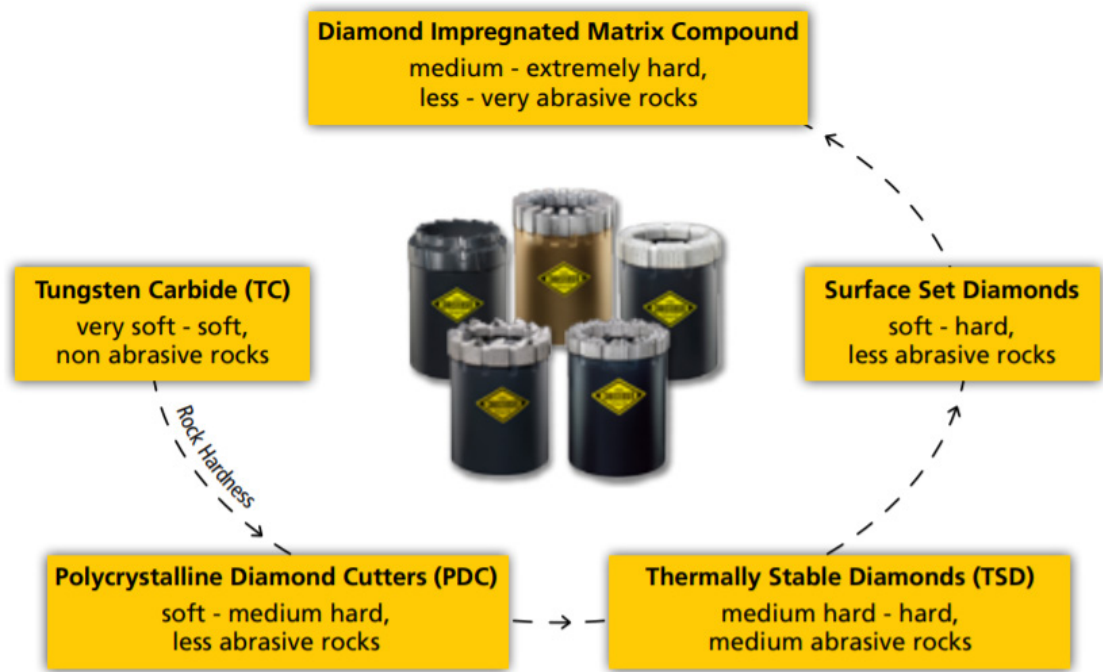


Fig. H-7: Selection of cutter types and formation hardness

Tungsten carbide – very soft to soft, non-abrasive rocks

Welded-on hard metal cutters guarantee a superior rate of penetration and sufficient wear resistance. Tungsten carbide (TC) core bits (Fig. H-8) are a cost-efficient solution for soft formations. Besides octahedral pins, rectangular plate cutters are available. They allow a very smooth core surface in salt formations.



Fig. H-8: Tungsten carbide core bit

Polycrystalline diamond compact – soft to medium hard, less abrasive rocks

Polycrystalline diamond compact (PDC) cutters (Fig. H-9) enable high rates of penetration and ensure long endurance. They consist of a hard metal cylinder covered by a synthetic diamond layer. PDC cutters are also known as 'stratapax', 'diapax' or 'PCD'. MICON offers a repair service for their PDC core bits. In most cases it is possible to renew the worn cutters, thereby reducing drilling costs significantly.



Fig. H-9: PDC core bit

Thermally stable diamond – medium hard to hard, medium abrasive rocks

Thermally stable diamond (TSD) cutters (Fig. H-10) are available in triangular or cubic shape. They are also known as 'tripax' or 'synset'. TSD cutters consist of multiple layers of synthetic diamond fragments. This feature gives TSD cutters a self-sharpening behaviour, ensuring a high endurance in abrasive formations.



Fig. H-10: TSD core bit

Surface set diamonds – soft to hard, less abrasive rocks

Surface set diamond core bits (Fig. H-11) are equipped with natural diamonds. Each diamond is oriented and inserted individually. This process ensures a maximum impact and wear resistance. Drilling diamonds are available in different sizes from 6 stones per carat to 30 stones per carat (st/ct). In general, smaller diamonds are used for harder formations.



Fig. H-11: Surface set core bit

Diamond impregnated matrix – medium hard to extremely hard, less to very abrasive rocks

Multiple layers of synthetic diamond fragments are sintered into a hard metal matrix. This compound has self-sharpening behaviour during progressing abrasion. Worn diamonds are released and replaced by new ones, until the matrix compound is completely eroded. The availability of different matrix materials allows these impregnated core bits (Fig. H-12) to be adapted to a variety of formation types. For this reason, they can be used in extremely hard as well as in extremely abrasive rocks. A colour coding (Fig. H-13) simplifies the reordering process.



Fig. H-12: Impregnated core bit

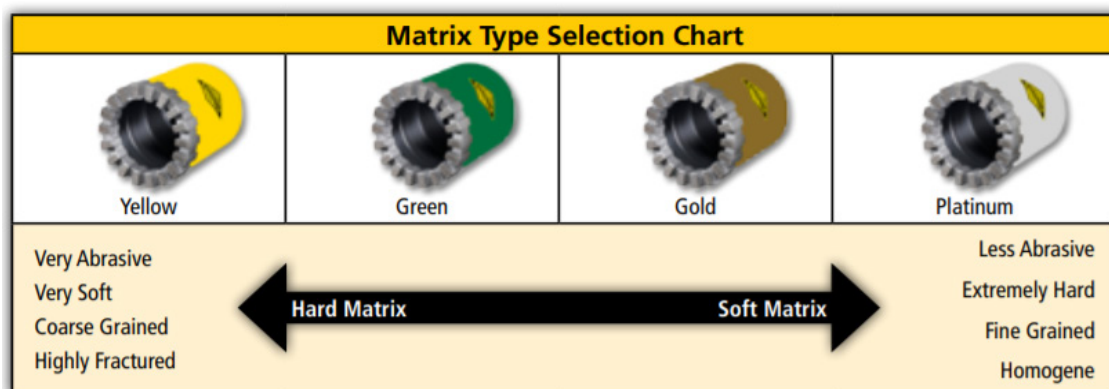


Fig. H-13: Matrix type selection chart

The general design characteristics of the core bit, especially the bit face profile, are important features that affect drilling speed, hole deviation and core recovery. MICON provides a wide range of designs and profiles to cover all common drilling conditions (see Tab. H-2 and Fig. H-14).

Tab. H-2: Profile – cutter matrix

Profile Cutter	W	BY	S	Teeth	Flat	Red. Cut- ting Area	Junk Slots	Ports	Counter- flush
TC							✓	✓	✓
PDC							✓	✓	✓
TSD							✓	✓	✓
Surface Set	✓	✓	✓				✓	✓	✓
Impregnated				✓	✓	✓	✓	✓	✓

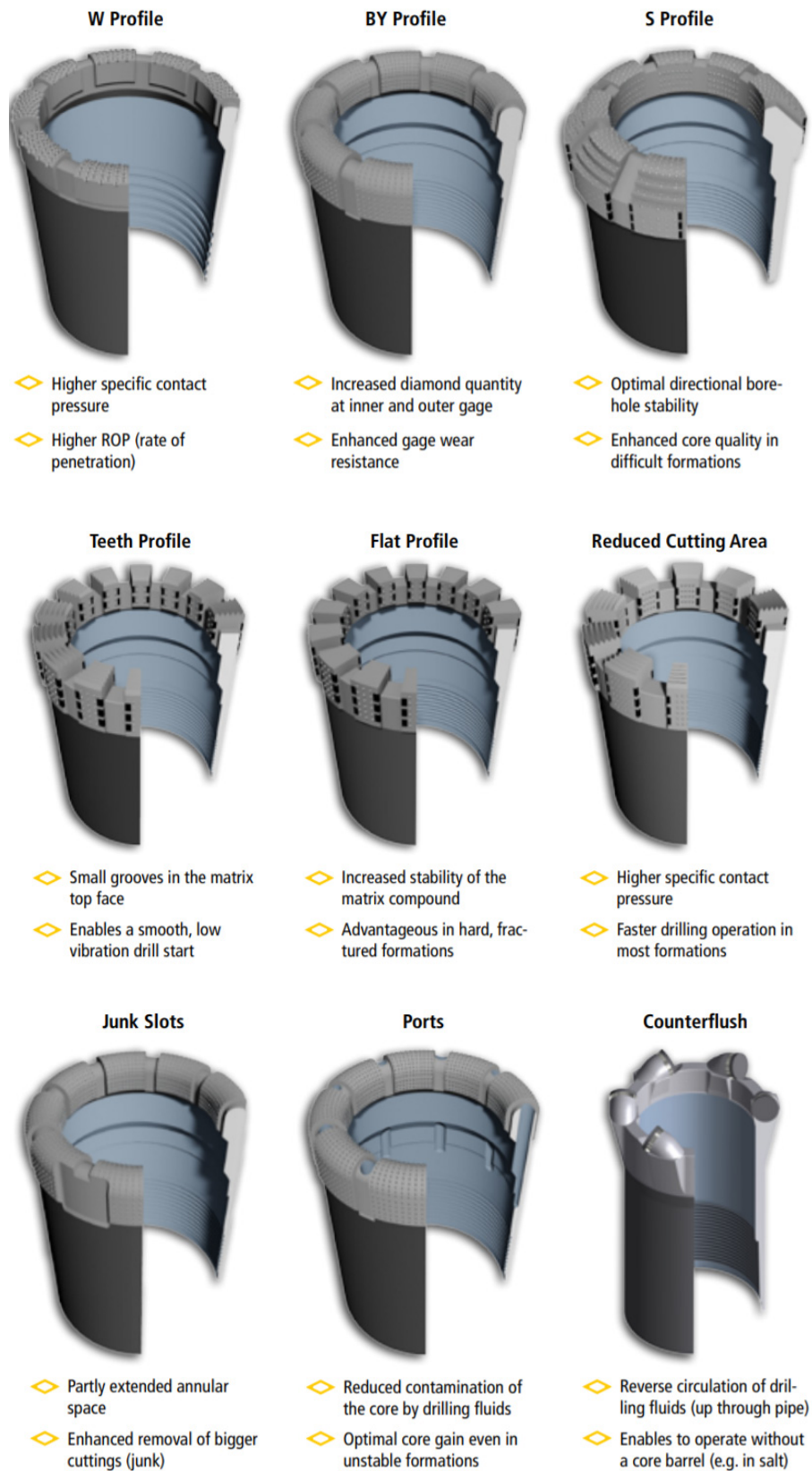


Fig. H-14: Core bit profiles

Tabs. H-3, H-4 and H-5 show optimum WOB, rpm and flowrate ranges for different bit designs.

Tab. H-3: Weight on bit for different core bits

* For reduced cutting area please correct values: red. 1 = 70%, red. 2 = 60%, red. 3 = 50%.

Weight on bit (WOB)					
System	Cutting area [cm ²]	PDC (ø 13 mm) min. – max. [t]	TSD min. – max. [t]	Surface set min. – max. [t]	Impregnated* min. – max. [t]
SK 5½" B	100.1	0.7 – 2.6	1.5 – 3.8	5.4 – 9.0	4.0 – 12.0
		50 – 200 kg/PDC	10 – 25 kg/TSD	3 – 5 kg/Diamond	40 – 120 kg/cm ²

Tab. H-4: Rotational speed of different core bits

** Correlates with 0.6 m/s to 1.5 m/s for PDC core bits, 0.6 m/s to 1.8 m/s for TSD core bits, 0.96 m/s to 2.4 m/s for surface set core bits and 1.6 m/s to 3.0 m/s for impregnated matrix compound core bits.

Rotational speed**					
System	Diameter [mm]	PDC (ø 13 mm) min. – max. [min-1]	TSD min. – max. [min-1]	Surface set min. – max. [min-1]	Impregnated min. – max. [min-1]
SK 5½" B	161.9	80 – 180	80 – 220	100 – 280	220 – 360

Tab. H-5: Pump rate during coring

*** Recommendations for VA (annular velocity) range from 200 ft/min to 300 ft/min. Please correct values according to fluid composition and drilled formation.

Circulation pump rate***						
System	Borehole diameter [mm]	Drill string OD [mm]	Pump rate [Gal (US)/min]		Pump rate [l/min]	
			min.	max.	min.	max.
SK 5½" B	161.9	141.0	298.3	447.5	1'129.2	1'694.0

H.2 Pictures of selected bits



Fig. H-15: Bit #1, drilled from 40 m to 229 m MD, balled up with clay

NOV bit with IADC code 435 drilled from 40 to 229 m in 129.45 hours was pulled because of low penetration rate. Bit grading 0-1-WT-G-E-I-NO-PR – ROP 1.46 m/h.

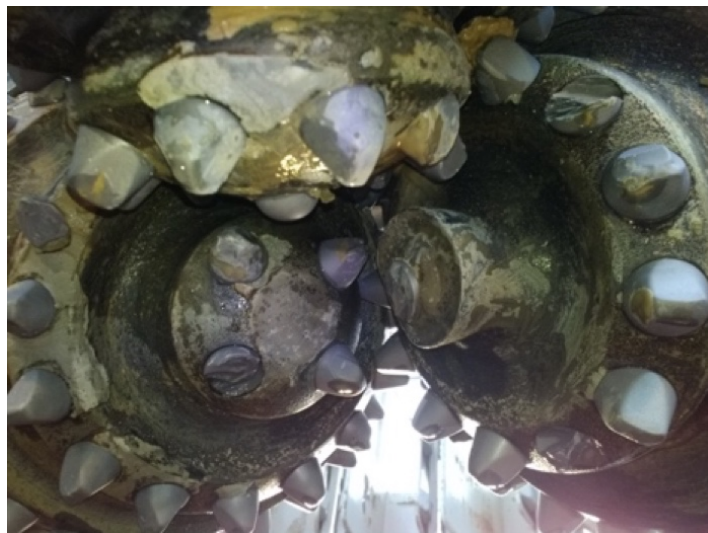


Fig. H-16: Bit #2, bit #1RR, drilled from 229 m to 332.4 m MD

NOV bit with IADC code 435 drilled from 229 to 332 m in 194.45 hours was pulled because of bit revolutions. Bit grading 0-1-WT-G-E-I-BT-HR – ROP 1.59 m/h. Because of the clay balled on the bit, the nozzles were changed from 3×20 to 3×18 .



Fig. H-17: Bit #3, drilled from 323.4 m to 493 m MD

NOV bit with IADC code 435 drilled from 332 to 493 m in 118.3 hours was pulled because of section TD. Bit grading 0-1-WT-G-E-I-BT-TD – ROP 1.36 m/h.



Fig. H-18: Bit #5, drilled from 479 m to 498 m MD

NOV bit with IADC code 115 drilled from 479 to 498 m in 6.5 hours was pulled because cement was drilled out. Bit grading 2-2-WT-A123-E-I-NO-TD – ROP 2.92 m/h.

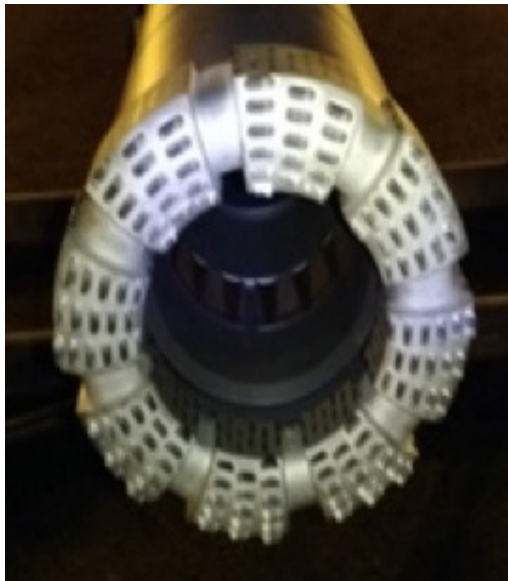


Fig. H-19: Core Bit #6, run in hole (RIH), drilled from 498 m to 505.18 m MD

MICON Ballas core bit drilled from 498 to 505 m in 3.75 and 7.0 hours and was pulled because it has side-tracked the well. Bit grading 1-2-WT-A-X-I-RP – ROP 1.6 and 0.17 m/h.



Fig. H-20: Bit #9 magnet

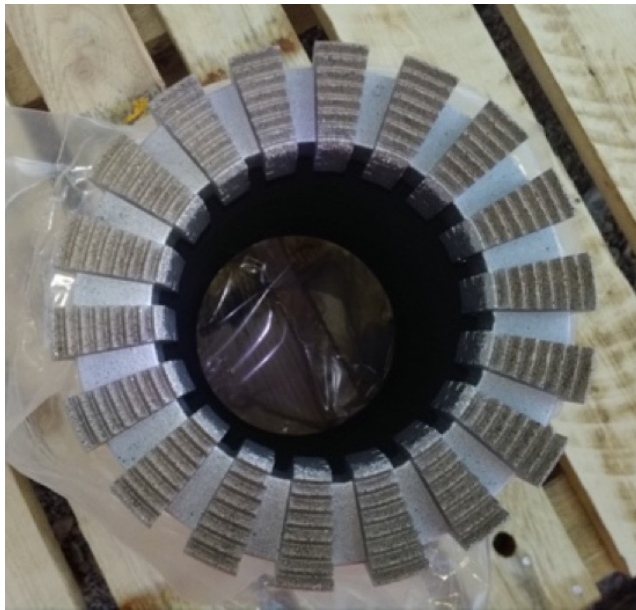


Fig. H-21: Bit #12, drilled from 513 m to 600 m MD

MICON Impregnated Gold core bit drilled from 513 to 600 m and 600 to 680 m in 33.5 and 76.0 hours and was pulled because of low penetration rate. Bit grading 4-4-WT-A-X-I-RP – ROP 2.6 and 1.88 m/h.



Fig. H-22: Bit #17, 8½" hole opener, drilled from 505 m to 711.80 m MD

NOV hole opener drilled from 505 to 711 m in 34.5 hours and was pulled because of section TD. ROP 5.97 m/h.



Fig. H-23: Bit #18, 12¼" hole opener, drilled from 505 m to 710.70 m MD

NOV hole opener drilled from 505 to 710 m in 37.5 hours and was pulled because of section TD. ROP 1.00 m/h.



Fig. H-24: Bit #19, 17½" hole opener, drilled from 498.00 m to 710.65 m MD

NOV hole opener drilled from 505 to 710 m in 37.5 hours and was pulled because of section TD. ROP 1.00 m/h.

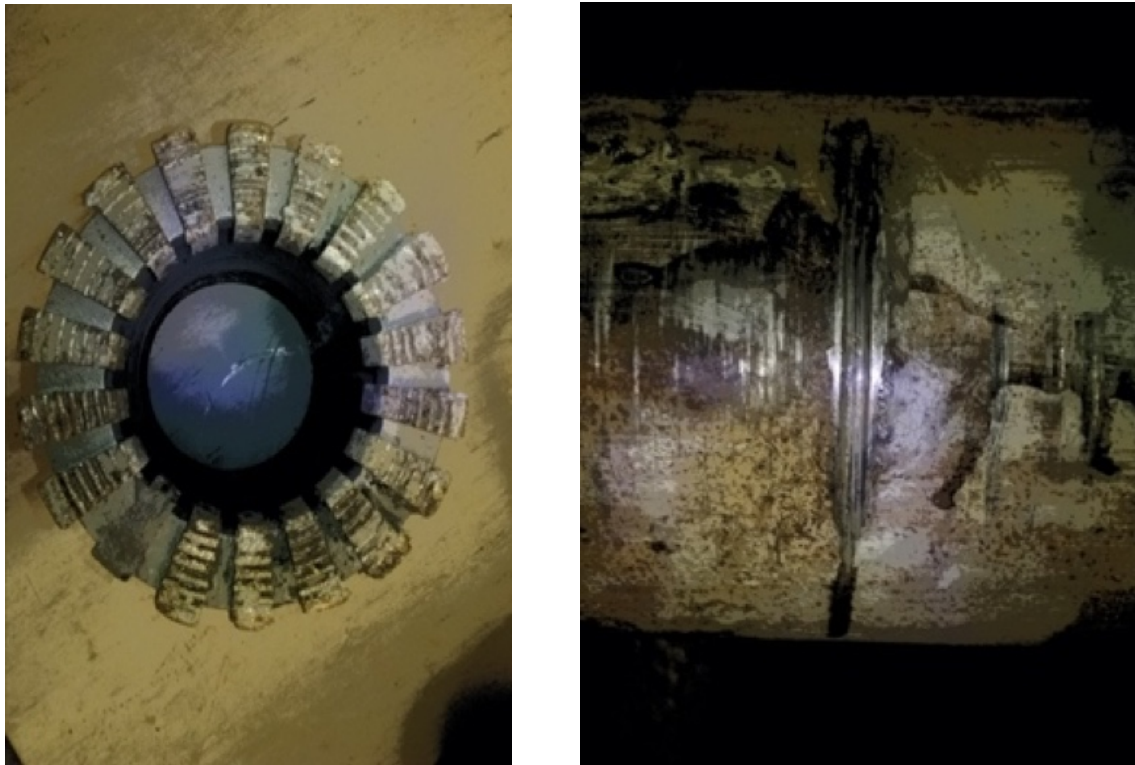


Fig. H-25: Bit #23, drilled from 719.8 m to 720.05 m MD

No progress, barrel empty, several deep grooves on first 2 m of the outer core barrel, damage on the shaft of the bit. MICON Ballas core bit drilled from 719 to 720 m in 6.25 hours and was pulled because of low ROP. Bit grading 8-8-BT-A-X-1/16-WT-RP – ROP 0.01 m/h.

