PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING AT IG BH04/05/06 IGNACE AREA

WP05 Data Report - Geophysical Well Logging for IG BH04

APM-REP-01332-0356 **July 2022**

Golder Associates Ltd.

NUCLEAR WASTE MANAGEMENT ORGANIZATION
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REPORT

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WP05 Data Report - Geophysical Well Logging for IG BH04

Submitted to:

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GEOPHYSICAL WELL LOGGING FOR IG_BH04

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1.0 INTRODUCTION

The Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06 project in the Ignace area of Ontario, is part of the Phase 2 Geoscientific Preliminary Field Investigations of the NWMO's Adaptive Phased Management (APM) Site Selection Phase.

This project involves testing of deep borehole IG_BH04 and the drilling and testing of deep boreholes IG_BH05 and IG_BH06 in the Ignace area within the identified Potential Repository Area (PRA). The work comprises a total of seven work packages and will be carried out by a team led by Golder Associates Ltd. (Golder) on behalf of the NWMO. The IG_BH04 program is described in the Borehole Characterization Plan (BCP) for IG_BH04 (Golder 2021a).

This data report describes the methodology, activities, and reporting for Work Package 5 (WP05): Geophysical Well Logging for IG_BH04. This report describes the methodology, calibration/verification, acquisition and processing of the borehole geophysical data. Information from borehole geophysical logging will be used to help assess the local thickness of potentially suitable rock units, the geophysical properties of the rock units at depth, and the presence and types of structural features at depth. The geophysical logging provides high-quality, and high-resolution estimates of rock properties including engineering, lithological, hydrogeological, and structural properties.

2.0 BACKGROUND INFORMATION

2.1 Geological Setting

The approximately 2.7-billion-year-old Revell batholith is located in the western part of the Wabigoon Sub-province of the Archean Superior Province. The batholith is roughly elliptical in shape trending northwest, is approximately 40 km in length, 15 km in width, and covers an area of approximately 455 km^2. Based on geophysical modelling, the batholith is approximately 2 km to 3 km thick through the center of the northern portion (SGL 2015). The batholith is surrounded by supracrustal rocks of the Raleigh Lake (to the north and east) and Bending Lake (to the southwest) greenstone belts (Figure 2).

IG_ BH04 is located within an investigation area of approximately 19 km^2 in size, situated in the northern portion of the Revell batholith. Bedrock exposure in the area is generally very good due to minimal overburden, few water bodies, and relatively recent logging activities. Ground elevations generally range from 400 to 450 m above sea level. The ground surface broadly slopes towards the northwest as indicated by the flow direction of the main rivers in the area. Local water courses tend to flow to the southwest towards Mennin Lake (Figure 1).

Four main rock units are identified in the supracrustal rock group: mafic metavolcanic rocks, intermediate to felsic metavolcanic rocks, metasedimentary rocks, and mafic intrusive rocks (Figure 2). Sedimentation within the supracrustal rock assemblage was largely synvolcanic, although sediment deposition in the Bending Lake area may have continued past the volcanic period (Stone 2009; Stone 2010a; Stone 2010b). All supracrustal rocks are affected, to varying degrees, by penetrative brittle-ductile to ductile deformation under greenschist- to amphibolite-facies metamorphic conditions (Blackburn and Hinz 1996; Stone et al. 1998). In some locations, primary features, such as pillow basalt or bedding in sedimentary rocks are preserved, in other locations, primary relationships are completely masked by penetrative deformation. Uranium-lead (U-Pb) geochronological analysis of the supracrustal rocks produced ages that range between 2734.6 +/-1.1 Ma and 2725 +/-5 Ma (Stone et al. 2010). Three main suites of plutonic rock are recognized in the Revell batholith, including, from oldest to youngest: a

Biotite Tonalite to Granodiorite suite, a Hornblende Tonalite to Granodiorite suite, and a Biotite Granite to Granodiorite suite (Figure 2) Plutonic rocks of the Biotite Tonalite to Granodiorite suite occur along the southwestern and northeastern margins of the Revell batholith. The principal type of rock within this suite is a white to grey, medium-grained, variably massive to foliated or weakly gneissic, biotite tonalite to granodiorite. One sample of foliated and medium-grained biotite tonalite produced a U-Pb age of 2734.2+/-0.8 Ma (Stone et al. 2010). The Hornblende Tonalite to Granodiorite suite occurs in two irregularly-shaped zones surrounding the central core of the Revell batholith. Rocks of the Hornblende Tonalite to Granodiorite suite range compositionally from tonalite through granodiorite to granite and also include significant proportions of quartz diorite and quartz monzodiorite. One sample of coarse-grained grey mesocratic hornblende tonalite produced a U-Pb age of 2732.3+/-0.8 Ma (Stone et al. 2010). Rocks of the Biotite Granite to Granodiorite suite underlie most of the northern, central and southern portions of the Revell batholith. Rocks of this suite are typically coarse-grained, massive to weakly foliated, and white to pink in colour. The Biotite Granite to Granodiorite suite ranges compositionally from granite through granodiorite to tonalite. A distinct potassium (K)-Feldspar Megacrystic Granite phase of the Biotite Granite to Granodiorite suite occurs as an oval-shaped body in the central portion of the Revell batholith (Figure 2). One sample of coarse-grained, pink, massive K-feldspar megacrystic biotite granite produced a U-Pb age of 2694.0+/-0.9 Ma (Stone et al. 2010).

The bedrock surrounding IG_BH04 is composed mainly of massive to weakly foliated felsic intrusive rocks that vary in composition between granodiorite and tonalite, and together form a relatively homogeneous intrusive complex. Bedrock identified as tonalite transitions gradationally into granodiorite and no distinct contact relationships between these two rock types are typically observed (SRK and Golder 2015; Golder and PGW 2017). Massive to weakly foliated granite is identified at the ground surface to the northwest of the feldspar-megacrystic granite. The granite is observed to intrude into the granodiorite-tonalite bedrock, indicating it is distinct from, and younger than, the intrusive complex (Golder and PGW 2017).

West-northwest trending mafic dykes interpreted from aeromagnetic data extend across the northern portion of the Revell batholith and into the surrounding greenstone belts. One mafic dyke occurrence, located to the northwest of IG_BH01, is approximately 15-20 m wide (Figure 2). All of these mafic dykes have a similar character and are interpreted to be part of the Wabigoon dyke swarm. One sample from the same Wabigoon swarm produced a U-Pb age of 1887+/-13 Ma (Stone et al. 2010), indicating that these mafic dykes are Proterozoic in age. It is assumed based on surface measurements that these mafic dykes are sub-vertical (Golder and PGW 2017).

Long, narrow valleys are located along the western and southern limits of the investigation area (Figure 1). These local valleys host creeks and small lakes that drain to the southwest and may represent the surface expression of structural features that extend into the bedrock. A broad valley is located along the eastern limits of the investigation area and hosts a more continuous, un-named water body that flows to the south. The linear and segmented nature of this waterbody’s shorelines may also represent the surface expression of structural features that extend into the bedrock.

Regional observations from mapping have indicated that structural features are widely spaced (typical 30 to 500 cm spacing range) and dominantly comprised of sub-vertical joints with two dominant orientations, northeast and northwest trending (Golder and PGW 2017). Interpreted bedrock lineaments generally follow these same dominant orientations in the northern portion of the Revell batholith (Figure 2) (DesRoches et al. 2018). Minor sub-horizontal joints have been observed with minimal alteration, suggesting they are younger and perhaps related to glacial unloading. One mapped regional-scale fault, the Washeibemaga Lake fault, trends east and is located to the west of the Revell batholith (Figure 2). Ductile lineaments, also shown on Figure 2, follow the trend of foliation mapped in the surrounding greenstone belts. Additional details of the lithological units and structures found at surface within the investigation area are reported in Golder and PGW (2017).