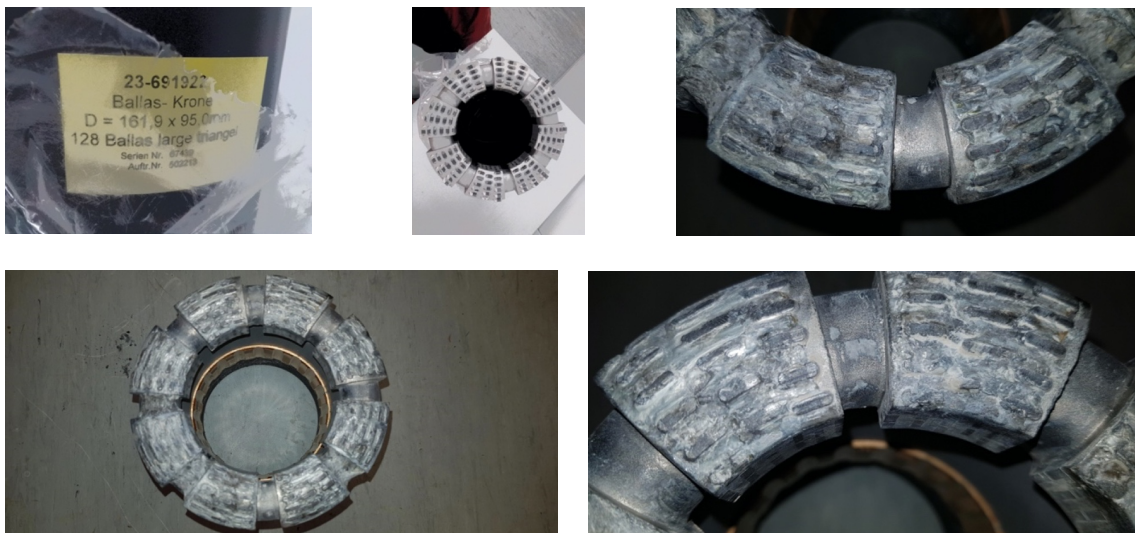


Fig. H-26: Bit #24, drilled from 720.05 m to 822.0 m MD

MICON Ballas core bit drilled from 720 to 822 m in 92.0 hours and was pulled because of low ROP. Bit grading 8-7-WT-A-X-I-CT-BHA – ROP 1.11 m/h.



Fig. H-27: Bottom hole assembly (BHA) #38, scraper run with 8 $\frac{3}{8}$ " bit

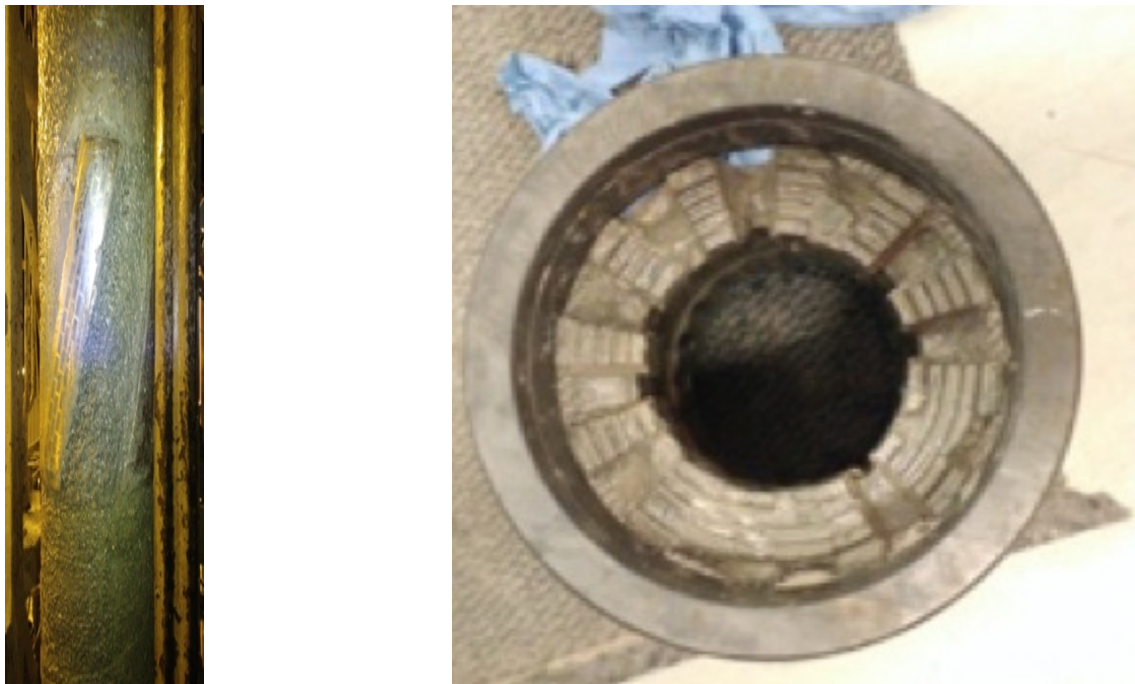


Fig. H-28: Bottom bit #38, BHA #47, bit $\frac{1}{16}$ " under gauged

MICON Impregnated Gold core bit drilled from 1'035 to 1'050 m in 15.0 hours and was pulled because of BHA change. Bit grading 2-1-WT-A-1/16-NO-BHA – ROP 0.88 m/h. Crystallisation of Silicate on tools causing standpipe pressure increase due to small flow are in annulus.



Fig. H-29: Bit #39, BHA #48

MICON Ballas core bit drilled from 1'050 to 1'074 m in 32.5 hours and was pulled because of low ROP. Bit grading 4-3-WT-A-X-CT-RP – ROP 0.74 m/h.



Fig. H-30: Bit #47, BHA #62 (stabiliser with OD larger than 6%", hanging up)

Security DBS bit drilled from 1'123 to 1'167 m in 24.0 hours and was pulled because section TD was reached. Bit grading 8-2-LC3-LT3-F-1/16-NO-TD – ROP 1.83 m/h.



Fig. H-31: Bit #49, BHA #63

NOV bit drilled from 1'280 to 1'288 m in 2.0 hours and was pulled because of low ROP. Bit grading 1-1-WT-A123-E-I-RP – ROP 1.00 m/h.

H.3 Staged hole opener

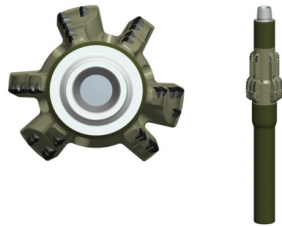
Staged hole openers (SHO) are used to enlarge the existing borehole to the required diameter for casing running and cementing, mostly in steps from 6¾" to 8½" and from 8½" to 12¼". These SHOs run with a bullnose or a pilot bit of the same size as the existing borehole at the bottom, which serves a guidance for the enlarged hole. The pilot section of the SHO itself (lower part of the SHO) consists of one or two rows of cuttings structures to recondition the pilot hole and remove any swelling clays or loose material. Gauge pads provide initial stabilisation to reduce torsional stick/slip and lateral whirl vibrations as well as tendencies to drill off centre. The lower cutters of the SHO are designed to minimise load on each cutter position for maximum durability. By stress relieving the formation with this intermediate stage, larger-hole drilling can be drilled with a more aggressive ROP. This part of the SHO recentralises the SHO on the given vertical borehole trajectory. The main body of the SHO completes the final hole diameter. With the formation already stress-relieved, the reaming section remains aggressive, even in more competent formations. Gauge trimmers and spiralled gauge pads ensure good hole quality.

A staged hole opener was used in BHA #15 and opened the hole from 505 to 710 m.

Staged Hole Opener (SHO)

12 1/4 in SHOSI616

(311mm) ID: 65271A0302



Concentric Staged Hole Openers (SHO) from Smith Bits have been developed from a tradition of application knowledge and technical excellence gained from the success of QUAD-D reaming products. SHO tools incorporate scientifically designed cutting structures to ensure fast, smoothly drilled and high quality hole opening under a wide range of application conditions. SHO tools are run successfully on rotary and rotary steerable assemblies in both straight and deviated holes.

Specifications	
Total Cutters	63
Cutter Size	16 mm (5/8 in)
Face Cutters	(38) 16mm
Gauge Cutters	(12) 16mm
Blade Count	6
Nozzles	6 Standard Series 60N
Lower Connection	4-1/2 IF PIN
Junk Slot Area, in2	41.5
Upper Connection	4-1/2 IF BOX
Gauge	Length: 2 in Protection: Options Available
Length	Make-Up: 72.304 in Overall: 76.742 in
Fishing Neck	Diameter: 7.01 in Length: 42.728 in

Operating Parameters	
Bit Rotary Speed (RPM)	Suitable for Rotary & PDM
Weight-on-Bit	6,000 to 36,000 (lbf) 2,727 to 16,362 (daN) 3 to 6 (Tonnes)
Max Flow Rate	50 to 150
Hydraulic Horsepower	1 to 6

Operating paramaters are typical ranges. Please contact your Smith Bits representative for recommendations for your individual well.

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Date 04/10/2018 Document 65271A0302

SMITH BITS

A Schlumberger Company

FEATURES

- Bit design and performance have been certified through the validation process prescribed by IDEAS simulation technology.
- SHARC high-abrasion-resistance cutting structure provides two rows of cutters for superior stability and durability, and allows the bit to drill at maximum ROP for longer periods of time.
- The PX feature extends PDC bit life by reinforcing its gauge areas with diamond-enhanced inserts (DEI) set in highly wear-resistant tungsten carbide.





slb.com/SHO

Fig. H-32: 12¼" staged hole opener

Appendix I: Coring parameters

The core recovery was 99% for the TRU1-1 borehole.

CS-Nr.	Ø core	depth MD drilling		depth MD core		core section			date	time RIH			time POOH			drilling duration			RpM	WoB	pump		dens.	mudloss		
		from	to	from	to	target	actual	rcy		from	to	Δ	from	to	Δ	from	to	Δ			ROP	[min-1]		[t]	[bar]	Flow in
	[mm]	[m]	[m]	[m]	[m]	[m]	[m]	[%]										[m/h]			[l/min]		[m3]	[l/min]		
1	95	498.00	501.00	498.00	500.90	3.00	2.90	97%	13/09/2019	15:00	01:20	10:20	05:52	07:15	01:23	01:20	05:52	04:32	0.8	108	1.5	8.0	350	1.09	0	0
2	95	501.00	504.00	500.90	503.99	3.00	3.09	103%	13/09/2019	07:44	08:10	00:26	11:07	12:24	01:17	08:10	11:07	02:53	1.0	100	3.0	10.0	352	1.08	0	0
1-Sidetrack	95	498.00	504.76	498.00	504.48	3.00	6.48	216%	13/09/2019	12:30	16:10	03:40	19:42	22:30	02:48	16:10	19:42	03:32	0.2	140	3.5	10.0	364	1.08	0	0
	3	95	505.00	506.89	505.00	506.89	1.89	1.89	100%	19/09/2019	09:00	15:00	06:00	22:50	23:50	01:00	15:00	22:50	07:50	0.5	145	4.0	9.0	370	1.08	0
4	95	506.89	510.00	506.89	510.08	3.11	3.19	103%	20/09/2019	00:00	00:30	00:30	08:34	09:22	00:48	00:30	08:34	08:04	0.4	140	4.0	10.0	360	1.07	0	0
5	95	510.00	513.00	510.08	513.09	3.00	3.01	100%	20/09/2019	09:39	10:07	00:28	22:54	23:40	00:46	10:07	22:54	12:47	0.2	190	7.0	11.0	368	1.08	0	0
6	95	513.00	516.00	513.09	516.14	3.00	3.05	102%	21/09/2019	05:30	11:00	05:30	12:26	16:10	03:44	11:00	12:26	01:26	2.1	190	3.2	11.0	400	1.08	0	0
7	95	516.00	519.00	516.14	519.05	3.00	2.91	97%	21/09/2019	16:16	16:50	00:34	17:57	18:49	00:52	16:50	17:57	01:07	2.7	180	2.7	12.0	405	1.08	0	0
8	95	519.00	522.00	519.05	522.08	3.00	3.03	101%	21/09/2019	18:49	20:10	01:21	21:28	22:10	00:42	20:18	21:28	01:10	2.5	187	3.0	12.0	407	1.08	0	0
9	95	522.00	525.00	522.08	525.19	3.00	3.11	104%	21/09/2019	22:20	22:56	00:36	00:12	00:59	00:47	22:56	00:12	01:16	2.5	182	3.0	14.0	410	1.08	0	0
10	95	525.00	528.00	525.19	528.10	3.00	2.91	97%	21/09/2019	01:00	01:37	00:37	02:37	03:20	00:43	01:37	02:37	01:00	3.0	188	2.9	14.0	402	1.08	0	0
11	95	528.00	531.00	528.10	531.21	3.00	3.11	104%	21/09/2019	03:30	03:55	00:25	05:04	05:48	00:44	03:55	05:04	01:09	2.6	183	3.0	13.0	405	1.07	0	0
12	95	531.00	534.00	531.21	534.14	3.00	2.93	98%	22/09/2019	05:48	06:21	00:33	07:47	08:38	00:51	06:21	07:47	01:26	2.1	190	3.2	13.0	402	1.07	0	0
13	95	534.00	537.00	534.14	537.17	3.00	3.03	101%	22/09/2019	08:38	09:00	00:22	10:17	11:00	00:43	09:00	10:17	01:17	2.3	190	2.7	13.0	405	1.07	0	0
14	95	537.00	540.00	537.17	540.11	3.00	2.94	98%	22/09/2019	11:00	11:25	00:25	12:42	13:25	00:43	11:25	12:42	01:17	2.3	180	2.9	12.0	400	1.07	0	0
15	95	540.00	543.00	540.11	543.23	3.00	3.12	104%	22/09/2019	13:25	13:58	00:33	15:26	16:15	00:49	13:58	15:26	01:28	2.0	185	3.0	13.0	400	1.07	0	0
16	95	543.00	546.00	543.23	546.21	3.00	2.98	99%	22/09/2019	16:15	17:11	00:56	18:55	19:40	00:45	17:11	18:55	01:44	1.7	190	3.5	13.0	400	1.08	0	0
17	95	546.00	549.00	546.21	549.24	3.00	3.03	101%	22/09/2019	19:40	20:05	00:25	21:26	22:10	00:44	20:06	21:26	01:20	2.2	190	4.0	12.0	400	1.08	0	0
18	95	549.00	552.00	549.24	552.26	3.00	3.02	101%	22/09/2019	22:10	22:46	00:36	23:52	00:35	00:43	22:46	23:52	01:06	2.7	180	4.0	12.0	402	1.08	0	0
19	95	552.00	555.00	552.26	555.22	3.00	2.96	99%	22/09/2019	00:35	01:10	00:35	02:03	03:00	00:57	01:10	02:03	00:53	3.3	186	3.6	13.0	405	1.08	0	0
20	95	555.00	558.00	555.22	558.17	3.00	2.95	98%	22/09/2019	03:00	03:30	00:30	04:27	05:16	00:49	03:30	04:27	00:57	3.2	186	4.0	13.0	401	1.08	0	0
21	95	558.00	561.00	558.17	561.21	3.00	3.04	101%	23/09/2019	05:16	05:50	00:34	06:45	07:38	00:53	05:50	06:45	00:55	3.3	186	3.5	13.0	404	1.08	0	0
22	95	561.00	564.00	561.21	564.23	3.00	3.02	101%	23/09/2019	07:38	08:19	00:41	09:32	10:17	00:45	08:19	09:32	01:13	2.5	195	4.0	13.0	400	1.08	0	0
23	95	564.00	567.00	564.23	567.21	3.00	2.98	99%	23/09/2019	10:17	10:47	00:30	11:46	12:31	00:45	10:47	11:46	00:59	3.0	205	3.6	13.0	405	1.08	0	0
24	95	567.00	570.00	567.21	570.24	3.00	3.03	101%	23/09/2019	12:31	13:07	00:36	14:11	14:54	00:43	13:07	14:11	01:04	2.8	197	4.0	14.0	394	1.08	0	0
25	95	570.00	573.00	570.24	573.27	3.00	3.03	101%	23/09/2019	14:54	15:49	00:55	17:16	17:57	00:41	15:49	17:16	01:27	2.1	195	3.3	15.0	400	1.08	0	0
26	95	573.00	576.00	573.27	576.31	3.00	3.04	101%	23/09/2019	17:57	18:30	00:33	19:38	20:20	00:42	18:30	19:38	01:08	2.6	198	3.8	14.0	400	1.08	0	0
27	95	576.00	579.00	576.31	579.29	3.00	2.98	99%	23/09/2019	20:20	20:36	00:16	21:33	22:25	00:52	20:36	21:33	00:57	3.0	197	4.0	16.0	402	1.08	0	0
28	95	579.00	582.10	579.29	582.34	3.10	3.05	98%	23/09/2019	22:35	23:00	00:25	23:58	00:44	00:46	23:00	23:58	00:58	3.0	195	3.7	15.0	404	1.08	0	0
29	95	582.10	585.00	582.34	585.18	2.90	2.84	98%	23/09/2019	00:33	01:00	00:27	01:44	02:38	00:54	01:00	01:44	00:44	4.0	200	4.0	15.0	444	1.08	0	0
30	95	585.00	588.00	585.18	588.34	3.00	3.16	105%	23/09/2019	02:38	03:15	00:37	04:00	04:45	00:45	03:15	04:00	00:45	4.0	187	3.9	16.0	411	1.08	0	0
31	95	588.00	591.00	588.34	591.33	3.00	2.99	100%	23/09/2019	04:45	05:11	00:26	05:58	06:59	01:01	05:11	05:58	00:47	4.0	183	3.6	16.0	402	1.08	0	0
32	95	591.00	594.00	591.33	594.28	3.00	2.95	98%	24/09/2019	06:59	07:38	00:39	08:29	09:12	00:43	07:38	08:29	00:51	3.5	185	3.6	15.0	405	1.08	0	0.09
33	95	594.00	597.00	594.28	597.38	3.00	3.10	103%	24/09/2019	09:15	10:00	00:45	11:00	11:47	00:47	10:00	11:00	01:00	3.0	185	3.7	14.0	402	1.08	0	0.05
34	95	597.00	600.00	597.38	600.38	3.00	3.00	100%	24/09/2019	11:47	12:28	00:41	13:26	14:19	00:53	12:28	13:26	00:58	3.1	190	2.7	13.0	403	1.08	0	0.05
35	95	600.00	601.00	600.38	601.30	1.00	0.92	92%	01/10/2019	07:00	17:00	10:00	17:45	18:45	01:00	17:00	17:45	00:45	1.3	184	3.0	16.0	406	1.06	1.1	24
36	95	601.00	604.00	601.30	604.30	3.00	3.00	100%	01/10/2019	19:10	19:40	00:30	21:03	21:54	00:53	19:40	21:03	01:23	1.4	180	4.0	15.0	405	1.06	1.5	18
37	95	604.00	606.00	604.30	606.39	2.00	2.09	105%	01/10/2019	22:00	22:40	00:40	23:38	00:45	01:07	22:42	23:38	00:56	2.1	185	3.6	15.0	405	1.06	0.9	15
38	95	606.00	609.00	606.39	609.32	3.00	2.93	98%	01/10/2019	01:05	01:49	00:44	03:11	04:08	00:57	01:49	03:11	01:22	2.2	182	3.8	16.0	405	1.06	2.7	32
39	95	609.00	612.00	609.32	612.40	3.00	3.08	103%	01/10/2019	04:20	04:35	00:15	06:13	07:13	01:00	04:35	06:13	01:38	1.8	180	3.8	16.0	400	1.06	5.1	52
40	95	612.00	615.00	612.40	615.28	3.00	2.88	96%	02/10/2019	07:13	07:46	00:33	08:45	09:40	00:55	07:46	08:45	00:59	2.7	192	3.3	17.0	402	1.06	1.6	36
41	95	615.00	618.00	615.28	618.28	3.00	3.00	100%	02/10/2019	11:10	11:40	00:30	12:40	13:40	01:00	11:40	12:40	01:								