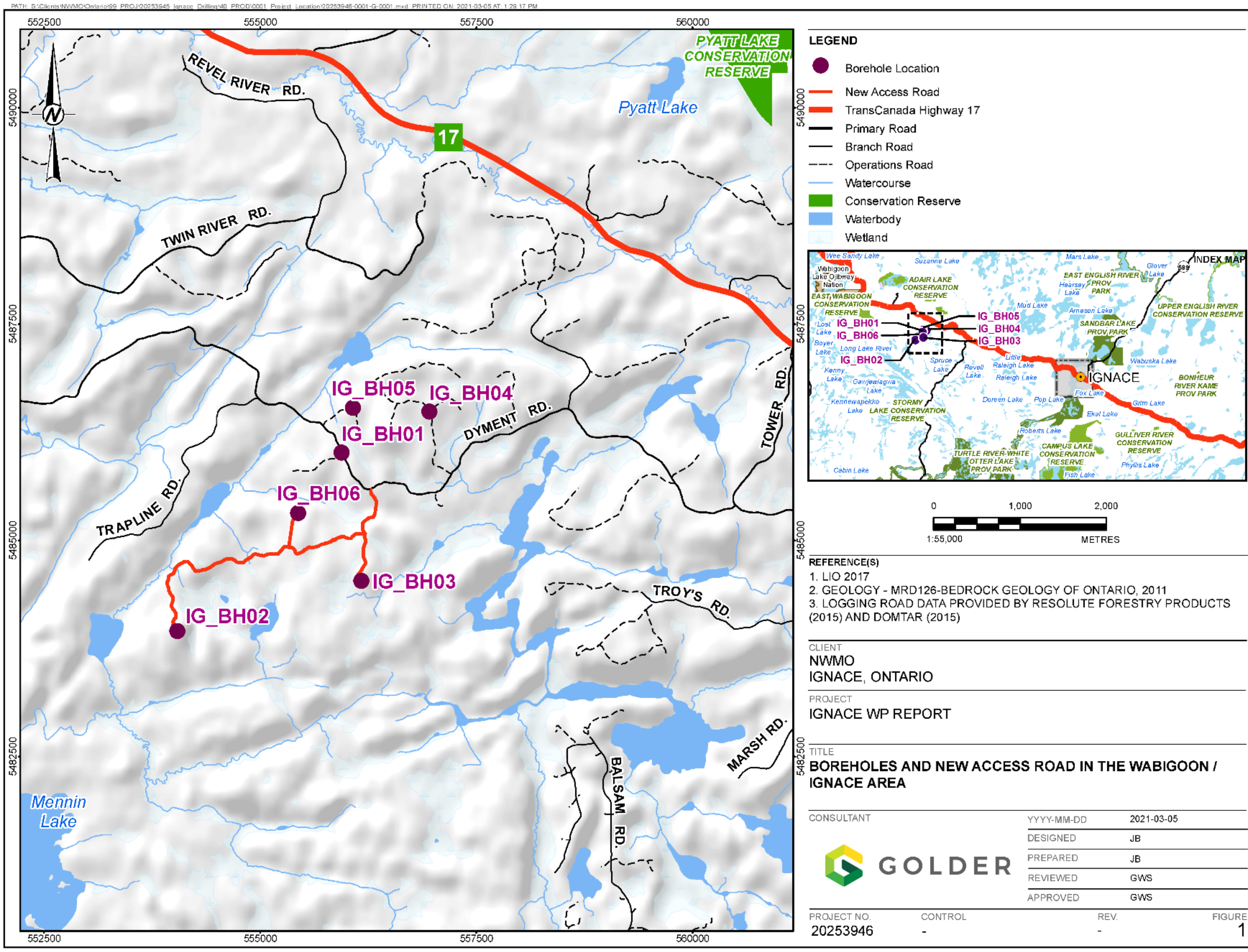

Figure 1: Location of IG_BH04 in relation to the Wabigoon / Ignace Area

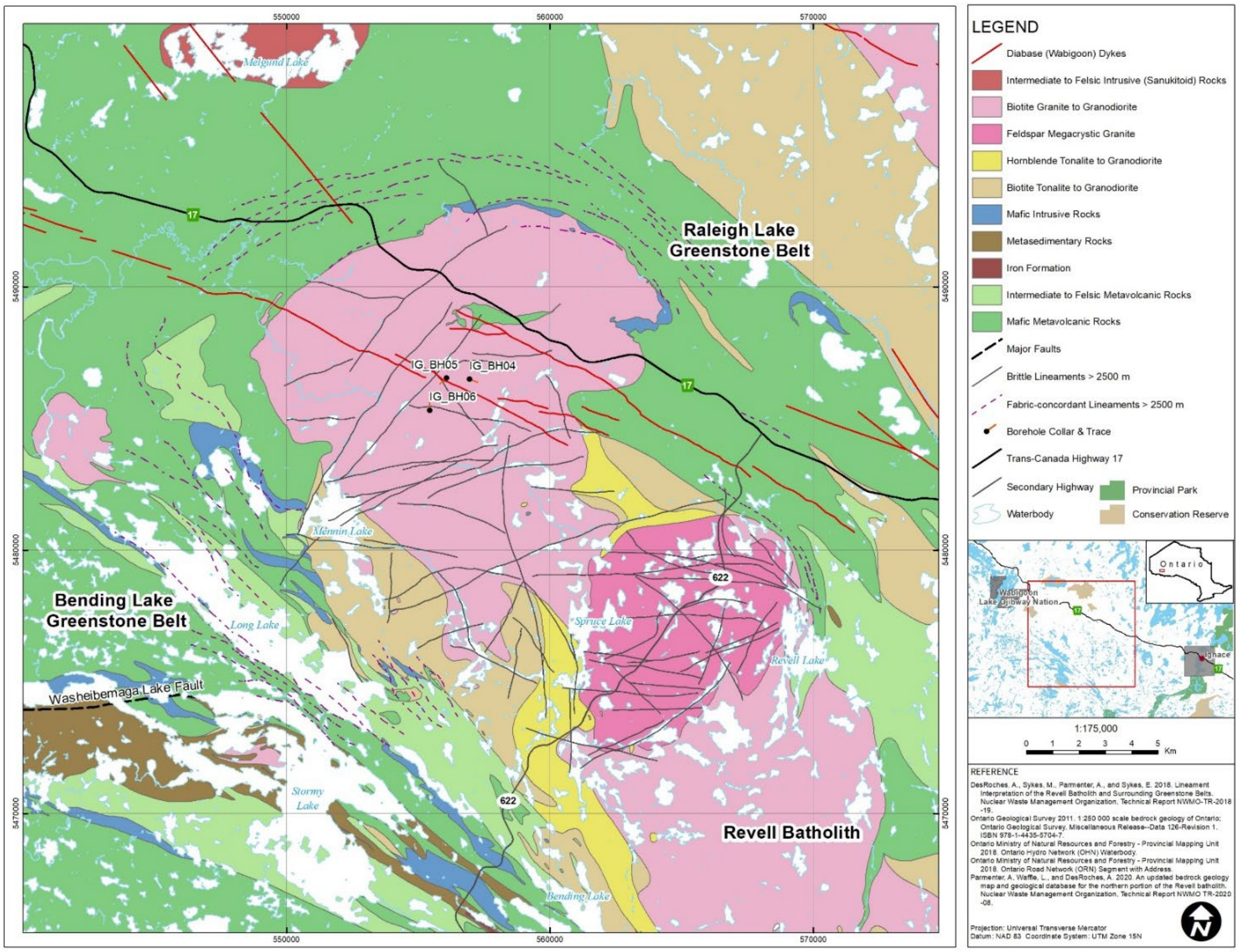

Figure 2: Geological setting and location of boreholes IG_BH04, IG_BH05 and IG_BH06 in the northern portion of the Revell batholith

3.0 DESCRIPTION OF ACTIVITIES

Golder completed the geophysical logging program from the bottom of the finished borehole to the bottom of the steel casing from April 30 to May 09, 2021, immediately after completion of flushing the borehole. The upper 100 m of the borehole was geophysically logged previously by Wood during borehole drilling and results were provided to Golder by NWMO for integration with the geophysical logs acquired as part of this contract.

The main geophysical logging program was completed by Golder and its subconsultants DGI Geoscience (DGI), Posiva Solutions Oy (Posiva), and consultant Frederick Paillet. Golder personnel carried out the majority of the geophysical logs, and DGI carried out gamma-gamma, sonic, neutron and resistivity logs, under Golder supervision. Posiva carried out the Posiva flow logging, under Golder' supervision. Frederick Paillet carried out the FFEC flow logging modelling and interpretation. The geophysical logging acquisition took place within the IG_BH04 work site at the drill pad constructed at the borehole collar.

3.1 Field Equipment

The following list presents the field equipment used to carry out geophysical borehole logging:

- One (1) Mount Sopris Instruments (MSI) 4MXA-1000 1,000m single conductor wireline winch (Figure 3);
- One (1) Mount Sopris Instruments (MSI) 4WNA 1,800m four conductor wireline winch with WCA-1000 Winch Depth-Tension-Speed Controller (Figure 3);
- Two (2) Advanced Logic Technology (ALT) Matrix logging box (Figure 3);
- One (1) Advanced Logic Technology (ALT) SCOUT logging box (Figure 3);
- Two (2) Laptop computers with LoggerSuite 11.2 (ALT) software (Figure 4);
- Posiva testing trailer and probes;
- Borehole wireline tripod and wheel (Figure 5);
- Borehole logging probes (see Table 1 in Section 3.4);
- Conductivity probe calibration ring;
- Caliper probe calibration jig;
- FTR probe calibration fluid;
- E-Log calibration box;
- MagSus calibration ring;
- Optical televiewer colour strip and housing;
- Televiewer orientation jigs;
- Tape measure (metric);
- Water level tape (metric);
- RST water level probe;
- Grundfos pump and controller;
- Portable shelter with table and chairs;
- Paper towels;
- Cable de-greaser;
- Alconox™ detergent;
- Silicone grease;
- HQ centralizers;
- Extension cord;
- Horiba Multiparameter Meter;
- Power Line Conditioner;
- 2 kW generator;
- 5 kW generator;
- Re-head kits for winches;
- Repacking syringe and accessories; and

- Tool kit for troubleshooting and maintaining equipment.

All equipment was tested and calibrated (when necessary) prior to mobilization to site and was confirmed to be in working order.

3.2 Equipment Checks and Calibration

All geophysical logging equipment was checked prior to shipping to the field, as well as prior to its use. All applicable calibrations or verifications were performed following the procedures outlined in the probe-specific user manuals, which were kept in hard copy on site throughout the geophysical logging program. Specific calibration procedures, documentation, and checks of individual borehole probes are detailed in their respective logging procedures itemized below. The results of calibration and verification checks are compiled in Appendix A, which includes all Calibration and Verification Forms, Data Quality Confirmation Forms, and Pre-use Check Forms.

A description of field verification checks is included in more detail in Section 3.4, and in the probe-specific manuals in Appendix B of this report.

A check of the odometer wheel on the winch wireline was performed prior to use to ensure it was reporting accurate depths, and the results of this check were recorded in a Data Quality Confirmation Form, included in Appendix A.

The logging scientists maintained a Record of Geophysical Logging for each shift, which were provided to NWMO, and recorded:

- The site conditions;
- The equipment setup arrangement (Figure 3);
- The reference point relative to ground surface;
- The probes used, including their make, model, serial numbers and detector offsets;
- The reported total depth of the borehole;
- The expected depth of investigation or log length;
- The static water level in the borehole;
- The reported depth to the bottom of the casing;
- Any reported zones of instability noted during drilling or coring; and
- Any damaged or malfunctioning equipment or components and the steps taken to rectify them.

The above information, where possible, was used to populate the headers of the individual LAS data files. The Records of Geophysical Logging are included in Appendix C.

3.3 Equipment Setup

Prior to setting up equipment on site, a Job Safety and Environmental Assessment (JSEA) was conducted to identify and eliminate or mitigate all safety hazards associated with the performance of the work. At each change of shift, the JSEA was updated to reflect any changes in site conditions or logging setup and the incoming cross-shift personnel were briefed of any new developments.

Figure 3:Winches bolted to ground with laptops to left, probes to left and right and DGI trailer opposite side of IG_BH04.

The wireline winch and logging box were set up approximately 4 m from the borehole collar, next to the workstation, within a heated shelter installed outside the drill rig, allowing easy access to the borehole. The tripod was installed adjacent to the borehole within the drill rig, with the wheel centred over the casing. The wireline winch and tripod were installed in-line allowing the logging scientist to maintain visual contact with the borehole collar at all times. The high side of the borehole stickup was established as the reference plane to be used for levelling each probe and was measured at 0.30 m above ground surface for the first 2 shifts and 0.76 m above ground surface for the remaining 11 shifts. Static water levels over the duration of the geophysical logging program were also measured relative to this reference point. The wireline winch (Figure 3) and tripod (Figure 5) were secured to the work surface floor to ensure zero movement during the logging activities. Figure 6 shows the DGI setup for borehole logging.

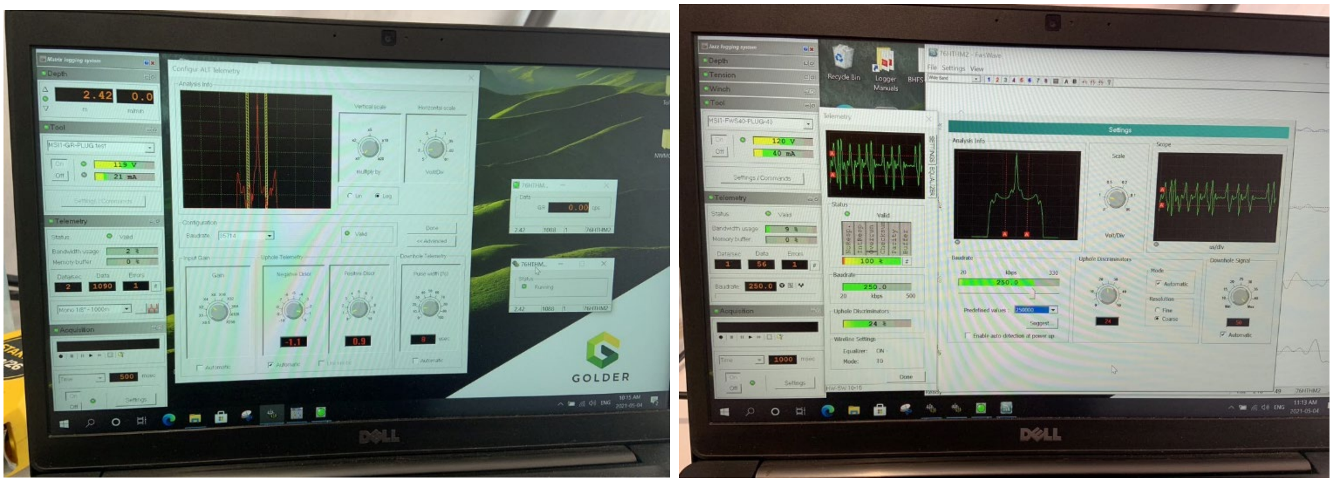

Figure 4:Laptop computer with ALT LoggerSuite software (left) and Jazz Logging System (right)