CS-Nr.	Ø core	depth MD drilling		depth MD core'		core section			date	time RIH			time POOH			drilling duration			RPM	WoB	pump		dens.	mudloss		
		from [m]	to [m]	from [m]	to [m]	target [m]	actual [m]	rcy [%]		from	to	Δ	from	to	Δ	from	to	Δ			ROP [m/h]	[min-1]		[t]	[bar]	Flow in [l/min]
51	95	645.00	648.00	645.35	648.32	3.00	2.97	99%	03/10/2019	19:55	20:17	00:22	22:04	22:50	00:46	20:17	22:04	01:47	1.7	195	4.0	19.0	404	1.05	0.8	7
52	95	648.00	651.00	648.32	651.32	3.00	3.00	100%	03/10/2019	23:00	23:16	00:16	00:55	01:55	01:00	23:16	00:55	01:39	1.8	190	3.8	19.0	400	1.05	1.7	17
53	95	651.00	654.00	651.32	654.31	3.00	2.99	100%	03/10/2019	01:55	02:45	00:50	04:32	05:30	00:58	02:45	04:32	01:47	1.7	184	3.3	19.4	395	1.05	2.1	20
54	95	654.00	657.00	654.31	657.32	3.00	3.01	100%	04/10/2019	05:29	05:55	00:26	06:55	07:56	01:01	05:55	06:55	01:00	3.0	187	3.6	18.0	410	1.05	2	33
55	95	657.00	660.00	657.32	660.35	3.00	3.03	101%	04/10/2019	08:05	08:20	00:15	09:22	10:25	01:03	08:20	09:22	01:02	2.9	192	4.0	18.0	406	1.05	1.5	24
56	95	660.00	663.00	660.35	663.33	3.00	2.98	99%	04/10/2019	10:34	10:59	00:25	12:02	13:18	01:16	10:59	12:02	01:03	2.9	184	3.6	19.0	407	1.05	2	32
57	95	663.00	666.00	663.33	666.27	3.00	2.94	98%	04/10/2019	13:18	13:34	00:16	14:40	15:50	01:10	13:34	14:40	01:06	2.7	188	4.0	18.0	420	1.05	2	30
58	95	666.00	669.00	666.27	669.33	3.00	3.06	102%	04/10/2019	15:50	16:56	01:06	18:04	19:06	01:02	16:56	18:04	01:08	2.6	190	4.2	18.0	416	1.05	1.5	22
59	95	669.00	672.00	669.33	672.35	3.00	3.02	101%	04/10/2019	19:23	19:43	00:20	20:40	21:37	00:57	19:43	20:40	00:57	3.1	185	4.0	18.0	405	1.04	0.7	12
60	95	672.00	675.00	672.35	675.30	3.00	2.95	98%	04/10/2019	21:37	22:50	01:13	23:43	00:36	00:53	22:57	23:43	00:46	4.0	174	5.3	17.6	404	1.04	0	0
61	95	675.00	678.00	675.30	675.35	3.00	0.05	2%	04/10/2019	00:45	01:05	00:20	02:30	03:28	00:58	01:05	02:30	01:25	2.1	185	5.3	20.0	405	1.04	1.4	16
62	95	675.00	678.47	675.35	677.24	3.47	1.89	54%	04/10/2019	03:34	04:08	00:34	05:12	06:19	01:07	04:08	05:12	01:04	0.4	175	5.2	17.0	398	1.04	1.3	20
63	95	678.47	679.69	678.47	679.63	1.22	1.16	95%	05/10/2019	07:00	08:33	01:33	09:27	11:54	02:27	08:33	09:27	00:54	1.4	172	4.0	16.5	403	1.04	0.8	19
64	95	679.69	680.00	679.69	679.86	0.31	0.17	55%	05/10/2019	12:19	12:38	00:19	13:13	19:00	05:47	12:39	13:12	00:33	0.0	173	4.0	16.0	409	1.04	0.8	30
65	95	680.00	681.00	679.86	680.79	1.00	0.93	93%	05/10/2019	19:00	23:41	04:41	01:30	02:16	00:46	23:41	01:30	01:49	0.5	188	5.5	19.0	407	1.04	0.9	10
66	95	681.00	681.50	680.79	681.33	0.50	0.54	108%	05/10/2019	02:25	02:45	00:20	03:23	11:10	07:47	02:45	03:23	00:38	0.8	178	6.6	18.5	441	1.04	0.3	8
67	95	681.50	685.15	681.33	685.03	3.65	3.70	101%	06/10/2019	11:20	18:25	07:05	20:02	21:05	01:03	18:25	20:02	01:37	2.6	178	3.0	16.0	395	1.04	1	11
68	95	685.15	688.00	685.03	687.90	2.85	2.87	101%	06/10/2019	21:15	21:43	00:28	22:44	23:55	01:11	21:43	22:44	01:01	2.8	185	4.5	18.0	400	1.04	0	0
69	95	688.00	691.00	687.90	690.84	3.00	2.94	98%	06/10/2019	23:55	00:20	00:25	01:17	02:10	00:53	00:20	01:17	00:57	3.1	165	3.7	17.0	407	1.04	0.7	11
70	95	691.00	694.00	690.84	693.90	3.00	3.06	102%	06/10/2019	02:30	03:15	00:45	04:24	05:24	01:00	03:15	04:24	01:09	2.6	193	4.0	18.0	400	1.04	0.8	11
71	95	694.00	697.00	693.90	696.93	3.00	3.03	101%	07/10/2019	05:35	06:06	00:31	07:12	08:35	01:23	06:06	07:12	01:06	2.7	195	3.7	19.0	407	1.04	0.3	5
72	95	697.00	700.00	696.93	699.85	3.00	2.92	97%	07/10/2019	08:50	09:15	00:25	10:20	11:28	01:08	09:15	10:20	01:05	2.7	190	4.0	18.0	396	1.04	0.1	2
73	95	700.00	703.00	699.85	702.85	3.00	3.00	100%	07/10/2019	11:30	12:28	00:58	13:20	14:35	01:15	12:28	13:20	00:52	3.5	190	3.8	19.0	413	1.04	0.1	2
74	95	703.00	706.00	702.85	705.98	3.00	3.13	104%	07/10/2019	14:37	15:06	00:29	16:04	17:20	01:16	15:06	16:04	00:58	3.1	194	3.9	19.0	411	1.04	0.1	2
75	95	706.00	709.00	705.98	708.95	3.00	2.97	99%	07/10/2019	17:33	17:48	00:15	19:12	20:14	01:02	17:48	19:12	01:24	2.1	182	4.0	18.0	391	1.04	0.2	2
76	95	709.00	712.00	708.95	711.97	3.00	3.02	101%	07/10/2019	20:20	20:54	00:34	22:56	00:02	01:06	20:20	22:56	02:36	1.5	160	3.7	20.0	397	1.04	0.2	2
77	95	720.00	720.04	720.00	720.00	0.04	0.00	0%	17/11/2019	23:30	12:32	13:02	13:39	15:00	01:21	12:32	13:32	01:00	0.0	90	4.0	13.0	302	1.10	0	0
78	95	720.04	720.06	720.00	720.00	0.02	0.00	0%	17/11/2019	15:12	15:53	00:41	16:11	21:20	05:09	15:53	16:11	00:18	0.0	106	4.0	15.0	413	1.10	0	0
79	95	720.06	720.30	720.00	720.13	0.24	0.13	54%	18/11/2019	22:30	02:47	04:17	03:27	04:20	00:53	02:47	03:27	00:40	0.4	140	2.0	17.0	400	1.10	0	0
80	95	720.30	723.00	720.13	721.50	2.70	1.37	51%	19/11/2019	04:30	04:47	00:17	10:22	11:27	01:05	04:47	10:22	05:35	0.5	140	3.0	16.0	402	1.10	0	0
81	95	723.00	723.54	721.50	723.37	0.57	1.87	328%	19/11/2019	11:45	12:40	00:55	13:49	14:43	00:54	12:40	13:49	01:09	0.5	139	1.4	17.0	402	1.10	0	0
82	95	723.54	726.00	723.37	725.96	2.46	2.59	105%	19/11/2019	14:45	15:48	01:03	19:01	19:50	00:49	15:48	19:01	03:13	0.9	142	3.3	15.3	402	1.10	0	0
83	95	726.00	729.00	725.96	729.01	3.00	3.05	102%	20/11/2019	20:00	20:24	00:24	23:15	23:55	00:40	20:24	23:12	02:48	1.1	144	3.5	20.0	402	1.10	0	0
84	95	729.00	732.00	729.01	732.05	3.00	3.04	101%	20/11/2019	00:25	00:39	00:14	05:00	05:50	00:50	00:39	05:00	04:21	0.7	146	3.7	26.0	408	1.11	0	0
85	95	732.00	735.00	732.05	735.04	3.00	2.99	100%	20/11/2019	05:52	06:45	00:53	10:06	10:55	00:49	06:45	10:06	03:21	0.9	168	2.6	20.0	403	1.11	0	0
86	95	735.00	738.00	735.04	738.04	3.00	3.00	100%	20/11/2019	11:02	11:50	00:48	14:48	15:54	01:06	11:50	14:48	02:58	1.0	185	2.5	21.0	405	1.11	0	0
87	95	738.00	741.00	738.04	741.05	3.00	3.01	100%	20/11/2019	15:54	16:38	00:44	18:06	19:10	01:04	16:38	18:06	01:28	2.1	183	3.5	25.0	408	1.11	0	0
88	95	741.00	744.00	741.05	743.75	3.00	2.70	90%	20/11/2019	19:10	20:00	00:50	22:50	23:43	00:53	20:00	22:50	02:50	1.0	184	3.5	21.0	404	1.11	0	0
89	95	744.00	747.00	743.75	747.05	3.00	3.30	110%	20/11/2019	23:49	00:23	00:34	03:53	04:37	00:44	00:23	03:53	03:30	0.9	181	4.2	22.0	405	1.11	0	0
90	95	747.00	750.00	747.05	749.83	3.00	2.78	93%	21/11/2019	04:37	05:12	00:35	07:18	08:06	00:48	05:17	07:18	02:01	1.5	166	5.0	25.0	400	1.12	0	0
91	95	750.00	753.00	749.83	753.09	3.00	3.26	109%	21/11/2019	08:47	09:00	00:13	11:00	11:55	00:55	09:00	11:00	02:00	1.5	179	5.0	25.0	410	1.12	0	0
92	95	753.00	756.00	753.09	755.96	3.00	2.87	96%	21/11/2019	12:54	13:10	00:16	16:12	16:58	00:46	13:10	16:12	03:02	1.0	173	4.0	25.0	40>			

CS-Nr.	Ø core	depth MD drilling		depth MD core'		core section			date	time RIH			time POOH			drilling duration			RpM	WoB	pump		dens.	mudloss		
		from [mm]	to [m]	from [m]	to [m]	target [m]	actual [m]	rcy [%]		from	to	Δ	from	to	Δ	from	to	Δ			ROP [m/h]	[min-1]		p [bar]	Flow in [l/min]	vol [g/cm3]
101	95	780.00	783.00	779.93	782.94	3.00	3.01	100%	22/11/2019	00:00	01:04	01:04	02:53	03:44	00:51	01:04	02:53	01:49	1.7	176	3.7	22.0	401	1.12	0	0
102	95	783.00	786.00	782.94	785.94	3.00	3.00	100%	22/11/2019	03:44	04:38	00:54	06:46	07:43	00:57	04:38	06:46	02:08	1.4	183	4.3	22.0	402	1.12	0	0
103	95	786.00	789.00	785.94	788.99	3.00	3.05	102%	23/11/2019	08:04	08:25	00:21	10:43	11:33	00:50	08:25	09:09	00:44	1.3	180	4.0	22.0	404	1.12	0	0
104	95	789.00	792.00	788.99	788.99	3.00	0.00	0%	23/11/2019	11:49	12:06	00:17	16:00	16:53	00:53	12:06	16:00	03:54	0.8	182	5.0	23.0	403	1.12	0	0
105	95	792.00	792.30	788.99	792.20	0.30	3.21	1070%	23/11/2019	17:08	17:25	00:17	17:38	18:35	00:57	17:25	17:38	00:13	1.4	179	5.0	24.0	411	1.13	0	0
106	95	792.30	795.00	792.20	795.00	2.70	2.80	104%	23/11/2019	17:35	18:57	01:22	20:38	21:20	00:42	18:57	20:38	01:41	1.6	178	3.8	23.0	408	1.13	0	0
107	95	795.00	798.00	795.00	797.91	3.00	2.91	97%	23/11/2019	21:20	22:23	01:03	02:16	03:05	00:49	22:23	02:16	03:53	0.8	179	4.8	27.0	404	1.13	0	0
108	95	798.00	801.00	797.91	801.03	3.00	3.12	104%	23/11/2019	03:05	03:56	00:51	07:00	07:52	00:52	03:56	07:00	03:04	1.0	179	4.2	23.0	405	1.13	0	0
109	95	801.00	804.00	801.03	804.02	3.00	2.99	100%	24/11/2019	08:18	08:38	00:20	10:42	11:31	00:49	08:38	10:42	02:04	1.5	182	4.2	22.0	400	1.12	0	0
110	95	804.00	807.00	804.02	806.93	3.00	2.91	97%	24/11/2019	11:50	12:15	00:25	13:30	14:22	00:52	12:15	13:30	01:15	2.4	184	4.0	21.2	406	1.12	0	0
111	95	807.00	810.00	806.93	809.92	3.00	2.99	100%	24/11/2019	14:41	14:58	00:17	16:39	17:29	00:50	14:58	16:39	01:41	1.8	179	4.0	23.2	398	1.13	0	0
112	95	810.00	813.00	809.92	813.03	3.00	3.11	104%	24/11/2019	17:50	18:10	00:20	20:19	21:09	00:50	18:10	20:19	02:09	1.5	174	4.0	20.2	403	1.13	0	0
113	95	813.00	816.00	813.03	816.02	3.00	2.99	100%	24/11/2019	21:09	22:00	00:51	23:53	00:44	00:51	22:00	23:53	01:53	1.6	179	4.2	21.0	408	1.13	0	0
114	95	816.00	819.20	816.02	816.42	3.20	0.40	13%	24/11/2019	00:44	01:30	00:46	04:19	05:11	00:52	01:30	04:19	02:49	1.2	180	4.6	22.0	408	1.13	0	0
115	95	819.20	819.50	816.42	819.41	0.30	2.99	997%	24/11/2019	05:11	05:49	00:38	06:01	06:59	00:58	05:49	06:01	00:12	1.5	181	5.0	23.8	401	1.13	0	0
116	95	819.50	822.00	819.41	822.15	2.50	2.74	110%	25/11/2019	07:35	07:49	00:14	11:22	12:16	00:54	08:37	11:22	02:45	0.9	179	4.0	20.0	404	1.13	0	0
117	95	822.00	825.00	822.15	822.15	3.00	0.00	0%	08/12/2019	01:00	08:08	07:08	10:30	11:25	00:55	08:08	10:30	02:22	1.5	168	2.3	15.0	327	1.20	0	0
118	95	825.00	825.50	822.15	825.57	0.50	3.42	684%	08/12/2019	11:25	12:46	01:21	12:46	13:39	00:53	12:24	12:46	00:22	1.5	168	2.3	15.0	327	1.20	0	0
119	95	825.50	825.66	825.57	825.66	0.16	0.09	56%	08/12/2019	14:07	14:32	00:25	15:09	21:23	06:14	14:32	15:09	00:37	0.3	192	2.3	71.0	326	1.20	0	0
120	95	825.66	826.82	825.66	826.82	1.16	1.16	100%	08/12/2019	22:00	04:30	06:30	05:40	06:50	01:10	04:30	05:40	01:10	1.0	169	2.4	16.3	347	1.20	0	0
121	95	826.82	830.00	826.82	830.00	3.18	3.18	100%	09/12/2019	06:50	07:32	00:42	09:20	10:30	01:10	07:32	09:20	01:48	1.8	195	3.7	21.5	410	1.20	0	0
122	95	830.00	833.00	830.00	832.98	3.00	2.98	99%	09/12/2019	10:30	11:27	00:57	13:21	14:20	00:59	11:27	13:21	01:54	1.6	182	3.3	25.9	397	1.20	0	0
123	95	833.00	836.00	832.98	835.89	3.00	2.91	97%	09/12/2019	14:20	14:58	00:38	16:15	17:10	00:55	14:58	16:15	01:17	2.0	186	4.8	22.9	397	1.20	0	0
124	95	836.00	839.00	835.89	839.00	3.00	3.11	104%	09/12/2019	17:10	17:49	00:39	19:10	20:08	00:58	17:49	19:10	01:21	2.2	191	5.2	21.8	403	1.20	0	0
125	95	839.00	842.00	839.00	841.90	3.00	2.90	97%	09/12/2019	20:30	20:59	00:29	22:02	22:59	00:57	20:59	22:02	01:03	2.9	182	3.0	24.2	401	1.20	0	0
126	95	842.00	845.00	841.90	844.97	3.00	3.07	102%	09/12/2019	23:19	23:47	00:28	01:04	01:59	00:55	23:47	01:04	01:17	2.3	179	2.8	22.4	399	1.20	0	0
127	95	845.00	848.00	844.97	847.94	3.00	2.97	99%	09/12/2019	02:28	02:46	00:18	04:20	05:10	00:50	02:46	04:20	01:34	1.9	193	3.3	26.1	402	1.20	0	0
128	95	848.00	851.00	847.94	850.95	3.00	3.01	100%	10/12/2019	05:31	06:01	00:30	07:08	08:05	00:57	06:01	07:08	01:07	2.7	189	2.2	21.5	388	1.20	0	0
129	95	851.00	854.00	850.95	854.05	3.00	3.10	103%	10/12/2019	08:05	08:55	00:50	10:00	11:00	01:00	08:55	10:00	01:05	2.7	193	2.8	23.2	395	1.20	0	0
130	95	854.00	857.00	854.05	856.95	3.00	2.90	97%	10/12/2019	11:54	12:16	00:22	13:21	14:11	00:50	12:16	13:21	01:05	2.7	198	3.6	26.0	395	1.20	0	0
131	95	857.00	860.00	856.95	860.03	3.00	3.08	103%	10/12/2019	14:55	15:34	00:39	17:03	18:00	00:57	15:34	17:03	01:29	2.1	201	2.3	12.8	389	1.20	0	0
132	95	860.00	863.00	860.03	862.95	3.00	2.92	97%	10/12/2019	18:20	18:48	00:28	20:26	21:19	00:53	18:48	20:26	01:38	1.8	192	4.5	25.5	400	1.20	0	0
133	95	863.00	866.00	862.95	866.07	3.00	3.12	104%	10/12/2019	21:45	22:04	00:19	00:15	01:12	00:57	22:04	00:15	01:11	1.4	199	3.3	23.2	400	1.20	0	0
134	95	866.00	869.00	866.07	869.08	3.00	3.01	100%	10/12/2019	01:36	02:05	00:29	03:24	04:24	01:00	02:05	03:24	01:19	2.3	182	3.7	21.3	403	1.20	0	0
135	95	869.00	872.00	869.08	871.99	3.00	2.91	97%	11/12/2019	04:46	05:48	01:02	07:03	08:05	01:02	05:48	07:03	01:15	2.4	188	3.6	19.0	402	1.20	0	0
136	95	872.00	875.00	871.99	875.01	3.00	3.02	101%	11/12/2019	08:30	08:54	00:24	11:22	12:20	00:58	08:54	10:22	01:28	2.0	185	4.2	24.5	412	1.20	0	0
137	95	875.00	878.00	875.01	878.11	3.00	3.10	103%	11/12/2019	11:45	12:02	00:17	13:45	14:45	01:00	12:02	13:45	01:43	1.7	193	3.5	24.5	411	1.20	0	0
138	95	878.00	881.00	878.11	879.83	3.00	1.72	57%	11/12/2019	15:10	15:46	00:36	17:15	18:26	01:11	15:36	17:15	01:39	1.8	197	5.0	29.5	407	1.20	0	0
139	95	881.00	883.00	879.83	883.10	2.00	3.27	164%	11/12/2019	18:50	19:18	00:28	20:55	21:55	01:00	19:18	19:59	00:41	1.2	190	3.7	22.6	404	1.20	0	0
140	95	883.00	885.50	883.10	884.54	2.50	1.44	58%	11/12/2019	22:15	22:34	00:19	00:40	01:36	00:56	22:34	00:40	01:56	1.3	190	4.5	22.4	408	1.20	0	0
141	95	885.50	888.00	884.54	888.13	2.50	3.59	144%	11/12/2019	01:59	02:27	00:28	04:23	05:20	00:57	02:27	04:23	01:56	1.3	189	4.6	28.7	452	1.20	0	0
142	95	888.00	891.00	888.13	891.03	3.00	2.90	97%	12/12/2019	05:20	06:00	00:40	07:47	08:47	01:00	06:00	07:47	01:47	1.7	184	4.2	27.4				

CS-Nr.	Ø core	depth MD drilling		depth MD core'		core section			date	time RIH			time POOH			drilling duration			RPM	WoB	pump		dens.	mudloss		
		from	to	from	to	target	actual	rcy		from	to	Δ	from	to	Δ	from	to	Δ			ROP	p		Flow in	vol	v
		[mm]	[m]	[m]	[m]	[m]	[m]	[%]								[m/h]	[min-1]	[t]			[bar]	[l/min]		[g/cm3]	[m3]	[l/min]
151	95	915.00	918.00	914.01	918.09	3.00	4.08	136%	14/12/2019	07:41	08:32	00:51	11:40	12:32	00:52	08:32	11:40	03:08	1.0	193	5.1	27.0	397	1.20	0	0
152	95	918.00	921.00	918.09	921.14	3.00	3.05	102%	14/12/2019	12:32	13:10	00:38	16:05	16:58	00:53	13:10	16:05	02:55	1.0	188	5.6	26.6	409	1.20	0	0
153	95	921.00	924.00	921.14	924.08	3.00	2.94	98%	14/12/2019	16:58	17:46	00:48	20:21	21:32	01:11	17:46	20:21	02:35	1.2	190	4.9	26.6	395	1.20	0	0
154	95	924.00	927.00	924.08	927.15	3.00	3.07	102%	14/12/2019	21:32	22:16	00:44	01:05	02:00	00:55	22:16	01:05	02:59	1.0	190	5.1	27.3	404	1.20	0	0
155	95	927.00	930.00	927.15	930.20	3.00	3.05	102%	14/12/2019	02:00	02:36	00:36	04:52	05:40	00:48	02:36	04:52	02:16	1.3	189	4.8	25.5	395	1.20	0	0
156	95	930.00	933.00	930.20	933.29	3.00	3.09	103%	15/12/2019	05:40	06:34	00:54	09:46	10:44	00:58	06:34	09:46	03:12	1.0	184	4.1	21.0	398	1.20	0	0
157	95	933.00	936.00	933.29	936.18	3.00	2.89	96%	15/12/2019	10:44	11:21	00:37	13:38	14:33	00:55	11:21	13:38	02:17	1.3	188	4.4	21.3	401	1.20	0	0
158	95	936.00	939.00	936.18	939.20	3.00	3.02	101%	15/12/2019	14:50	15:25	00:35	18:07	18:55	00:48	15:25	18:07	02:42	1.1	186	4.8	20.2	400	1.20	0	0
159	95	939.00	942.00	939.20	942.32	3.00	3.12	104%	15/12/2019	18:55	19:43	00:48	22:56	23:47	00:51	19:43	22:56	03:13	0.9	190	5.3	19.7	403	1.20	0	0
160	95	942.00	945.00	942.32	945.31	3.00	2.99	100%	15/12/2019	23:47	00:32	00:45	03:41	04:30	00:49	00:32	03:41	03:09	1.0	201	5.3	20.4	414	1.20	0	0
161	95	945.00	948.00	945.31	948.24	3.00	2.93	98%	15/12/2019	04:30	05:11	00:41	06:55	07:50	00:55	05:11	06:55	01:44	1.7	193	5.1	21.6	416	1.20	0	0
162	95	948.00	951.00	948.24	951.27	3.00	3.03	101%	16/12/2019	07:50	08:31	00:41	10:41	11:41	01:00	08:31	10:41	02:10	1.4	189	4.3	20.0	412	1.20	0	0
163	95	951.00	954.00	951.27	954.35	3.00	3.08	103%	16/12/2019	11:41	12:16	00:35	14:15	15:03	00:48	12:16	14:15	01:59	1.5	192	4.3	23.9	413	1.20	0	0
164	95	954.00	957.00	954.35	957.27	3.00	2.92	97%	16/12/2019	15:20	16:00	00:40	18:22	19:16	00:54	16:00	18:22	02:22	1.3	192	4.7	22.8	415	1.20	0	0
165	95	957.00	960.00	957.27	960.27	3.00	3.00	100%	16/12/2019	19:16	20:09	00:53	22:34	23:28	00:54	20:09	22:34	02:25	1.2	189	4.5	25.0	421	1.20	0	0
166	95	960.00	963.00	960.27	963.38	3.00	3.11	104%	16/12/2019	23:28	00:14	00:54	03:21	04:10	00:49	00:14	03:21	03:07	1.0	192	5.0	22.9	422	1.20	0	0
167	95	963.00	966.00	963.38	966.26	3.00	2.88	96%	16/12/2019	04:10	04:56	00:46	07:25	08:28	01:03	04:56	07:25	02:29	1.1	197	5.1	22.2	418	1.20	0	0
168	95	966.00	969.00	966.26	969.32	3.00	3.06	102%	17/12/2019	08:28	09:20	00:52	12:11	13:07	00:56	09:20	12:11	02:51	1.1	190	4.6	22.6	420	1.20	0	0
169	95	969.00	971.36	969.32	971.78	2.36	2.46	104%	17/12/2019	13:07	13:47	00:40	16:49	17:44	00:55	13:47	16:49	03:02	0.8	192	5.6	25.2	415	1.20	0	0
170	95	971.36	973.00	971.78	973.34	1.64	1.56	95%	17/12/2019	17:44	18:30	00:46	19:56	20:54	00:58	18:30	19:56	01:26	1.2	196	5.1	22.9	412	1.20	0	0
171	95	978.00	978.50	978.00	978.30	0.50	0.30	60%	26/01/2020	06:00	16:56	10:56	19:25	20:30	01:05	16:56	19:25	02:29	0.2	118	4.0	19.4	397	1.17	0	0
172	95	978.50	979.00	978.30	978.84	0.50	0.54	108%	26/01/2020	20:30	21:20	00:50	23:26	20:26	01:00	21:20	23:26	02:06	0.2	128	5.0	18.7	410	1.17	0	0
173	95	979.00	979.50	978.84	978.97	0.50	0.13	26%	26/01/2020	00:26	01:12	00:46	03:50	04:50	01:00	01:12	03:50	02:38	0.2	132	7.0	22.4	397	1.17	0	0
174	95	979.50	980.00	978.97	979.84	0.50	0.87	174%	27/01/2020	10:00	15:20	05:20	16:57	18:00	01:03	15:20	16:57	01:37	0.3	118	4.5	20.3	400	1.17	0	0
175	95	980.00	983.00	979.84	982.82	3.00	2.98	99%	27/01/2020	18:20	18:54	00:34	23:25	00:46	01:21	18:54	23:25	04:31	0.7	158	5.0	21.1	397	1.20	0	0
176	95	983.00	986.00	982.82	985.86	3.00	3.04	101%	27/01/2020	00:46	01:35	00:49	04:18	05:26	01:08	01:35	04:18	02:43	1.2	173	6.2	21.8	410	1.20	0	0
177	95	986.00	989.00	985.86	988.91	3.00	3.05	102%	28/01/2020	05:26	05:59	00:33	10:43	11:55	01:12	05:59	10:43	04:44	0.6	180	4.5	22.2	397	1.20	0	0
178	95	989.00	991.54	988.91	991.01	2.54	2.10	83%	28/01/2020	11:55	12:17	00:22	15:40	16:55	01:15	12:17	15:40	03:23	0.6	180	4.3	20.0	400	1.20	0	0
179	95	991.54	992.30	991.01	991.55	0.76	0.54	71%	28/01/2020	15:40	16:55	01:15	19:00	20:04	01:04	16:55	19:00	02:05	0.5	195	7.4	21.9	390	1.20	0	0
180	95	992.30	992.75	991.55	991.64	0.45	0.09	20%	28/01/2020	20:04	20:42	00:38	21:06	03:05	05:49	20:42	21:16	00:34	0.8	189	6.2	21.7	410	1.20	0	0
181	95	992.75	993.72	991.64	992.34	0.97	0.70	72%	29/01/2020	04:40	09:50	05:10	10:40	11:50	01:10	09:50	10:40	00:50	1.0	196	2.6	19.2	394	1.20	0	0
182	95	993.72	994.70	992.34	993.39	0.98	1.05	107%	29/01/2020	11:50	12:15	00:25	12:59	14:10	01:11	12:15	12:59	00:44	1.3	182	2.7	19.0	352	1.20	0	0
183	95	994.70	995.70	993.39	994.32	1.00	0.93	93%	29/01/2020	14:10	14:41	00:31	15:29	16:40	01:11	14:41	15:29	00:48	1.3	169	2.2	17.0	300	1.20	0	0
184	95	995.70	997.70	995.70	997.73	2.00	2.03	102%	29/01/2020	16:40	17:12	00:32	19:12	20:02	00:50	17:12	19:12	02:00	1.0	171	3.4	16.5	300	1.20	0	0
185	95	997.70	1001.00	997.73	1001.11	3.30	3.38	102%	29/01/2020	20:02	20:57	00:55	22:35	23:25	00:50	20:57	22:35	01:38	2.0	178	4.0	20.5	307	1.20	0	0
186	95	1001.00	1004.00	1001.11	1004.11	3.00	3.00	100%	29/01/2020	23:25	00:18	00:53	02:21	03:17	00:56	00:18	02:21	02:03	1.5	189	3.6	18.0	308	1.20	0	0
187	95	1004.00	1005.00	1004.11	1005.14	1.00	1.03	103%	30/01/2020	03:17	04:14	00:57	06:27	07:31	01:04	04:14	06:27	02:13	0.5	179	5.9	21.0	305	1.20	0	0
188	95	1005.00	1008.00	1005.14	1008.18	3.00	3.04	101%	30/01/2020	07:31	08:12	00:41	13:03	20:00	06:57	08:12	13:03	04:51	0.6	171	5.0	23.1	310	1.20	0	0
189	95	1008.00	1010.50	1008.18	1010.46	2.50	2.28	91%	31/01/2020	20:00	02:33	06:33	07:27	08:29	01:02	02:33	07:27	04:54	0.5	167	5.5	22.0	335	1.20	0	0
190	95	1010.50	1014.00	1010.46	1014.10	3.50	3.64	104%	31/01/2020	08:29	09:01	00:32	13:12	14:10	00:58	09:01	13:12	04:11	0.8	189	4.7	22.7	330	1.20	0	0
191	95	1014.00	1017.00	1014.10	1017.15	3.00	3.05	102%	31/01/2020	14:10	15:00	00:50	19:28	20:23	00:55	15:00	19:28	04:28	0.7	189	4.0	23.5	347	1.20	0	0
192	95	1017.00	1020.00	1017.15	1020.18	3.00	3.03	101%	31/01/2020	20:23	21:09	00:46	00:00	0												

CS-Nr.	Ø core	depth MD drilling		depth MD core'		core section			date	time RIH			time POOH			drilling duration			RpM	WoB	pump		dens.	mudloss		
		from	to	from	to	target	actual	rcy		from	to	Δ	from	to	Δ	from	to	Δ			ROP	p		Flow in	vol	v
		[mm]	[m]	[m]	[m]	[m]	[m]	[%]													[m/h]	[min-1]		[t]	[bar]	[l/min]
201	95	1041.00	1044.00	1041.00	1043.88	3.00	2.88	96%	09/02/2020	05:34	06:12	00:38	08:33	09:27	00:54	06:12	08:33	02:21	1.3	185	5.7	32.0	384	1.20	0	0
202	95	1044.00	1047.00	1043.88	1046.95	3.00	3.07	102%	09/02/2020	09:27	10:12	00:45	12:10	13:06	00:56	10:12	12:10	01:58	1.5	184	5.3	32.0	381	1.20	0	0
203	95	1047.00	1050.00	1046.95	1050.05	3.00	3.10	103%	09/02/2020	13:06	14:01	00:55	15:51	16:44	00:53	14:01	15:51	01:50	1.8	184	4.5	31.0	381	1.20	0	0
204	95	1050.00	1051.00	1050.05	1050.95	1.00	0.90	90%	10/02/2020	00:50	19:40	18:50	20:53	21:54	01:01	19:40	20:53	01:13	0.8	170	2.5	27.3	380	1.20	0	0
205	95	1051.00	1053.00	1050.95	1052.97	2.00	2.02	101%	10/02/2020	21:54	03:10	05:16	05:13	06:22	01:09	03:10	05:13	02:03	1.0	178	2.3	26.7	393	1.19	0	0
206	95	1053.00	1055.00	1052.97	1055.06	2.00	2.09	105%	11/02/2020	06:22	07:02	00:40	09:42	10:34	00:52	07:02	09:42	02:40	0.8	176	2.8	27.3	380	1.19	0	0
207	95	1055.00	1057.13	1055.06	1057.22	2.13	2.16	101%	11/02/2020	10:34	12:18	01:44	14:46	15:44	00:58	12:18	14:46	02:28	0.9	187	3.2	27.5	381	1.19	0	0
208	95	1057.13	1060.00	1057.22	1060.08	2.87	2.86	100%	11/02/2020	15:44	16:37	00:53	21:17	22:19	01:02	16:37	21:17	04:40	0.6	185	3.5	27.5	380	1.19	0	0
209	95	1060.00	1063.00	1060.08	1062.96	3.00	2.88	96%	11/02/2020	22:19	22:57	00:38	01:29	02:37	01:08	22:57	01:29	02:32	1.2	185	2.8	30.0	380	1.19	0	0
210	95	1063.00	1065.00	1062.96	1065.00	2.00	2.04	102%	11/02/2020	02:37	03:21	00:44	06:55	07:55	01:00	03:21	06:55	03:34	0.6	181	3.2	28.5	380	1.19	0	0
211	95	1065.00	1068.00	1065.00	1067.96	3.00	2.96	99%	12/02/2020	07:55	08:47	00:52	11:48	15:44	03:56	08:47	11:48	03:01	1.0	188	3.5	28.4	380	1.19	0	0
212	95	1068.00	1071.00	1067.96	1070.98	3.00	3.02	101%	12/02/2020	15:44	16:31	00:47	20:37	21:41	01:04	16:31	20:37	04:06	0.7	188	3.5	28.0	380	1.19	0	0
213	95	1071.00	1073.81	1070.98	1073.91	2.81	2.93	104%	12/02/2020	21:41	22:34	00:53	04:30	05:35	01:05	22:34	04:30	05:26	0.5	181	3.5	29.0	380	1.19	0	0
214	95	1073.81	1074.00	1073.91	1074.03	0.19	0.12	63%	13/02/2020	05:35	06:27	00:52	07:16	12:54	05:38	06:27	07:16	00:49	0.2	186	3.7	27.7	380	1.19	0	0
215	95	1074.00	1077.00	1074.03	1077.00	3.00	2.97	99%	13/02/2020	13:08	20:41	07:33	23:00	00:00	01:00	20:41	23:00	02:19	1.3	181	4.3	30.0	380	1.19	0	0
216	95	1077.00	1080.00	1077.00	1080.10	3.00	3.10	103%	14/02/2020	00:00	00:37	00:37	01:55	02:55	01:00	00:37	01:55	01:18	2.3	185	4.3	31.0	380	1.19	0	0
217	95	1080.00	1083.00	1080.10	1083.10	3.00	3.00	100%	14/02/2020	02:55	03:31	00:36	04:54	05:54	01:00	03:31	04:54	01:23	2.2	186	4.5	31.0	380	1.19	0	0
218	95	1083.00	1086.00	1083.10	1086.13	3.00	3.03	101%	14/02/2020	05:54	06:51	00:57	08:15	09:22	01:07	06:51	08:15	01:24	2.1	184	3.8	30.8	380	1.19	0	0
219	95	1086.00	1089.00	1086.13	1089.09	3.00	2.96	99%	14/02/2020	09:22	10:02	00:40	12:24	13:32	01:08	10:02	12:24	02:22	1.3	184	3.6	31.7	380	1.19	0	0
220	95	1089.00	1092.00	1089.09	1092.09	3.00	2.99	100%	14/02/2020	13:32	14:52	01:20	16:51	17:51	01:00	14:52	16:51	01:59	1.5	183	3.9	32.8	380	1.19	0	0
221	95	1092.00	1095.00	1092.09	1095.13	3.00	3.04	101%	14/02/2020	17:51	18:45	00:54	20:00	21:00	01:00	18:45	20:00	01:15	2.4	186	4.3	30.0	380	1.19	0	0
222	95	1095.00	1098.00	1095.13	1098.17	3.00	3.04	101%	14/02/2020	21:00	21:44	00:44	23:11	00:11	01:00	21:44	23:11	01:27	2.1	185	4.3	30.0	380	1.19	0	0
223	95	1098.00	1101.00	1098.17	1101.21	3.00	3.04	101%	15/02/2020	00:11	01:01	00:50	02:07	03:07	01:00	01:01	02:07	01:06	2.7	186	4.2	33.0	380	1.19	0	0
224	95	1101.00	1104.00	1101.21	1104.09	3.00	2.88	96%	15/02/2020	03:07	03:53	00:46	05:01	06:01	01:00	03:53	05:01	01:08	2.7	184	4.2	32.0	380	1.20	0	0
225	95	1104.00	1107.00	1104.09	1107.17	3.00	3.08	103%	15/02/2020	06:01	06:57	00:56	08:10	09:23	01:13	06:57	08:10	01:13	2.5	182	3.5	32.9	380	1.20	0	0
226	95	1107.00	1110.00	1107.17	1110.25	3.00	3.08	103%	15/02/2020	09:32	10:04	00:32	11:08	12:19	01:11	10:04	11:08	01:04	2.9	180	3.5	33.1	382	1.20	0	0
227	95	1110.00	1113.00	1110.25	1113.21	3.00	2.96	99%	15/02/2020	12:19	13:07	00:48	14:34	15:48	01:14	13:07	14:34	01:27	2.1	184	3.7	35.1	382	1.20	0	0
228	95	1113.00	1116.00	1113.21	1116.20	3.00	2.99	100%	15/02/2020	15:48	16:44	00:56	18:11	19:11	01:00	16:44	18:11	01:27	2.1	180	3.6	35.7	383	1.20	0	0
229	95	1116.00	1119.00	1116.20	1119.24	3.00	3.04	101%	15/02/2020	19:11	20:00	00:49	21:40	22:40	01:00	20:00	21:40	01:40	1.8	180	4.1	34.0	372	1.20	0	0
230	95	1119.00	1122.00	1119.24	1122.31	3.00	3.07	102%	15/02/2020	22:40	23:25	00:45	01:39	02:39	01:00	23:25	01:39	02:14	1.3	187	4.3	33.0	370	1.20	0	0
231	95	1122.00	1125.00	1122.31	1125.18	3.00	2.87	96%	15/02/2020	02:39	03:22	00:43	05:07	06:10	01:03	03:22	05:07	01:45	1.7	185	4.2	35.0	380	1.20	0	0
232	95	1125.00	1128.00	1125.18	1128.23	3.00	3.05	102%	16/02/2020	06:10	06:58	00:48	09:07	10:18	01:11	06:58	09:07	02:09	1.4	183	3.8	38.2	383	1.20	0	0
233	95	1128.00	1131.00	1128.23	1131.16	3.00	2.93	98%	16/02/2020	10:18	11:12	00:54	13:23	14:39	01:16	11:12	13:23	02:11	1.4	182	4.3	31.6	383	1.20	0	0
234	95	1131.00	1134.00	1131.16	1134.00	3.00	2.84	95%	16/02/2020	22:26	06:00	06:27	09:11	10:25	01:14	06:53	09:11	02:18	1.3	184	4.2	33.8	383	1.20	0	0
235	95	1134.00	1137.00	1134.00	1137.03	3.00	3.04	101%	17/02/2020	10:25	11:07	00:42	13:44	14:49	01:05	11:07	13:44	02:37	1.2	183	4.2	34.5	383	1.20	0	0
236	95	1137.00	1140.00	1137.03	1139.96	3.00	2.93	98%	17/02/2020	14:49	16:03	01:14	19:10	20:10	01:00	16:03	19:10	03:07	1.0	186	4.3	31.0	383	1.20	0	0
237	95	1140.00	1143.00	1139.96	1142.86	3.00	2.90	97%	17/02/2020	20:11	20:54	00:43	23:52	00:52	01:00	20:54	23:52	02:58	1.0	185	4.3	32.0	380	1.20	0	0
238	95	1143.00	1146.00	1142.86	1145.96	3.00	3.10	103%	18/02/2020	00:52	01:40	00:48	04:02	05:02	01:00	01:40	04:02	02:22	1.3	185	4.5	34.0	380	1.20	0	0
239	95	1146.00	1149.00	1145.96	1149.04	3.00	3.08	103%	18/02/2020	05:02	05:56	00:54	08:40	09:53	01:13	05:56	08:40	02:44	1.1	185	4.8	30.9	383	1.20	0	0
240	95	1149.00	1152.00	1149.04	1152.01	3.00	2.97	99%	18/02/2020	09:53	11:18	01:25	14:02	15:13	01:11	11:18	14:02	02:44	1.1	184	4.3	35.6	383	1.20	0	0
241	95	1152.00	1155.00	1152.01	1154.44	3.00	2.43	81%	18/02/2020	15:13	15:55	00:42	17:47	18:53	01:06	15:55	17:47	01:52	1.6	181	4.4	35.8	383	1.20	0	0
242	95	1155.00	1158.00	1154.44	1158.00	3.00	3.56	119%	18/02/2020	18:53	19:44	00:51	21:21	22:21	01:00	19:44	21:21	01:37	1.9	184	3.8	36.0	380	1.20	0	0
243	95	1158.00	1161.00	1158.00	1161.03	3.00	3.03	101%	18/02/2020	22:21	23:02	00:41	00:56	02:00	01:04	23:02	00:56	01:54	1.6	185	4.0	35.0	380	1.20	0	0

Appendix J: IADC bit dull grading

An eight-point dull grading system has been established by the IADC to enable drillers and bit manufacturers to evaluate the performance of a drill bit. This eight-point system is described below and is used on tricones, fixed cutter and impregnated bits.