Figure 5: Borehole wireline tripod and wheel

Figure 6: DGI setup for borehole logging

The wireline winch, logging box and the laptop were connected to each other and powered using an external generator through an extension cord and power bar. Real-time telemetry and data monitoring was available through the software applications, Matrix Logger, Jazz Logging System or Matrix Heat (exclusively for the Heat-Pulse Flowmeter) running on the dedicated laptop computer (Figure 4). An area within the shelter was cleared for assembly, pre-use checks, and calibration of borehole probes. During the apparent conductivity calibration and testing periods, the calibration ring was left at the same location to ensure repeatable calibration values for the post survey calibration.

3.4 Summary of Borehole Geophysical Logging

Geophysical well logging was conducted in accordance with the requirements of ASTM D5753-18 – Standard Guide for Planning and Conducting Geotechnical Borehole Geophysical Logging (ASTM 2018). The geophysical well logging program consisted of 15 distinct logging tests using 13 different downhole probes. The logging probes were chosen to help assess the structural, hydrogeological, lithological, and geomechanical properties of the rock, as follows:

- Televiewer, deviation, and caliper logging was carried out to help assess structural properties of the rock, in conjunction with WP03, rock core logging and photography, carried out by Wood.
- Apparent conductivity, natural gamma, E-log resistivity, spectral gamma, and magnetic susceptibility logging was carried out to help assess lithological properties of the rock, again in conjunction with WP03, rock core logging and photography, carried out by Wood.
- Full waveform sonic (FWS) and gamma-gamma (density) logging was carried out to help assess the geomechanical properties of the rock, in conjunction with WP04B, geomechanical core testing carried out by Wood.

- Flowing fluid electrical conductivity (FFEC), Posiva flow logging, fluid temperature and resistivity (FTR), neutron (porosity), and heat-pulse flowmeter (HPFM) logging was carried out to help assess hydrogeologic properties of the rock, in conjunction with WP06, hydraulic testing (Golder 2022a) and WP07, opportunistic groundwater sampling (Golder 2022b).

The geophysical logging probes used in this investigation are listed Table 1 below, in the order that the logs were acquired in the field. The logging sequence was selected to maximize data quality and minimize the risk of disturbing the borehole walls for subsequent logging probes. The table also provides the main acquisition parameters for each logging probe, including sample interval, logging speed and direction of acquisition (i.e., up or down)

Table 1: Geophysical Logging Probes and Acquisition Parameters

Geophysical Test	Probe Model	Sample Interval (m)	Logging Speed (m/min)	Logging Direction
Flowing Fluid Electrical Conductivity	2SFA-1000	0.05 / 0.10	10 / 20	Down / Up
Apparent Conductivity	2PIA-1000	0.05	4.5	Up
Gamma-Gamma (Density)	QL40-DEN	0.025	2.5	Up
Acoustic Televiewer	QL40-ABI-2G	0.002	1	Up
Natural Gamma	QL40-GR	0.025	2.25	Up
Neutron (Porosity)	QL 2NUA-1000/2C	0.025	2.5	Up
Full-Waveform Sonic	QL40-FWS	0.05	2	Up
Mechanical Caliper	2PCA-1000	0.01	2.5	Up
E-log Resistivity + SP + SPR	QL40-IP	0.05	3	Up
Spectral Gamma	2SNA-1000	0.025	2.25	Up
Fluid Temperature / Resistivity	2SFA-1000	0.05	10 / 20	Down / Up
Magnetic Susceptibility	HMI-453	0.05	4.5	Up
Optical Televiewer	QL40-OBI-2G	0.0016	4	Up
Heat-Pulse Flowmeter	HFP-2293	20	Stationary	Stationary
Deviation	QL40-OBI-2G	0.10	10	Down and Up
Posiva Flow Log	n/a	0.01 / 0.05	Stationary	Stationary

The .TOL files containing the parameters and settings for each probe are provided in Appendix D.
The geophysical logging results are provided in Appendix E at a scale of 1:5000. Geophysical log acquisition, processing and interpretation are described in the subsections below.