Tab. J-1: IADC dull grading system

Cutting structure							
Inner rows	Outer rows	Dull grading characteristics	Location	Bearings / seals	Gauge $\frac{1}{16}$ "	Other dull	Reason pulled
1.	2.	3.	4.	5.	6.	7.	8.

1. Inner cutting structure

Used to report the condition of the cutting elements not touching the wall of the hole. Inner cutting structure wear is classified by a number ranging from 0 to 8, with 0 being no wear and 8 being total wear.

2. Outer cutting structure

Used to report the condition of the cutting elements that touch the wall of the hole. Outer cutting structure wear is classified by a number ranging from 0 to 8, with 0 being no wear and 8 being total wear. Does not include heel elements.

Steel tooth bits

A measure of lost tooth height due to abrasion and/or damage.

0 – No loss of tooth height

8 – Total loss of tooth height

Insert bits

A measure of total cutting structure reduction due to lost, worn and/or broken inserts.

0 – No lost, worn and/or broken inserts

8 – All inserts lost, worn and/or broken

Fixed cutter bits

A measure of total cutting structure reduction due to lost, worn and/or broken cutting structure.

0 – No lost, worn and/or broken cutting structure

8 – All cuttings lost, worn and/or broken

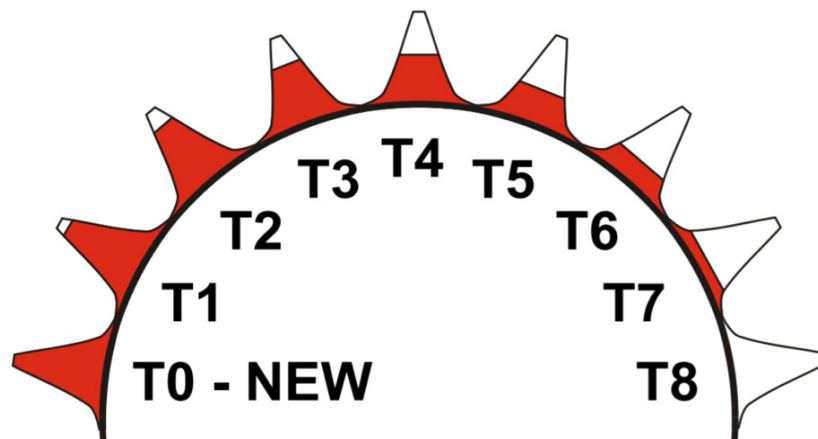


Fig. J-1: Cutting structure wear

3. Dull grading characteristics

Dull characteristics allow the bit salesperson or driller to determine the overall, distinctive aspect of the dulled drill bit according to IADC standards as follows:

BC	broken cone	
BF	bond failure	not used for roller cone bits
BT	broken teeth / cutters	
BU	balled up	
CC	cracked cone	show cone # or #'s under location 4
CD	cone dragged	show cone # or #'s under location 4
CI	cone interference	
CR	cored	
CTc	hipped teeth / cutters	
ER	erosion	
FC	flat crested wear	
HC	heat checking	
JD	junk damage	
LC	lost cone	show cone # or #'s under location 4
LN	lost nozzle	
LT	lost teeth / cutters	
NO	no dull characteristics	
NR	not rerun able	
OC	off centre wear	
PB	pinched pit	
PN	plugged nozzle / flow passage	
RG	rounded gauge	
RO	ring out	show cone # or #'s under location 4
RR	rerunnable	
SD	shirttail damage	
SS	self-sharpening wear	
TR	tracking	
WO	wash out	
WT	worn teeth/cutters	

4. Location

Location describes where the damage is on the cone.

N	nose row
M	middle row
G	gauge row
A	all rows

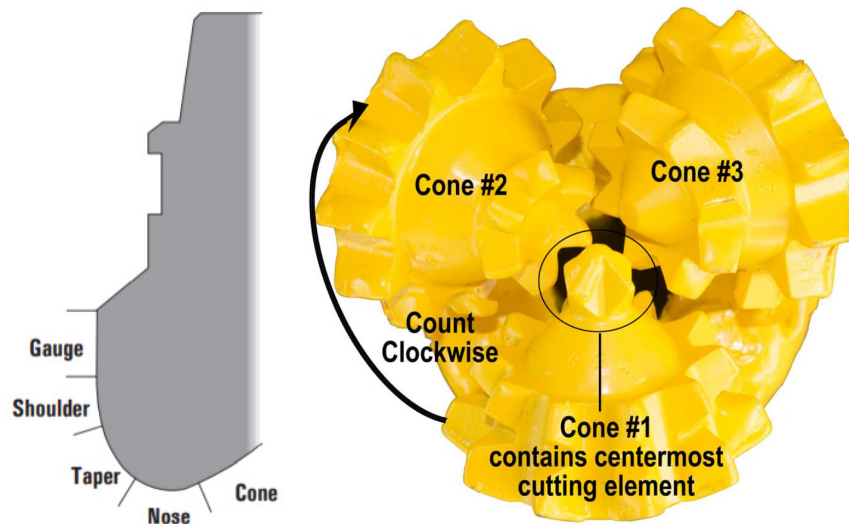


Fig. J-2: Cone numbering and different locations

Cone number 1 contains the centremost cutting component. Cones number 2 and 3 follow in a clockwise manner. Nose row is the centremost cutting structure. Gauge row is the outermost cutting structure.

5. Bearings / seals

For open or roller bearing bits, bearing life is estimated on a scale of 0 to 8.

Non-sealed bearings

0	no life used
8	all life used, i.e. no bearing life remaining

Sealed bearings

E	seals effective
F	seals failed
N	not able to grade
"X"	indicates fixed cutter

Items to check when determining seal / bearing effectiveness:

- ability to rotate cone
- cone springback
- seal squeak
- internal sounds
- weeping grease
- shale burn
- shale packing
- gaps – backface or throat
- bearing letdown – inner or outer

6. Gauge

Gauge measures the amount of gauge wear a drill bit has suffered.

I	in gauge
1	$\frac{1}{16}$ " out of gauge
2	$\frac{1}{8}$ " out of gauge
4	$\frac{1}{4}$ " out of gauge

- round the gauge to nearest $\frac{1}{16}$ "
- bits with bearing/seal failures: amount out of gauge can be measured as long as cones do not have any axial or radial movement
- measurement to be made on either gauge or heel elements, whichever is closer to gauge
- applies to cutting structure elements only
- ensure that a nominal ring gauge is used. If nominal ring gauges are not available, true gauge condition cannot be determined

7. Other dull characteristics

Any other dull grading characteristics should be noted here using the codes from #3.

8. Reason pulled

The following codes are used to indicate the reason a bit was pulled from the hole:

BHA	change bottom hole assembly
CM	condition mud
CP	core point
DMF	downhole motor failure
DP	drill plug
DSF	drill string failure
DST	drill stem test
DTF	downhole tool failure

FM	formation change
HP	hole problems
HR	hours on bit
LIH	left in hole
LOG	run logs
PP	pump pressure
PR	penetration rate
RIG	rig repair
TD	total depth / casing depth
TQ	torque
TW	twist off
WC	weather conditions
WO	washout – drill string

Appendix K: Cementing

Tab. K-1: Cementation

Item	TOC [m MD]	Lead slurry volume [m ³]	Lead slurry weight [SG]	Tail slurry volume [m ³]	Tail slurry weight [SG]	Type
30" conductor	Surface					CEM 3
18 $\frac{5}{8}$ " casing	Surface	62.5	1.70	8.7	1.88	Lead: CEM 3/B 32.5 N Tail: BLN 014
13 $\frac{3}{8}$ " casing	Approx. 78	57.7	1.70	9.3	1.88	Lead: CEM 3 Tail: BLN 014
9" casing	No bump of plug	16.3	1.88	N/A	N/A	BLN-014 HMR + Blend
	Surface	23.5	1.88			BLN-014 HMR + Blend
7" liner	925.45	4.1	1.83	N/A	N/A	CEM 3

K.1 30" conductor casing

The 30" conductor (S355 Baustahl) was run to 46.3 m MD and cemented with CEM III 32.5 HRS to surface.

K.2 18 $\frac{5}{8}$ " anchor casing

The 23" hole was drilled with a packed BHA with 23" near bit stabiliser and two 23" string stabilisers to 493.0 m MD. Casing running and circulation tools were made up on 03.09.2019 and the 94.5 ppf, K-55 BTC 18 $\frac{5}{8}$ " casing was RIH as per tally in Appendix G (Tab. G-1). During RIH, several hours of NPT were accumulated due to problems with the running tool and some crossed threads. Without hole problems, the casing was landed on the landing plate with 55 t string weight and a shoe depth of 491.2 m MD.

A 2 $\frac{7}{8}$ " cement stinger was then installed, and the casing was cemented through the stinger with 4.5 m³ mix water, 63.3 m³ lead cement (1.7 kg/l) and 8.7 m³ tail cement (1.88 kg/l). The cement was seen at the surface, no backflow through the float valve.

During WOC, the 29 $\frac{1}{2}$ " diverter line was disassembled and the 30" and 18 $\frac{5}{8}$ " casing conductor were cut and a new diverter installed.

Cement bond was evaluated from 44 to 493 m. No free pipe was found and cement at surface. Good cement bond from 474 to 493 and 400 to 413 m. Poor cement bond log from 53 to 63, 241 to 248 and 321 to 330 m. All other regions were measured with medium cement bond log.

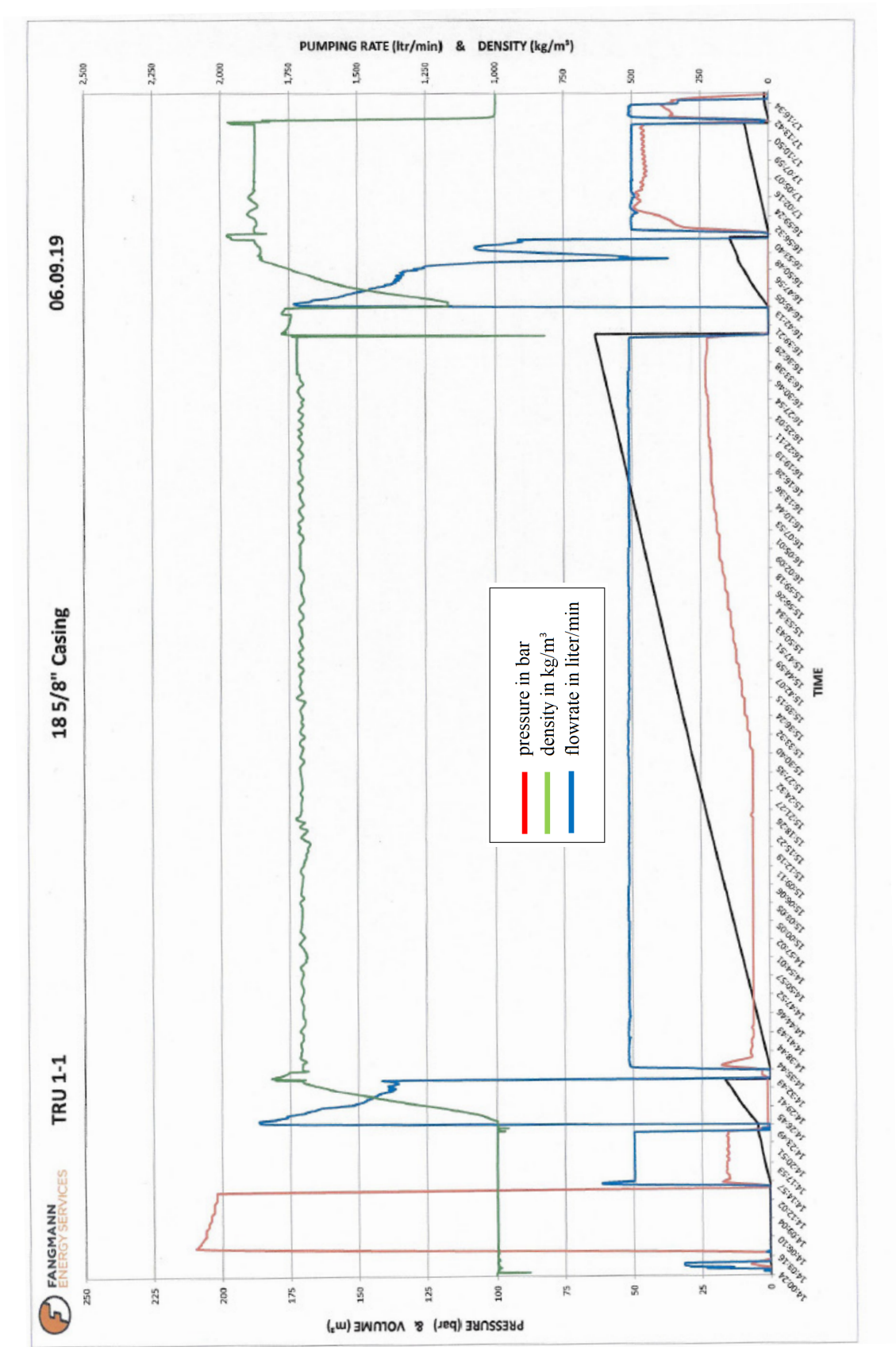


Fig. K-1: 18 5/8" cement job pressure, density and flowrate vs. time

Client: Marriott Drilling

Well: Trölikon (Switzerland)

Cementing: 18 5/8" Casing

MD 488,9 m

TVD 488,9 m

Max. Dev 0°

YG 3,0°/100m

BHST 25°C

Test Temp. 22°C

Volume Calculation

TOC

30" FS

Top bit

18 5/8" FC

18 5/8" PS

TD

Depth	OD	Description	Length	Capacity	Comment	Volume
0m	30"	Previous casing	46m	426,80l/m	Total cap.	+ 19,63 m³
46m	23"	13,5% OH XS	443m	268,20l/m	OH without XS	+ 118,79 m³
	24,50"	39,2% annular XS		128,54l/m in annulus	OH XS	+ 16,04 m³
	18 5/8"	94,5 ppf	489m	158,19l/m	Total displ.	- 85,98m³
			0m	0,00l/m		- 0,00m³
			0m	0,00l/m		- 0,00m³
			0m	0,00l/m		- 0,00m³
439m			12m		Shoetrack	+ 1,9 m³
					Cement volume	70,40m³
476,9m	5"	19,5 ppf	486m	9,03l/m	Total cap.	4,39m³
488,9m			0m	0,00l/m		0,00m³
488,9m			0m	0,00l/m		0,00m³
					Displacement volume	4,39m³

End pressure **32 bar**
Casing lift: **-10 To**
CSP **34 bar**

Fluid Design

Lead 1,70kg/l dead vol. 0,0 m³ **62,1m³**

	per m³ in case	per m³	total
Fresh water	608,3	643,7	39973,14
CMT-003	1,0	1,1	65,72

Yield **1t** 945,0

Tail 1,88kg/l dead vol. 0,0 m³ **8,3m³**

	per m³ in case	per m³	total
Fresh water	579,8	490,9	4074,80
CSL-944	127,2	107,7	893,95
BLN-014	1,5	1,3	10,65

Yield **1t** 1181,0

Logistics

Personnel

Supervisor: 1

Operator: Pump

Operator: Mixtank

Operator: Bulk

Equipment

Pumptruck Incl. Data recording 1x

7 m³ Mixtank Incl. Power source 1x

27 t Cement silo Incl. Compressor 2x

27 t Bulktruck Incl. Compressor 2x

From client:

Suction truck (fluid disposal) 1x

Material

CMT-003 65,72 tonne

BLN-014 10,65 tonne

CSL-944 893,95 kg

From client:

Fresh water for spacer 5,60 m³

Fresh water for cement 44,10 m³

Quantity

65,72 tonne

10,65 tonne

893,95 kg

Comments

CDH III B (BPS cement)

HHR + Blend

Salt NaCl

Pumping Schedule

Time	Step	Comm.	Volume	Density	Rate	Duration
			m³	kg/ltr	ltr/min	min
	Wellbore circulation min. 2 bottoms-up / Job Safety Analysis (JSA)					
	Prime the lines		0,30		300	1
	Pressure test	200 bar				10
	Pump fresh water spacer		4,50	1,00	900	5
	Premix first 7 m³ of lead cement					20
	Mix & pump Lead cement		62,10	1,70	800	78
	when lead to surface, switch to tail					
	Mix & pump Tail cement	50 m	8,30	1,88	800	10
	Pump fresh water spacer		0,50	1,00	800	1
	Pump mud		3,59	1,10	800	4
	Pump fresh water (surface lines)		0,30	1,00	300	1
	Flow Check, Sting-out, Circulate DP clean, WOC (check also with surface sample)					
					Pumping time:	129min

Recommendations / Comments

- tubular capacities & mud weight to be confirmed
- Casing to be chained down to avoid any lifting while pumping.

Document info

Prepared by: T. Preup

Client: Marriott Drilling

Version #: 5

Status: Draft

Date: 02.09.2019

This program is based on the most recent information provided by the client.

Prepared by FES and controlled by client representative.

All steps have been communicated and approved prior to the job.

FES Supervisor _____

Date _____

CoMan _____

Date _____

Fig. K-2: 18⁵/₈" cement programme

[illegible]

Fig. K-3: 18⁵/₈" cement job service ticket

K.3 13³/₈" casing

The 68 ppf, K-55 BTC 13³/₈" casing was RIH on 26.10.2019 without problems to 708.57 m MD with a final pick up weight (PUW) of 71 t and slack off weight (SOW) of 62 t. The casing was then hung off on the rig floor with a shoe depth of 708.9 m MD. The tally list is provided in Appendix G (Tab. G-2). A 2⁷/₈" cement stinger was installed, and the casing was cemented according to programme. A volume of 6.5 m³ spacer was pumped followed by lead cement with a density of 1.7 kg/l. Unfortunately, after pumping 54 m³ of lead cement with 500 l/min and 42 bar, there were no returns at surface. The flowrate was reduced to 200 l/min and lead cement was pumped to the planned volume of 57.7 m³ followed by 9.3 m³ of tail cement with a density of 1.88 kg/l (400 l/min with 41 bar). The stinger was POOH and the rig waited on cement. Top of cement in the annulus was found at 64 m.

The 12" diverter lines and the 21¹/₄" diverter were rigged down and the 13³/₈" CHH with 13⁵/₈" BOP (double ram and annular) were nipped-up and tested successfully. Top of cement was located at 46 m MD based on CBL/USIT. The reason for not getting cement to surface was the losses and therefore no returns seen after pumping 55.4 m³ of lead cement.

Cement bond was evaluated from 9 to 702 m. Top of cement identified by the logs at 46 m even during cementation cement was pumped to surface. Good cement bond from 59 to 101, 267 to 333, 335 to 359, 363 to 375, 379 to 386, 394 to 402, 411 to 430, 436 to 448, 452 to 457 and 493 to 702 m. Poor cement bond log from 10 to 46, 120 to 261 and 457 to 463 m. All other regions were measured with medium cement bond log.

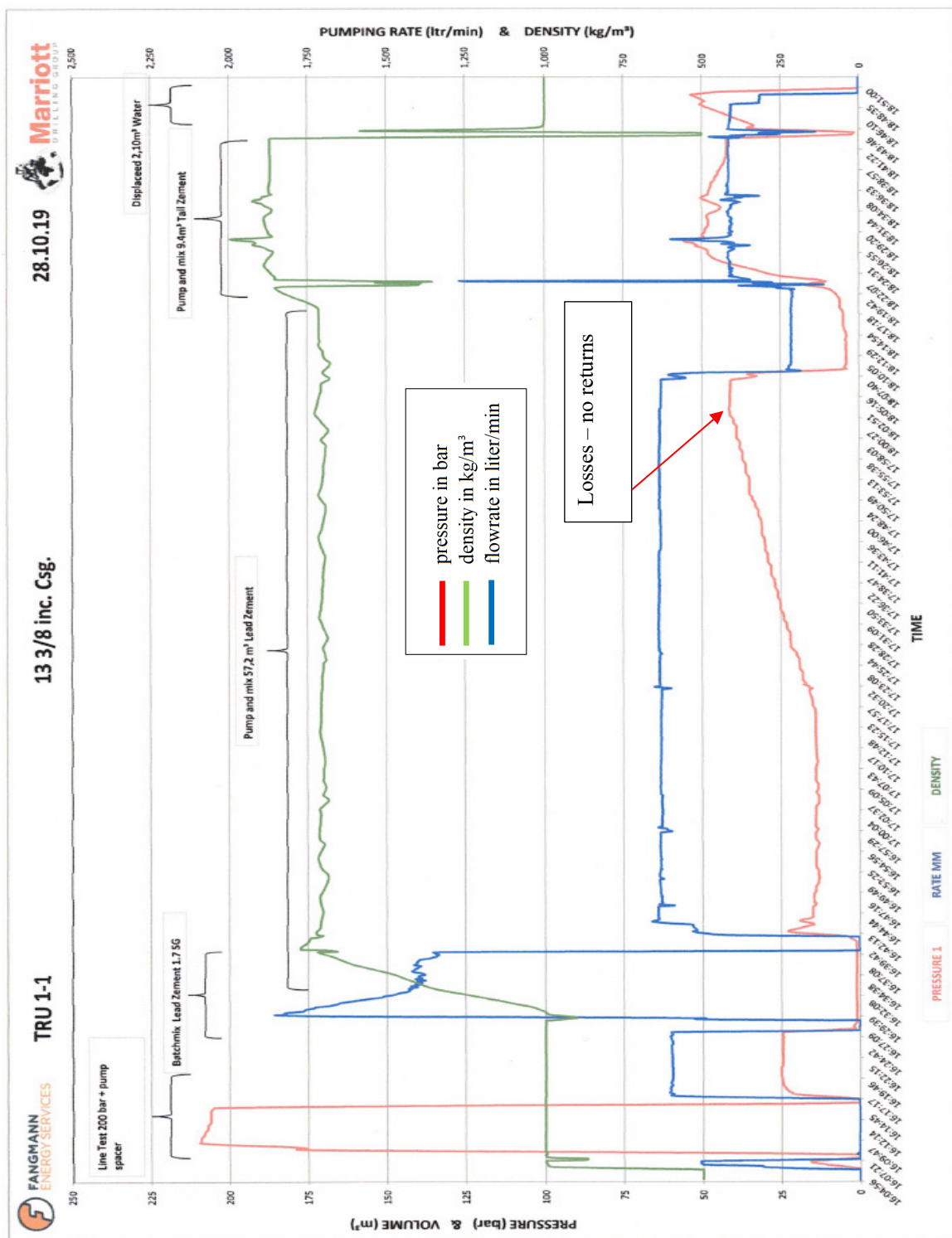
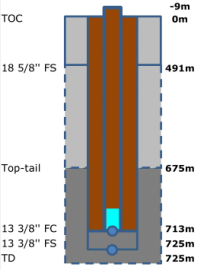


Fig. K-4: 13³/₈" cement job pressure, density and flowrate vs. time

	Client Marriott Drilling Well Trüllikon (Switzerland) Cementing 13 3/8" Casing	MD 725,0 m TVD 725,0 m Max. Dev 0°	TG 3,0°/100m BHST 37°C Test Temp. 22°C	
---	---	---	---	---

Volume Calculation								
	Previous casing	OD 18 5/8 "	Description 94,5 ppf	Length 491m	Capacity 158,19l/m 0,00l/m	Comment Total cap.	Volume + 77,67 m³ + 0,0 m³	
	Open hole	17 1/2 " 20,81 "	41% OH XS 100% annular XS	234m	155,27l/m 128,85l/m in annulus	OH without XS OH XS	+ 36,33 m³ + 15,04 m³	
	Casing to be cemented	13 3/8 "	68,0 ppf	725m	90,70l/m 0m 0,00l/m	Total displ.	- 65,76m³ - 0,00m³ - 0,00m³	
						Displacement	Shoetrack	+ 0,04 m³
						Cement volume	63,30m³	
	Drill pipe	2 7/8 "	6,5 ppf	722m	Capacity 3,02l/m 0m 0,00l/m	Total cap.	2,18m³ 0,00m³ 0,00m³	
						Displacement volume	2,20m³	
	End pressure 43 bar							

Fluid Design							
Lead	1,70kg/l	dead vol. 0,0 m³	56,8m³	Tail	1,88kg/l	dead vol. 0,3 m³	6,8m³
Fresh water	per.1000 kg cmt.	per.m²	total	Fresh water	per.1000 kg cmt.	per.m²	total
CMT-003	608,3	643,7	36561,58	CSL-944	579,8	490,9	3338,39
tonne	1,0	1,1	60,11	BLN-014	127,2	107,7	732,40
kg	1,5	1,3	8,72	tonne	1,5	1,3	8,72
Yield	It	945,0		Yield	It	1181,0	

Logistics			
Personnel	Equipment	Material	Quantity
Supervisor: 1	Pumptruck incl. Data recording 1x	CMT-003 CEM III B (BFS cement)	60,11 tonne
Operator: Pump	Mixtank incl. Power source 1x	BLN-014 HMR+ Blend	8,72 tonne
Operator: Bulk	27 t Cement silo incl. Compressor 2x	CSL-944 Salz NaCl	732,40 kg
Operator: Mixtank	27 t Bulktruck incl. Compressor 2x		
From client:		From client:	
Suction truck (fluids disposal) 1x		Fresh water for spacer 7,60 m³	
		Fresh water for cement 39,90 m³	

Pumping Schedule						
Time	Step	Comm.	Volume m³	Density kg/ltr	Rate ltr/min	Duration min
	Wellbore circulation min. 2 bottoms-up / Job Safety Analysis (JSA)					
	Prime the lines		0,30		300	1
	Pressure test	200 bar				10
	Pump fresh water spacer	50 m	6,50	1,00	600	11
	Premix first 7 m³ of lead cement					20
	Mix & pump Lead cement		56,80	1,70	600	95
	when lead to surface, switch to tail					
	Mix & pump Tail cement	50 m	6,50	1,88	600	11
	Pump fresh water spacer		0,50	1,00	600	1
	Pump mud		1,70	1,10	600	3
	Pump fresh water (surface lines)		0,30	1,00	300	1
	Flow Check, Sting-out, Circulate DP clean, WOC (check also with surface sample)					15
					Pumping time:	145min

Recommendations / Comments - OH XS, tubular capacities & mud weight to be confirmed - max. 1/2 shoetrack extra displacement volume	Document info Prepared by: T. Precup Client: Marriott Drilling Limited Version #: 4 Status: Proposal Date: 22.10.2019
This program is based on the most recent information provided by the client. Prepared by FES and controlled by client representative. All steps have been communicated and approved prior to the job.	
FES Supervisor _____ Date _____	CoMan _____ Date _____

Fig. K-5: 13 3/8" cement programme

[illegible]

Fig. K-6: 13³/₈" cement job service ticket

K.4 9 $\frac{5}{8}$ " casing

The 40 ppf, K-55 BTC 9 $\frac{5}{8}$ " casing with stage tool (307 m MD) was RIH on 20.01.2020 without problems to 960 m MD. The casing hanger was installed, and the casing was then hung off in the spool under the BOP with a final PUW of 81.5 t and SOW of 32 t, 1.2 m below surface, bringing the shoe depth to 969.43 m MD. The casing then was cemented with a two-stage cementation according to programme. The tally list is provided in Appendix G (Tab. G-3).

The casing was cemented according to programme. A volume of 3 m³ freshwater and 7.6 m³ saltwater spacer were pumped, followed by 16.3 m³ HMR cement with a density of 1.88 kg/l (700 l/min with 44 bar). Unfortunately, after pumping 5 m³ of freshwater, 5.1 m³ mud, 5 m³ of freshwater and 22.6 m³ of mud (700 l/min, 62 bar) no bump of the plug was seen. Float was holding, no backflow. The opening dart was released, stage tool opened, and excess cement circulated out of the hole (9 m³ of spacer and 1 m³ contaminated cement slurry with a density of 1.44 kg/l dumped).

WOC and 2nd stage cementation performed. Pumped 3 m³ freshwater and 3.2 m³ saltwater spacer with a density of 1.2 kg/l followed by 23.5 m³ HMR cement with a density of 1.88 kg/l. The closing plug was released, and the stage tool closed, confirmed by flow check.

A 13 $\frac{5}{8}$ " $\times$ 7" 5M casing spool and preventer stack were installed. Tested successfully.

Cement bond was evaluated from 16 to 976 m. No free pipe was found and cement at surface. Good cement bond from 663 to 812, 964 to 976 and 926 to 958 m. Poor cement bond log from 16 to 52, 84 to 105, 140 to 150, 336 to 360 and 435 to 458 m. All other regions were measured with medium cement bond log.