3.4.1 Geophysical Logging Depths

Two main factors affect the accurate reporting of the depth of geophysical logging data, particularly in holes as deep as 1000 m. The steel cable is known to stretch according to the weight of the vertical length of wireline down the hole, as well as the weight of the probe itself. Additionally, the odometer wheel used to track the movement of the cable, and therefore the depth of the probe, has limitations in its precision, which compound over large depths to result in cumulative error at the bottom of a deep hole.

3.4.1.1 Wireline Cable Stretch Correction

After carefully analysing all processing procedures, and in consultation with NWMO, it was decided to not apply a cable stretch factor for IG_BH04 data. Final depth corrections were applied to all BH04 logs using the results of structural integration between televiewer logs and WP03 core logs and according to formulae described in Section 3.4.1.2.

3.4.1.2 Cumulative Odometer Error Correction

A depth correction factor was identified after integrating structural features from televiewer logs and core logs, completed as part of the single-hole geoscientific data integration. Because of the rigid nature of the drill rods, it was concluded that structure depths recorded during core logging were not subject to cumulative error, and that discrepancies between core and televiewer logged features were caused by the wireline winch odometer.

The difference in recorded depths between corresponding structures in the core and televiewer was plotted against the depth recorded in the televiewer logs. The resulting plot (Figure 7) shows a trend from which a correction factor was derived.

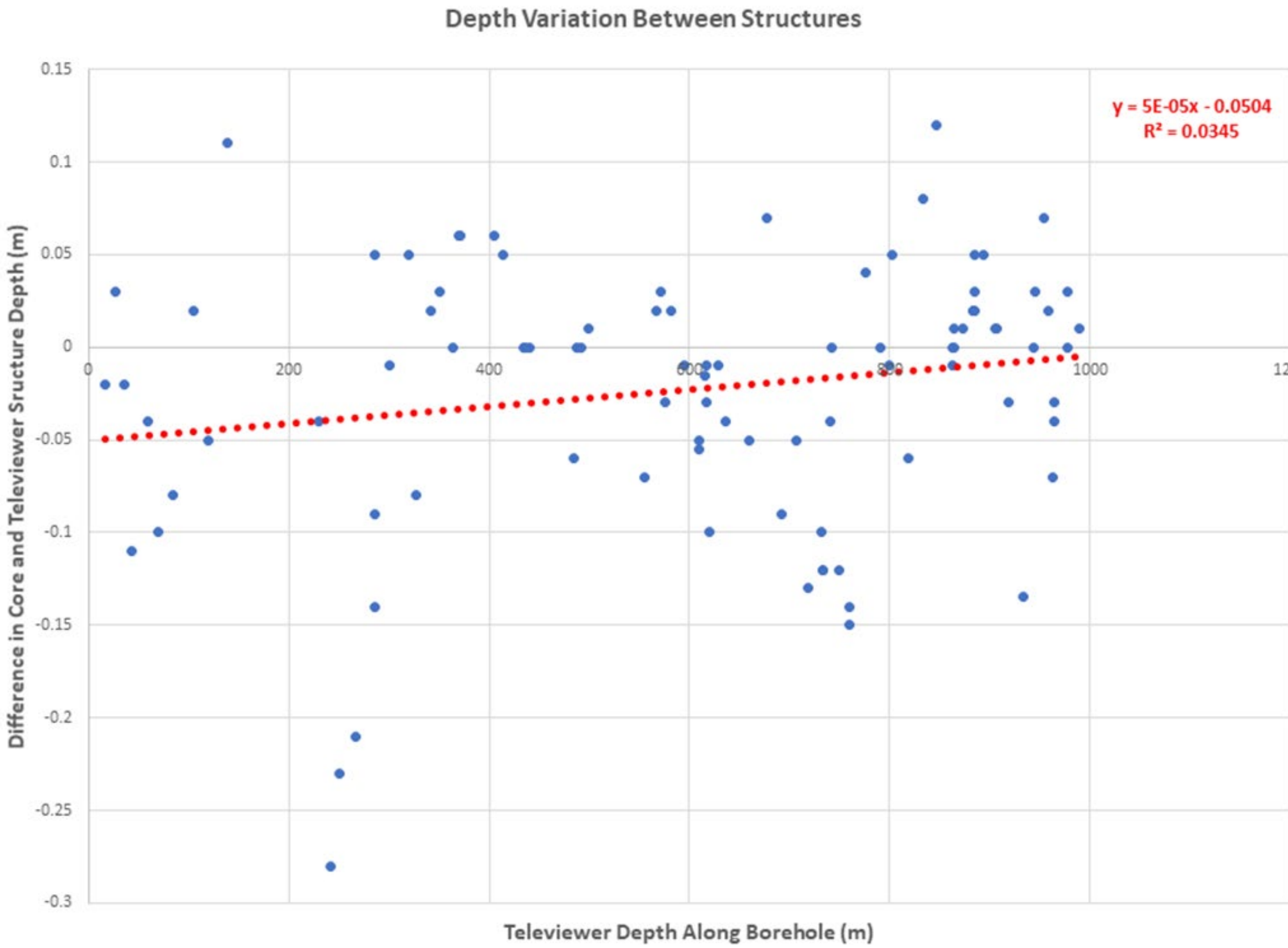

Figure 7: Comparison between depths of structures logged in core and televiewer (acoustic and optical) data