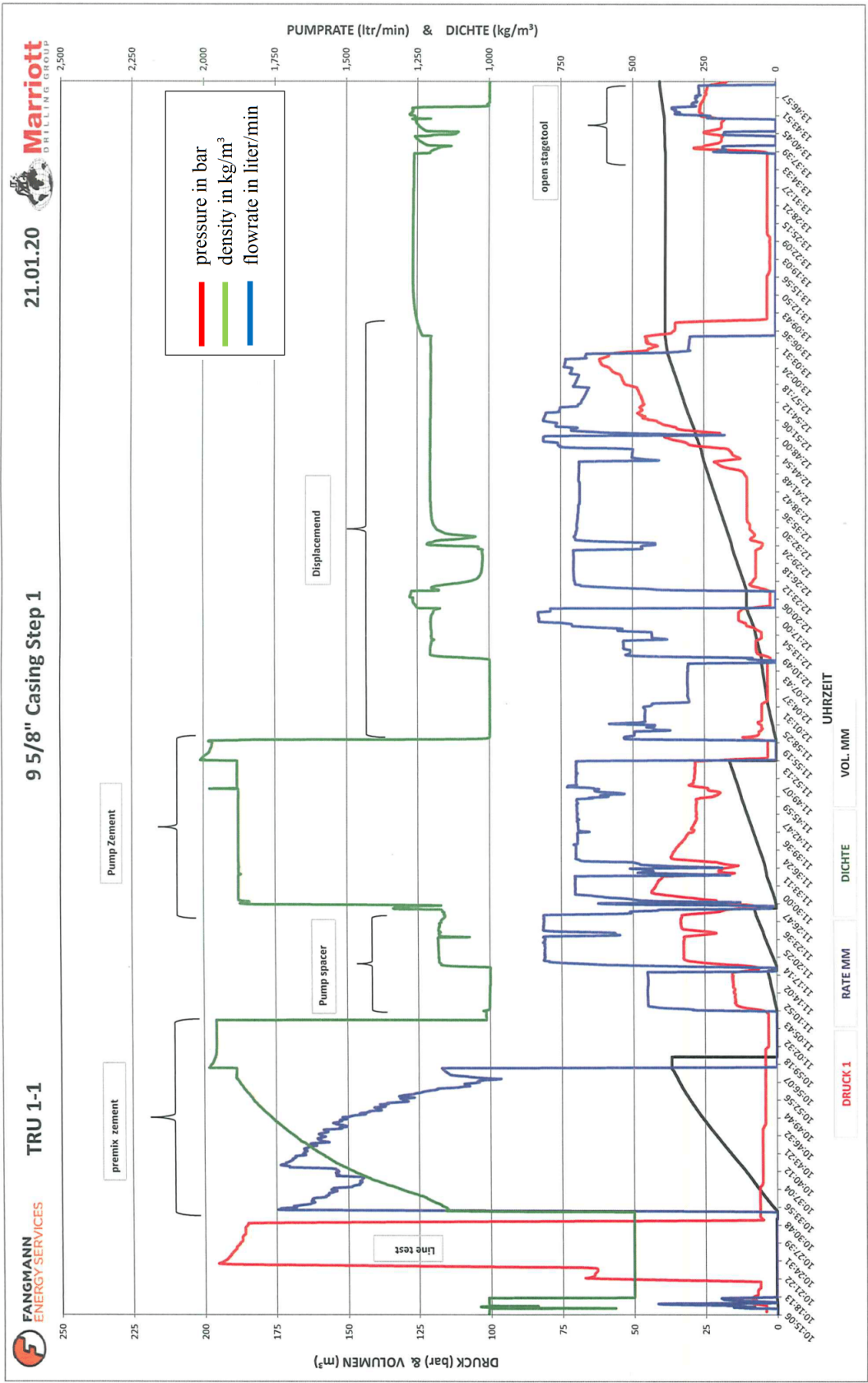


Fig. K-7: 9 5/8" cement job step 1: pressure, density and flowrate vs. time

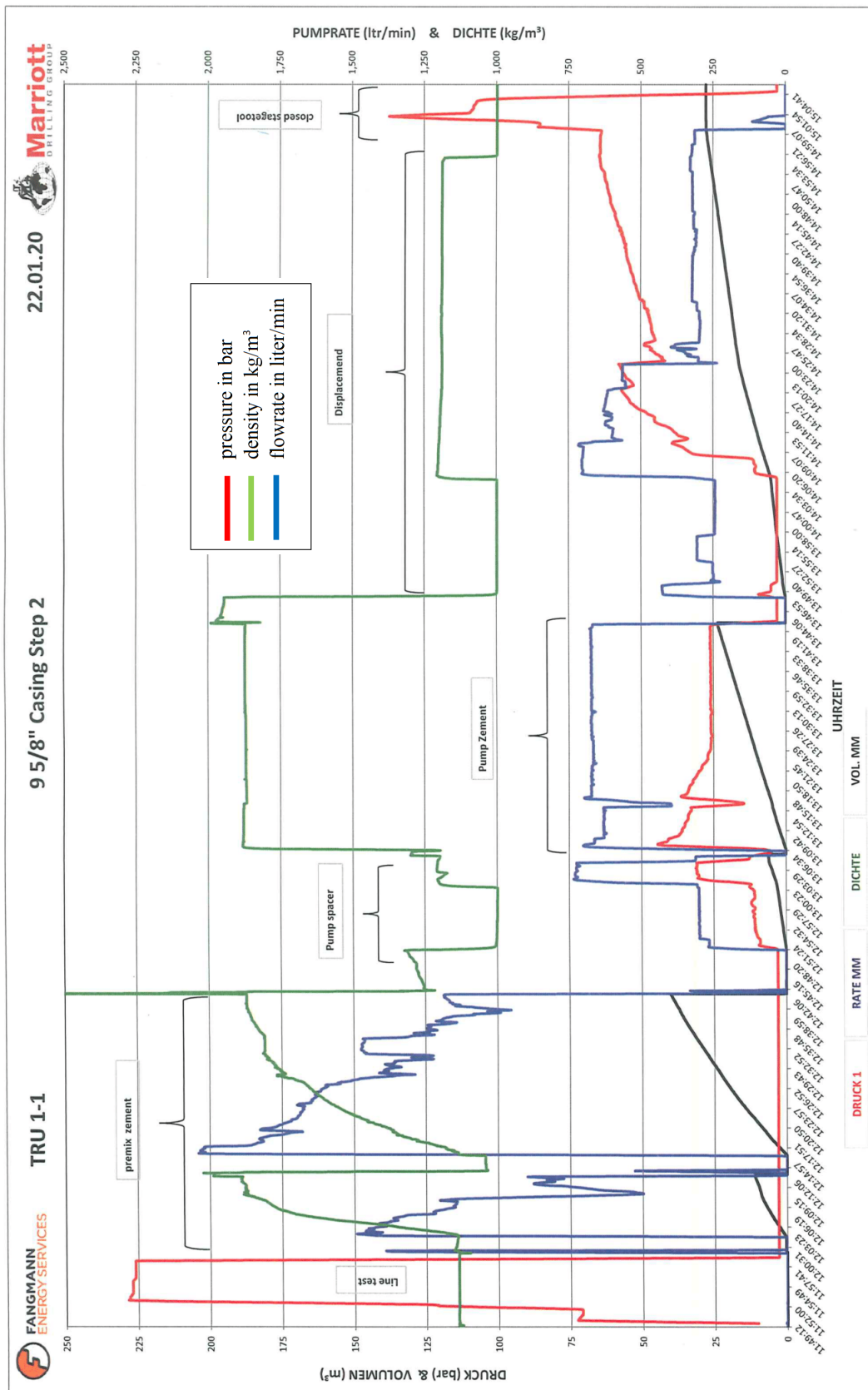


Fig. K-8: 9 5/8" cement job step 2: pressure, density and flowrate vs. time

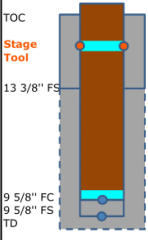
		Client Well Cementing		Marriott Drilling Trüllikon (Switzerland) 9 5/8" Casing		MD 973,0 m TVD 973,0 m Max. Dev 0°		TG 3,0°/100m BHST 42°C Test Temp. 27°C			
Volume Calculation											
		-9m 0m		OD		Description		Length		Capacity	
		661,6m		13 3/8 "		68,0 ppf		709m		77,98l/m	
		708,5m		12 2/3 "		24% OH XS 56% annular XS		265m		81,39l/m	
				14,08 "						53,55l/m in annulus	
				9 5/8 "		40,0 ppf		969m		46,97l/m	
								0m		0,00l/m	
								0m		0,00l/m	
								12m			
										Shoetrack	
										Cement volume	
										39,80m³	
										Capacity	
										966m	
										39,49l/m	
										0m	
										0,00l/m	
										0m	
										0,00l/m	
										Displacement volume	
										38,20m³	
										End pressure	
										41 bar	
Fluid Design											
Zement Step 1		1,88kg/l		dead vol. 1,0 m³		17,3m³		Zement Step 2		1,88kg/l	
		per ton.cmt.		per m³		total				per ton.cmt.	
Fresh water		lt		573,9		486,4		Fresh water		lt	
CAF-902		lt		1,5		1,3		CAF-902		lt	
CSL-944		kg		125,9		106,7		CSL-944		kg	
CDI-213		kg		3,0		2,5		CDI-213		kg	
CRE-120		kg		1,7		1,4		CRE-120		kg	
BLN-014		tonne		1,5		1,3		BLN-014		tonne	
Yield		lt		1180,4				Yield		lt	
										1179,9	
Logistics											
Personnel		Equipment		Material		Quantity		Comments			
Supervisor:		Stage Tool		Pumptruck		1x		53,68 tonne		81 mt. vor Ort bereitgestellt	
Supervisor:		1		incl. Data recording				53,14 lt			
Operator:		Pump		Mixtank		2x		6966,42 kg			
Operator:		Mistank		Generator, Compressor		2x		106,28 kg			
Operator:		Bulk		9 5/8" 2-Plug CH		1x		24,93 kg		Lot.-Nr. MM11J-11SD3	
				27 t Bulktruck incl. Comp		1x		102,00 kg			
				27 t Cement silo		2x					
				9 5/8" Stage tool		1x					
				incl. Plug set							
				From client:							
				Suction truck		1x		21,80 m³			
				(fluids disposal)				20,40 m³			
Pumping Schedule											
Time		Step		Comm.		Volume		Density		Rate	
						m³		kg/ltr		ltr/min	
										min	
		Wellbore circulation min. 2 bottoms-up / Job Safety Analysis (JSA)									
		Prime the lines				0,30				300	
		Pressure test		200 bar							
		Premix cement									
		Pump fresh water spacer				3,00		1,00		900	
		Pump Saltwater-Spacer		131 m		7,00		1,15		900	
		Pump cement				16,30		1,88		800	
		Release latch-down plug									
		Pump fresh water spacer				5,00		1,00		800	
		Pump mud				5,10		1,20		800	
		Pump spacer (prepared by mud company)				5,00				800	
		Pump mud				22,60		1,20		700	
		Pump fresh water (surface lines)				0,50		1,00		300	
		Flow check, Release opening dart, Open stage tool & circulate out extra cement									
		WOC 24 hrs., meanwhile continously circulate min. 300 LPM									
		Wellbore circulation min. 2 bottoms-up / Job Safety Analysis (JSA)									
		Prime the lines				0,30				300	
		Pressure test		200 bar							
		Premix cement									
		Pump fresh water spacer				3,00		1,00		900	
		Pump Saltwater-Spacer		103 m		3,20		1,15		900	
		Pump cement				23,50		1,88		800	
		Release closing displacement plug									
		Pump fresh water spacer				5,00		1,00		800	
		Pump mud				20,98		1,20		700	
		Pump fresh water (surface lines)				0,50		1,00		300	
		Closing plug lands & Stage tool closes, Flow check									
										Pumping time:	
										169min	
Recommendations / Comments								Document info			
- OH-Vol. nach Kaliber = 21,5 m³ -> Programm nimmt 10% XS über den äquivalent-Durchmesser an (standard)								Prepared: T. Precup			
								Client: Marriott Drilling			
								Version #: 8			
								Status: Field Version			
								Date: 21.01.2020			
This program is based on the most recent information provided by the client.											
Prepared by FES and controlled by client representative.											
All steps have been communicated and approved prior to the job.											
FES Supervisor				CoMan							
Date				Date							

Fig. K-9: 9 5/8" cement programme

FANGMANN		SERVICE REPORT 1				FANGMANN	
Base	Auftraggeber				Serviceart		Komm-Nr
CLP	Marriott				9 5/8" Casing Step 1		C 20012
Abteilung	Bohrung				Rig		Entfernung
FES	TRU 1-1				Marriott		750
Verantwortlicher FES	Personal				Ausrüstung		Transport
Schreiber, Roman	Tag	von	Tag	bis	Beschreibung	ID Nummer	An- Ab-
Schreiber, R.					Pumpunit	SAW FA 172	19.01.2020 23.01.2020
Kiritschenko, A.					Zugmaschine	SAW FA 462	19.01.2020 23.01.2020
Sawadsky, V.					Bulkwagen	SAW FA 187	19.01.2020 23.01.2020
Tegler, F.					Zugmaschine	SAW FA 173	19.01.2020 23.01.2020
	19.01.2020	9:00	19.01.2020	23:00	PKW	SAW FA 276	19.01.2020 23.01.2020
	20.01.2020	6:00	20.01.2020	23:59	Generator	FES-GEN-003	19.01.2020 23.01.2020
	21.01.2020	6:00	21.01.2020	20:00	Kompressor	FES-KOMP-002	19.01.2020 23.01.2020
	22.01.2020	8:00	22.01.2020	21:00	Misch tanks	FES-MTS-008	19.01.2020 23.01.2020
	23.01.2020	7:00	23.01.2020	19:00	Zementsilo		on site on site
	24.01.2020	7:00	24.01.2020	17:00	Zementsilo		on site on site
					Auflieger	SAW FA 177	19.01.2020 23.01.2020
					Misch tanks	FES-MT20-002	19.01.2020 23.01.2020
Materialverbrauch					Allgemeiner Kommentar		
Name	Menge	Einheit	Beschreibung				
BLN-014	56.0	mt	HRB (Hoch-Resistenter Blend) bei korrosiven Bedingungen				
CAF-902	60.0	lt	Entschäumer				
CRE-120	27.0	kg	Verzögerer LT				
CDI-213	120.0	kg	Verflüssiger MT/HT				
CSL-944	8000.0	kg	Salz NaCl				
SGL-312	100.0	kg	Xanthan Gel				
Perf. / OH	von	bis	TD	MD	Neigung °	Temperatur °C	Spülung Rheologie
						BHST: 600	
						BHCT: 300	
Rohrtour	#/ft	von	bis	Inhalt		ID	Gewinde
DP/Tbg.	#/ft	von	bis	Inhalt		Verdrängung	Gewinde
Datum	Zeit	Druck bar	Rate ltr/min	Vol. m³	Dichte kg/ltr	Bemerkungen	
19.01.20						Arrival to the customer	
20.01.20						Arrival to the customer	
	14:30					Arrived at location, loaded cement	
	15:00					Waiting time for rig crew to clean the location for rig-up cement equipment	
	17:00					Rig up FES Equipment	
	18:30					Waiting time for fresh water supply line to be mounted by rig crew	
	20:30					Prepared Mix fluid step 1	
	23:00					Departed from location to hotel	
21.01.20	7:00					Arrived at location	
	7:15					Prepare for cement job	
	9:45					Safety meeting	
	10:26	10	300	0.3	1.00	Prime the lines	
	10:30	60-190				Pressure test	
	10:43					Premix cement	
	11:20	15	450	3.0	1.00	Pump fresh water	
	11:27	30	800	7.6	1.18	Pump saltwater-spacer	
	11:38	42	700	16.3	1.88	Pump cement	
	12:04					Release latch-down plug	
	12:07	10-59	300-600	38.5	1.00-1.20	displacement as per program	
	13:18					Flow check	
	13:25					Release opening dart	
	13:42					Open stage tool	
	14:00					Equipment cleaned	
	16:00					Prepared Mix fluid step 2	
	19:00					Departed from location to hotel	
Info:		Nein		Auftraggeber		Fangmann Energy Services	
Anschlag gehabt				Martin Buxton		Roman Schreiber	
Zement zu Tage				Datum		Datum	
Verluste gehabt				22.01.2020		22.01.2020	
Gestänge abgelaufen							

Fig. K-10: 9 5/8" cement job step 1 service ticket

FANGMANN ENERGY SERVICES		SERVICE REPORT 2				Marriott DRILLING GROUP	
Base	Auftraggeber				Serviceart		Komm-Nr:
CLP	Marriott				9 5/8" Casing Step 2		C 20012
Abteilung	Bohrung				Rig		Entfernung
FES	TRU 1-1				Marriott		750
Verantwortlicher FES		Personal		Ausrüstung		Transport	
Schreiber, Roman		Tag	von	Tag	bis	Beschreibung	ID Nummer
Schreiber, R.						Pumpunit	SAW FA 172
Kritschenko, A.						Zugmaschine	SAW FA 462
Sawadsky, V.						Bulkwagen	SAW FA 187
Tegler, F.						Zugmaschine	SAW FA 173
	19.01.2020	9:00	19.01.2020	23:00		PKW	SAW FA 276
	20.01.2020	6:00	20.01.2020	23:30		Generator	FES-GEN-003
	21.01.2020	6:00	21.01.2020	20:00		Kompressor	FES-KOMP-002
	22.01.2020	8:00	22.01.2020	22:00		Misch tanks	FES-MT5-008
	23.01.2020	7:00	23.01.2020	19:00		Zementsilo	on site
	24.01.2020	7:00	24.01.2020	17:00		Zementsilo	on site
						Auflieger	SAW FA 177
						Misch tanks	FES-MT20-002
Materialverbrauch				Allgemeiner Kommentar			
Name	Menge	Einheit	Beschreibung				
BLN-014	56.0	mt	HRS (Hot-Resistable Blend) bei korrosiven Bedingungen				
CAF-902	60.0	lt	Entschäumer				
CRE-120	27.0	kg	Verzögerer LT				
CDI-213	120.0	kg	Verflüssiger MT/HT				
CSL-944	8000.0	kg	Salz NaCl				
SGL-312	100.0	kg	Xanthan Gel				
Perf. / OH	von	bis	TC	MD	Neigung *	Temperatur °C	Spülung
						BHST:	Typ: WBM
						BHCT:	Dichte: 300
Rohrtour	#/ft	von	bis	Inhalt		ID	Gewinde
							PV: 200
							Tv: 100
							6
							3
DP/Tbg.	#/ft	von	bis	Inhalt		Verdrängung	Gewinde
							sonstiges Bohrloch Info
Datum	Zeit	Druck bar	Rate ltr/min	Vol. m³	Dichte kg/ltr	Bemerkungen	
22.01.20	9:00					Arrived at location	
	9:15					Prepare for cement job	
	10:44	10	300	0.3	1.00	Prime the lines	
	11:45					Safety meeting	
	12:00	70-220				Pressure test	
	12:12					Premix cement	
	13:00	10	300	3.0	1.00	Pump fresh water	
	13:11	32	700	3.2	1.20	Pump saltwater-spacer	
	13:17	40-26	670	23.5	1.88	Pump cement	
	13:54					Release closing plug	
	13:57	3	250	5.0	1.00	Pump fresh water	
	14:16	10-63	700-300	22.0	1.20	Pump mud	
	15:10	150				Closing plug landed, closed stage tool	
	15:15					Flow check, 240ltr. Return	
	15:30					Equipment cleaned and rig down	
	21:00					Departed from location	
Info:		Anschlag gehabt		Ja		Fangmann Energy Services	
		Zement zu Tage		Ja		Roman Schreiber	
		Verluste gehabt				Datum	
		Gestänge abgelaufen				Datum	
				22.01.2020		22.01.2020	

Fig. K-11: 9 5/8" cement job step 2 service ticket

K.5 7⁵/₈" liner

The 29.7 ppf, K-55 BTC 7⁵/₈" casing was made up on 14.03.2020 to 220.45 m MD, liner hanger installed and RIH on 5" DP without major problems to 1'153 m MD. PUW at shoe depth was 49.3 t, SOW was 48.6 t, the string rotated with 20 rpm resulting in 570 daNm. It was washed down to 1'159 m MD and circulated with 700 l/min at 25 bar. The liner hanger was then set according to procedure, bringing the shoe depth to 1'158.40 m MD and the top of the PBR at 925.45 m MD. The tally list is provided in Appendix G (Tab. G-4) of this report.

The liner was cemented according to programme. A volume of 3.5 m³ spacer with a density of 1.45 kg/l and 4.1 m³ cement with a density of 1.83 kg/l were pumped, the dart dropped. After pumping 1 m³ of water spacer, 3.2 m³ of mud with a density of 1.20 kg/l, a freshwater spacer of 2 m³, 6 m³ mud with a density of 1.20 kg/l and 0.5 m³ water plug were bumped. Dart shear and bump plug were observed as per programme.

The liner was successfully pressure-tested to 100 bar for 20 minutes and the packer on top of the liner was set. The cement head was removed, the sponge ball dropped, and the setting tool pulled above the polished borehole receptacle (PBR) to circulate the cement out. Spacer but no cement was observed at surface. The liner setting tool was retrieved successfully.

Cement bond was evaluated from 926 to 1'158 m. No free pipe was found, top of cement was above logged interval. Medium cement bond from 958 to 972 and 1'020 to 1'024 m. No poor cement bond, all other parts of the liner with good bond.

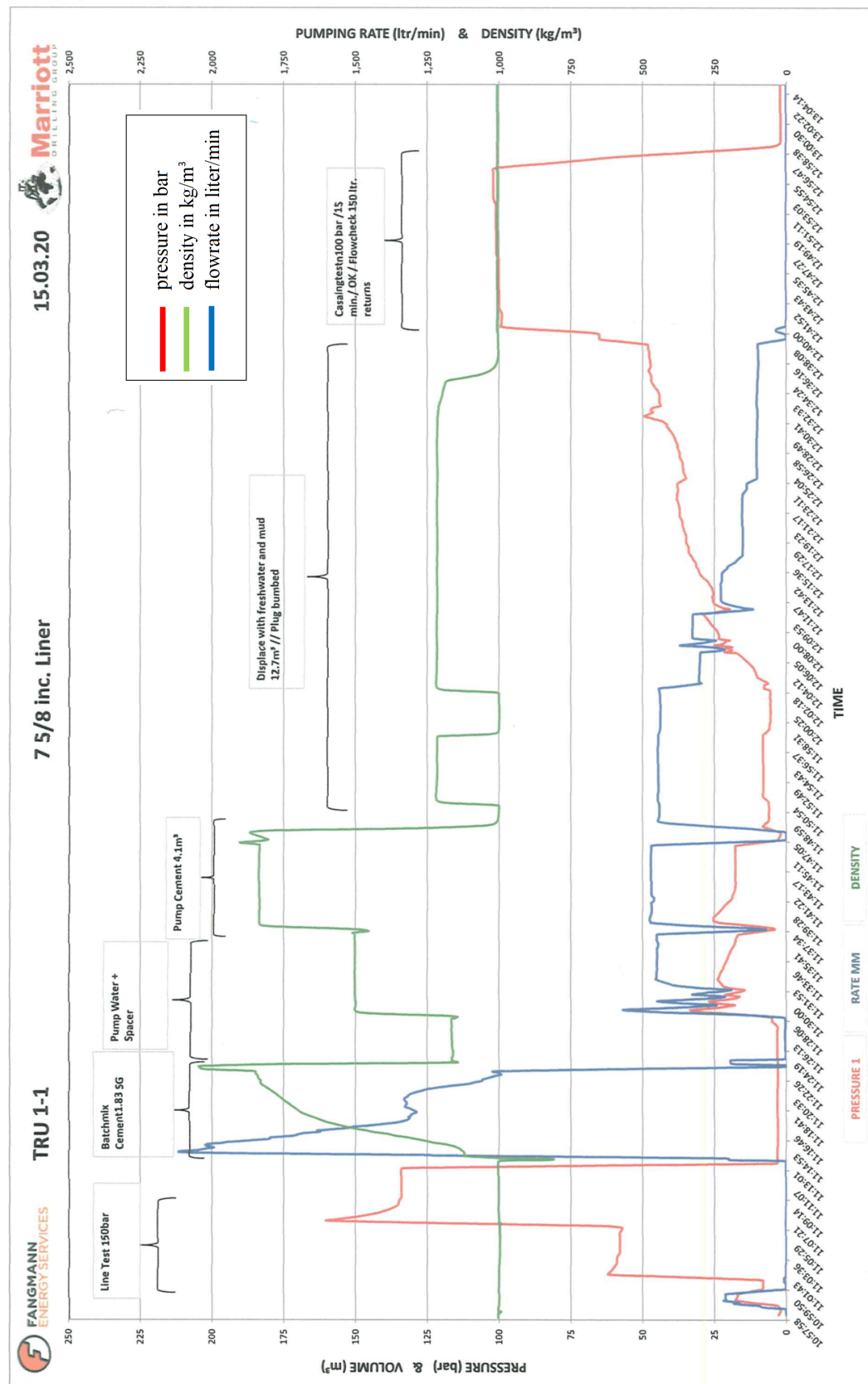


Fig. K-12: 7 5/8" cement job pressure, density and flowrate vs. time

	Client Marriott Drilling Well Trüllikon (Switzerland) Cementing 7 5/8" Liner	MD 1166,0 m TVD 1166,0 m Max. Dev 0°	TG 3,0°/100m BHST 45°C Test Temp. 30°C	
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Volume Calculation								
		-9m						
	TOC	870m	Previous casing	OD 9 5/8"	Description 40,0 ppf	Length 98m	Capacity 39,49l/m	Comment Total cap. + 3,87 m³
	7 5/8" LH	920m	Open hole	8 1/2"	20% OH XS	198m	36,63l/m	OH without XS + 7,25 m³
	9 5/8" FS	968m		9,29"	100% annular XS		14,30l/m in annulus	OH XS + 1,41 m³
			Liner to be cemented	7 5/8"	39,0 ppf	246m	29,48l/m	Total displ. - 7,25m³
						0,00l/m	- 0,00m³	
						0,00l/m	+ 0,57 m³	
							Cement volume 5,20m³	
			Drill pipe	5"	19,5 ppf	929m	9,03l/m	Total cap. 8,39m³
						0m	0,00l/m	0,00m³
					0m	0,00l/m	0,00m³	
					0m	0,00l/m	0,00m³	
7 5/8" FC	1142m	Liner to be cemented	7 5/8"	29,7 ppf	222m	23,92l/m	Total cap. 5,31m³	
7 5/8" FS	1166m				0m	0,00l/m	0,00m³	
TD	1166m				0m	0,00l/m	0,00m³	
							Displacement volume 13,70m³	
							End pressure 40 bar	

Fluid Design							
Spacer	1,45kg/l	dead vol. 0,5 m³	4,0m³		Cement	1,70kg/l	dead vol. 0,5 m³
		per m³	total				per m³
Fresh water	lt	850,7	3402,8		Fresh water	lt	577,7
CSP-205	kg	50,0	200,0		CAF-902	lt	1,5
CWA-831	kg	551,8	2207,2		CFL-380	kg	4,5
					CDI-213	kg	0,5
					BLN-014	tonne	1,5
							1,1
							6,3
Yield	lt	1000,0			Yield	lt	1372,4

Logistics							
Personnel		Equipment		Material		Quantity	Comments
Supervisor:	1	Pumptruck	1x	BLN-014	CEM III B + Fly Ashes	6,29 tonne	
Operator:	Pump	incl. Data recording		CAF-902	Antifoam	6,23 lt	
Operator:	Bulk	Mixtank	2x	CFL-380	Fluidloss	18,69 kg	
Operator:	Mixtank	Generator, Compressor	2x	CDI-213	Dispersant MT/HT	2,08 kg	
		Silo	1x	CSP-205	SMR Spacer	200,00 kg	
				CWA-831	Barite	2207,20 kg	Weighting agent for spacer
		From client:		From client:			
		Suction truck	1x	Fresh water for spacer		7,30 m³	
		(fluids disposal)		Fresh water for cement		2,40 m³	

Pumping Schedule						
Time	Step	Comm.	Volume	Density	Rate	Duration
			m³	kg/ltr	ltr/min	min
	Wellbore circulation min. 2 bottoms-up @ max. allowable rate (check with LH Specialist) / JSA					
	Prime the lines		0,30		300	1
	Pressure test	150 bar				5
	Premix cement					20
	Pump SMR Spacer	245 m	3,50	1,45	400	9
	Pump cement		5,20	1,70	400	13
	Release dart (LH Supervisor)					5
	Total displacement volume	13,7 m³				
	Pump fresh water spacer		1,00	1,00	400	3
	Pump mud		3,40	1,20	400	9
	Pump fresh water spacer	LH area	2,00	1,00	400	5
	Pump mud		6,80	1,20	400	17
	Pump fresh water (surface lines)		0,50	1,00	300	2
	Flow check, Set LH packer, Release, Circulate out extra cement					30
					Pumping time:	111min

Recommendations / Comments	Document info
- OH XS to be confirmed - Wiper-Plug shear pressure to be confirmed by LH Specialist - max. 1/2 shoetrack extra displacement volume	Prepared: T. Precup Client: Marriott Drilling Version #: 3 Status: Draft Date: 04.03.2020
This program is based on the most recent information provided by the client. Prepared by FES and controlled by client representative. FES Supervisor _____ CoMan _____ All steps have been communicated and approved prior to the job. Date _____ Date _____	

Fig. K-13: 7 5/8" cement programme

		SERVICE REPORT							
Base	Client					Type of Service			Comm. Nr
CLP	Marriott					7 5/8 inc. Liner			C20035-1
Dep.	Well					Rig			Distance
FES	TRU 1-1					Marriott			750
Responsible FES. Rep		Personnel				Equipment		Transport	
Wehri, Benjamin		Date	from	Date	till	Description	Code	from	till
						Pumpunit	SAW FA 172	on site	17.03.2020
Wehri, B.						Zugmaschine	SAW FA 173	on site	17.03.2020
van Lienen, S.						Aufleger	SAW FA 174	on site	17.03.2020
Baro, Di.									
Wirtelewski, J.									
	13.03.2020	8:00	13.03.2020	20:30		PKW	SAW FA 150	13.03.2020	17.03.2020
	14.03.2020	7:00	14.03.2020	17:00		Generator	FES-GEN-003	on site	17.03.2020
	15.03.2020	7:00	15.03.2020	20:30		Kompressor	FES-KOMP-002	on site	17.03.2020
	16.03.2020	8:00	16.03.2020	21:00		Misch tanks	FES-MT5-008	on site	17.03.2020
	17.03.2020	6:00	17.03.2020	16:00		Zementsilo	FES-DS25-007	on site	on site
						Zementsilo	FES-DS25-006	on site	on site
						Misch tanks	FES-MT10-001	on site	17.03.2020
Materials used						General comments			
Name	Q-ty	Units	Description						
CMT-003	6.0	mt	CEM III/B 32,5 N - LH/HS/NA Zement Entschäumer FluidLoss Verflüssiger LT/MT Verzögerer LT Schwamm-Kugel 150 Barite						
CAF-902	6.0	lt							
CFL-380	17.0	kg							
CDI-112	12.0	kg							
CRE-120	4.0	kg							
SK150	1.0	Stk							
CWA-831	2500.0	kg							
Perf / OH	from	till	TD	MD	Dev°	Temperature °C		Mud Rheology	
8 1/2 "	969.0m	1161.0m	1161m	1161m	0.0 °	BHST: 48 °C	Type WBM	600	
						BHCT: 35 °C	Density 1.20	300	
Casing	#/ft	von	till	Capacity		ID	Thread	PV:	200
7 5/8 "	29.7	1160m	925m	23.95 l/m				Ty:	100
									6
									3
DP/Tbg.	#/ft	von	till	Capacity		Met.Displ.	Thread	Other well info	
n.c.									
Date	Time	Pressure bar	Rate ltr/min	Vol. m³	Density kg/ltr	Remarks			
13.03.20	08:00-20:30					Start journey over one days			
14.03.20	7:00					Arrived at location / meeting with client			
	10:00					Start Rig up FES Equipment			
	16:00					departed from location to hotel 17:00			
15.03.20	7:00					Client call out for cement job			
	8:00					Completed Rig Up / preapre spacer and mixwater			
	10:45					Safty-Meeting with Rig crew + FES crew			
	10:57					Flush line + pressure-test with 150 bar / 10 min. / ok			
	11:13					Prepare 4.5m³ cement-slurry			
	11:24	30	500	3.5	1.50	Pump spacer			
	11:37	25	400-500	4.1	1.83	Pump cement			
	11:48					Release darf (LH Operator)			
	11:50	20	500	1.0	1.00	Pump freshwater-spacer			
	11:52	20	500	3.2	1.20	Pump mud			
	12:00	30	500	2.0	1.00	Pump freshwater-spacer			
						Reduce pump rate to see WP-shear			
	12								

Fig. K-14: 7⁵/₈" cement job service ticket

K.6 Cement plug below the 7 $\frac{5}{8}$ " liner

After the borehole was drilled to TD at 1'310 m MD (50 m into the crystalline basement), 5 m³ of HMR cement were pumped on 03.04.2020 for the cement plug. With a theoretical borehole diameter of 6 $\frac{3}{8}$ ", this volume of cement creates a top of cement at 1'067 m MD, the liner shoe was set at 1'158.4 m MD. That means, the cement is theoretically 91 m above the 7 $\frac{5}{8}$ " shoe.

The cement string was POOH to 1'126 m MD and, with reverse circulation of 0.5 m³ of cement, 2.7 m³ of spacer and 4 m³ of contaminated mud were circulated out. Cement was dressed to 1'138 m.

Appendix L: Cement bond log

For the cement evaluation from USIT and CBL logs, the cement bond has been classified into three levels: good, medium and low.

A **good bond** is classified as having:

- no casing arrivals – good bond to casing
- strong formation arrivals – good bond to formation
- low CBL amplitude

A **medium bond** is classified as having:

- moderately visible casing arrivals – partial bond to casing
- formation arrivals still present
- medium CBL amplitude

A **low bond** or free pipe is classified as having:

- strong casing arrivals – no bond to cement
- weak or non-existent formation arrivals – low to no bond formation
- high CBL amplitude

Tab. L-1: Cement zone description for Phase 1 (based on Run 1.2.1)

From	To	Lithostratigraphic units	Zone descriptions
[m MD]			
Surface		Top of cement	
0	44.4	Quaternary – OMM	Unable to evaluate because VDL readings were fully attenuated
44.4	52.7	USM	Medium to high CBL amplitude, strong casing arrivals and weak formation arrivals – medium to poor bond
52.7	63.2	USM	High CBL amplitude, strong casing arrivals and weak formation arrivals – poor bond
63.2	241	USM	Intermittent zones of medium to high CBL amplitude, medium casing arrivals, weak formation arrivals – medium bond
241	248	USM	High CBL amplitude, strong casing arrivals and weak formation arrivals – poor bond
248	321	USM	Medium to high CBL amplitude, medium casing arrivals and weak formation arrivals – medium bond
321	330	USM	High CBL amplitude, strong casing arrivals and weak formation arrivals – poor bond
330	400	USM	Medium to high CBL amplitude, medium casing and formation arrivals – medium bond
400	413	USM	Medium to low CBL amplitude, weak casing arrivals and more distinct formation arrivals – medium to good bond
413	474	USM, Siderolithikum	Medium to high CBL amplitude, medium to strong casing arrivals and medium formation arrivals – medium bond
492		18 5/8" casing shoe	
474	493	USM, Siderolithikum «Felsenkalke» + «Massenkalk»	Medium to low CBL amplitude, weak casing and strong formation arrivals – good bond

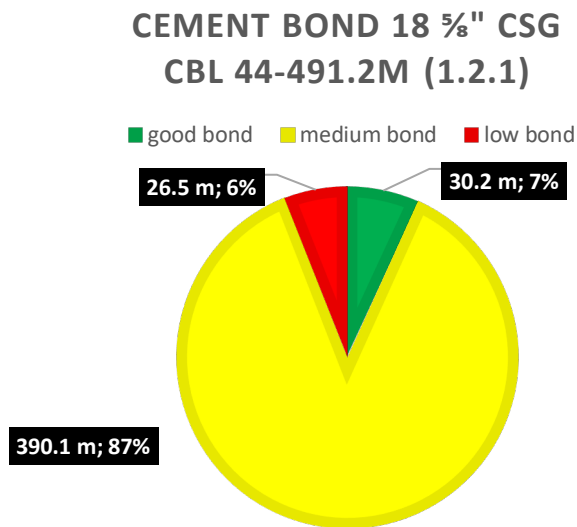


Fig. L-1: 18 5/8" cement job and cement bond evaluation

Tab. L-2: Cement zone descriptions for Phase 2 (based on Run 3.6.1)

From	To	Lithostratigraphic units	Zone descriptions
[m MD]			
46		<i>Top of cement</i>	
0	9.8	Quaternary	Readings attenuated
9.8	46.4	Quaternary – OMM	CBL is at free-pipe amplitude (43 mV), strong casing arrivals on the VDL, USIT/IBC maps show no cement, bond index shows annulus filled with liquid – free pipe
46.4	59.3	OMM, USM	Transition from no cement to good cement – medium bond
59.3	100.5	USM	Low CBL, weak casing and strong formation arrivals on VDL, acoustic impedance map dark – good bond
100.5	120	USM	Weak casing and formation arrivals, bond index shows micro-annulus, transition from good cement to no cement – medium bond
120	260.5	USM	USIT/IBC maps show very little to no cement. Cement has likely "fallen back" into a loss zone. The only cement in this section is probably related to cement stringers, which were left there when the cement fell downhole into the loss zone – poor bond
260.5	266.8	USM	Transition from no cement to good cement – medium bond
266.8	333	USM	Cement is excellent on the USIT/IBC maps, CBL is low, however, casing arrivals still very strong on the VDL – good bond
333	335	USM	USIT/IBC cement maps show patchy cement – medium bond

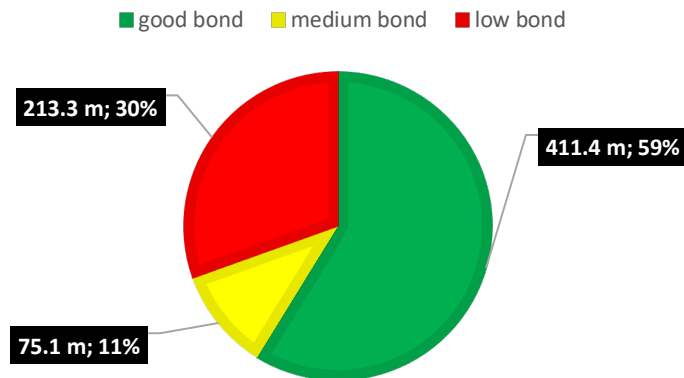
Tab. L-2: Cont.

From	To	Lithostratigraphic units	Zone descriptions
[m MD]			
335	358.8	USM	Cement is excellent on the USIT/IBC maps, CBL is low, however, casing arrivals still very strong on the VDL – good bond
358.9	362.7	USM	USIT/IBC cement maps show patchy cement – medium bond
362.7	374.5	USM	Weak casing and strong formation arrivals on the VDL, low CBL, acoustic impedance map dark – good bond
374.5	379.2	USM	Galaxy pattern on acoustic impedance cement map indicating that casing is close to the wellbore, therefore less cement – medium bond
379.2	386	USM	Cement appears to be good on the USIT/IBC, which is not consistent with the CBL/VDL – good bond
386	393.7	USM	Strong casing and formation arrivals on VDL, medium CBL, flexural attenuation map shows little cement and bond index shows micro-debonding – medium bond
393.7	402	USM	Cement appears to be good on the USIT/IBC, which is not consistent with the CBL/VDL – good bond
402	411.2	USM	Strong casing and formation arrivals on VDL, medium to high CBL, flexural attenuation map shows little cement and USIT bond index shows micro-annulus – medium bond
411.2	430.4	USM	Cement appears to be good on the USIT/IBC, which is not consistent with the CBL/VDL – good bond
430.4	435.6	USM	Strong casing and formation arrivals on VDL, medium CBL, flexural attenuation map shows little cement and bond index shows micro-annulus – medium bond
435.6	448	USM	Cement appears to be good on the USIT/IBC, which is not consistent with the CBL/VDL – good bond
448	451.7	USM	Strong casing and formation arrivals on VDL, medium CBL, flexural attenuation map shows little to no cement and USIT bond index shows micro-annulus – medium bond
451.7	457.1	USM	Cement appears to be good on the USIT/IBC, which is not consistent with the CBL/VDL – good bond
492		18½" casing shoe (in previous phase)	
457.1	492.5	USM, Siderolithikum «Felsenkalk» + «Massenkalk»	Strong casing and formation arrivals on VDL, medium to high CBL, bond index shows micro-annulus, possibly due to a fluid channel which is evident on the cement map from below the casing shoe up to 460 m – poor bond

Tab. L-2: Cont.

From	To	Lithostratigraphic units	Zone descriptions
[m MD]			
492.5	702	«Felsenkalke» + «Massenkalk» Schwarzbach Fm., Villigen Fm.	Excellent bond along the entire open hole section is shown by the USIT cement map (impedance values greater than 7 mRayls) and the VDL (strong formation arrivals and no casing arrivals). However, the flexural attenuation map incorrectly shows no cement in areas of fast formation, much like the CBL amplitude – good bond
708.8		13 $\frac{3}{8}$ " casing shoe (not logged)	

CEMENT BOND 13 $\frac{3}{8}$ " CSG
CBL 9-702M 2.2.1/2.4.1/3.6.1

Fig. L-2: 13 $\frac{3}{8}$ " cement job and cement bond evaluation

Tab. L-3: Cement zone descriptions for Phase 4 (based on Runs 3.7.1 and 4.6.1)

From	To	Lithostratigraphic units	Zone descriptions
[m MD]			
Surface		<i>Top of cement</i>	
0	16	Quaternary	Readings attenuated
16	52	Quaternary OMM USM	Medium to high CBL, strong casing arrivals and weak formation arrivals on the VDL, USIT was affected by the low readings on the amplitude map often indicating residue on the inner casing – poor bond
52	84	USM	Medium CBL amplitude, medium casing arrivals and weak formation arrivals on the VDL, bond index shows pockets of no cement (liquid) – medium bond
84	105	USM	Very high CBL reaches free-pipe amplitude, strong casing arrivals and no formation arrivals, USIT shows very little to no cement – poor bond
105	140	USM	Medium to high CBL, medium casing arrivals and weak formation arrivals – medium bond
140	150	USM	Very high CBL reaches free-pipe amplitude, strong casing arrivals and no formation arrivals, USIT shows very little to no cement – poor bond
150	336	USM	Medium to high CBL amplitude with medium casing arrivals and medium to weak formation arrivals – medium bond
336	360	USM	Medium to high CBL amplitude, strong casing arrivals and no formation arrivals, change of the bond index is correlated with the change of casing collar locator – poor bond
360	435	USM	Medium to high CBL amplitude with medium casing arrivals and medium to weak formation arrivals, strong chevron patterns are present on the VDL, acoustic impedance indicates cement but it is bonded poorly to the casing – medium bond
435	458	USM	Medium to high CBL amplitude, strong casing arrivals and no formation arrivals on VDL, bond index shows annulus filled with liquid and less cement present – poor bond
458	663	USM Siderolithikum «Felsenkalke» + «Massenkalk» Schwarzbach Fm., Villigen Fm.	Medium CBL amplitude, medium casing arrivals and formation arrivals on the VDL indicating marginal bonding, USIT indicates some channeling, high acoustic impedance and cement appears as good – medium to good bond
708.8		13⅜" casing shoe (in previous phase)	

Tab. L-3: Cont.

From	To	Lithostratigraphic units	Zone descriptions
[m MD]			
663	812	Villigen, Wildeg, Wutach, Variansmergel, «Parkinsoni-Württembergica-Schichten» «Humphriesoolith», Wedelsandstein, «Murchisonae-Oolith» Fms.	Very low CBL amplitude, no casing arrivals and strong formation arrivals, USIT indicates good cement with strong acoustic impedance – very good bond
812	857	Opalinus Clay	Medium to low CBL amplitude, medium to weak casing arrivals and strong formation arrivals, acoustic impedance is high and bond index shows cement but the cement bond is weak, as indicated by the casing signals and chevron patterns – medium bond
857	959	Opalinus Clay Staffelegg Fm.	Medium to high CBL amplitude, strong casing and medium formation arrivals on the VDL, USIT impedance map indicates good cement and zonal isolation which is not consistent with the VDL. Cement is weakly bonded to the casing due to the presence of micro-annulus or channeling – medium bond
970.1		9 5/8" casing shoe	
964	976	Staffelegg Fm.	Medium to low CBL, medium to weak casing arrivals and strong formation arrivals, USIT indicates very good cement – good bond

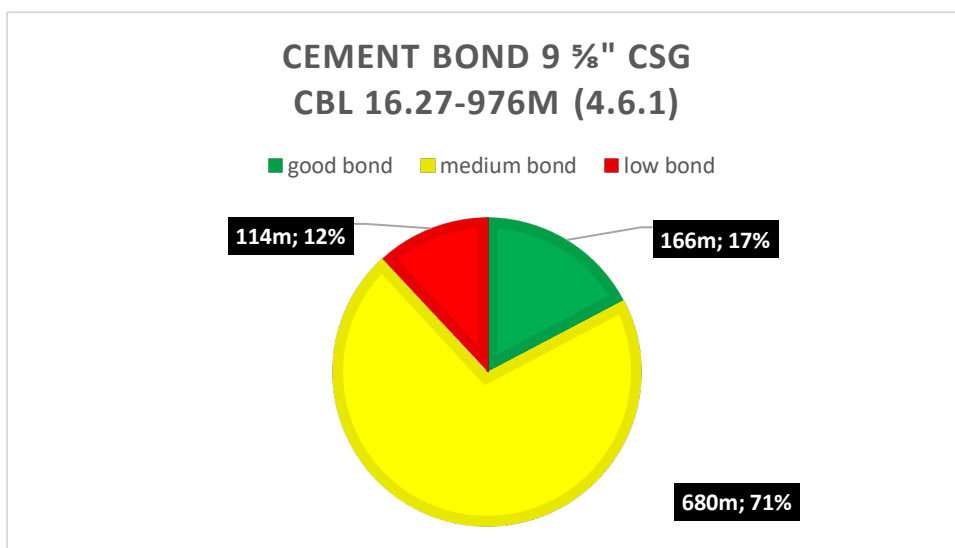


Fig. L-3: 9 5/8" cement job and cement bond evaluation

Tab. L-4: 7½" Liner cement bond

From	To	Lithostratigraphic units	Zone descriptions
[m MD]			
N/A		<i>Top of cement</i>	
926	958	Staffelegg Fm.	In the double casing section, the bonding shown on the USIT is excellent. A thin cement sheath on the lower side of the wellbore is indicated, but no channels are apparent. The MSIP shows marginal bonding because of the effect of double casing – good bond
970.1		9½" casing shoe (in previous phase)	
958	972.3	Staffelegg Fm. Klettgau Fm.	USIT shows wet micro-annulus, with marginal bonding, MSIP shows medium casing and formation arrivals, also affected by the double casing – medium bond
972.3	990.8	Klettgau Fm.	Low CBL amplitude when exiting the double casing, weak casing arrivals and medium to strong formation arrivals, the USIT cement map and bond index also show excellent bonding – good bond
990.8	997.4	Klettgau Fm.	VDL shows formation arrivals before casing arrivals, i.e. fast formation, which results in high CBL amplitude. This is indicative of good bonding as shown on USIT logs – good bond
997.4	1'004.3	Klettgau Fm.	Low CBL, weak casing and strong formation arrivals on VDL, USIT shows high ratio of cement – good bond
1'004.3	1'013.7	Klettgau Fm.	CBL amplitude less than 5 mV, no casing arrivals and medium formation arrivals. This is a slow formation zone with excellent bonding. The USIT shows clear indication of formation bedding planes on the acoustic impedance cement map – good bond
1'013.7	1'015.5	Klettgau Fm.	Fast formation zone – good bond
1'015.5	1'020	Klettgau Fm.	Good cement coverage is indicated by both the USIT and MSIP, breakout is apparent on the USIT cement map – good bond

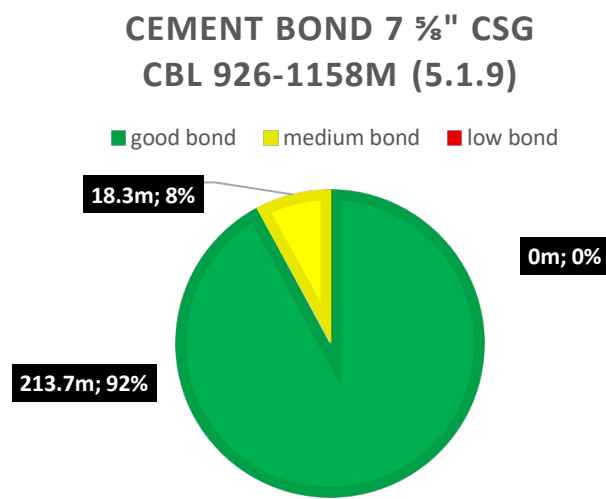


Fig. L-4: 7 $\frac{5}{8}$ " cement job and cement bond evaluation