It was decided to apply this correction factor to the geophysical logs, according to the relationship:

$$Final\ Depth\ (m) = D * 0.00005 - 0.0504$$

where:

$$D = Corrected\ Depth\ (m)$$

This correction factor is interpreted to result from micro-slippage of the wireline winch odometer wheel and/or cable-stretch beyond the original formulae effective measurable range. The remaining discrepancies between core and televiewer structure depths, typically in the range of ±0.1 m, is attributed to imprecision in structure depth measurement on the core due to irregular or non-planar structure shapes.

3.4.1.3 After-Survey Depth Error

The difference between the initial reference depth of the probe relative to ground surface and the final reported depth at the reference point after completion of the logging is called the After-Survey Depth Error (ASDE). For this project, the tolerance for depth error is given as 30 cm (centimetres) plus 0.1% of the total depth of the borehole, meaning for a 1,000 m deep borehole, the maximum allowable ASDE is 1.30 m. This is a stricter tolerance than the allowable ASTM vertical depth error of 0.4%, or 4.0 m for a 1,000 m borehole (ASTM 2018).

Logs which were collected in multiple sections were shifted to the ASDE of the shallowest section, and depth-matched across the other sections using common features. Table 2 shows the recorded ASDE values. Depth shifts were completed using these ASDE values to adjust the logs either upward (negative ASDE value) or downward (positive ASDE value) during the processing stage.

Table 2: After-survey Depth Errors Reported for Each Geophysical Log Acquired

Borehole Log	After-Survey Depth Error (m)
FFEC (147 mins)	0.00
FFEC (217 mins)	0.01
FFEC (348 mins)	0
FFEC (516 mins)	-1.09
FFEC (631 mins)	0
FFEC (725 mins)	0.05
FFEC (861 mins)	0
FFEC (1283 mins)	0
FFEC (1569 mins)	0.18
FFEC (1712 mins)	0
FFEC (1928 mins)	1.74
FFEC (2028 mins)	0
FFEC (2125 mins)	1.16
FFEC (2213 mins)	0
FFEC (2296 mins)	0.85
FFEC (2375 mins)	0
FFEC (2453 mins)	1.18
FFEC (2530 mins)	0
FFEC (2608 mins)	0.75
FFEC (2635 mins)	0
FFEC (2770 mins)	0.93
FFEC (2845 mins)	0
FFEC (2950 mins)	1.04
Electromagnetic Induction (Apparent Conductivity)	-0.17
Gamma-Gamma Density	0.59
Acoustic Televiewer	-0.58

Borehole Log	After-Survey Depth Error (m)
Natural Gamma	-0.17
Neutron	0.06
Full Waveform Sonic	-0.17
Resistivity (E-LOG)	0.05
Mechanical Caliper	-0.92
Spectral Gamma	1.70
Fluid Temperature / Resistivity	0.27
Magnetic Susceptibility	0.05
Optical Televiewer (Deviation Run)	0.05
Optical Televiewer	0.05
Heat-Pulse Flowmeter	0.45

In the instance where the ASDE was larger than 1.0 m for the spectral gamma log the gamma response was used to correct the log depth based on the natural gamma log. The FFEC logs with error were depth corrected based on adjacent runs.

3.4.2 Flowing Fluid Electrical Conductivity

In order to help characterize flowing zones within the borehole, flowing fluid electrical conductivity (FFEC) testing was carried out. FFEC testing uses the contrast between the electrical conductivity of the formation fluid and water column within the borehole to identify the location of flow into the borehole and to estimate the flow rate (Paillet et al. 2010). The method requires a measurable contrast in electrical conductivity between the formation and borehole column, and if this does not exist at certain intervals then the FFEC method may not be useful to characterize flow in these intervals. The contrast in electrical conductivity could be easily generated by prior flushing of the hole with fluorescein traced fluid of known electrical conductivity. Modelling the changes in fluid column electrical conductivity under static and pumping conditions, allows for calculation of the hydraulic transmissivity, and fluid inflow rate of the flowing fractures within the borehole. Running FFEC tests under static conditions illustrated ambient inflow of fluid, while stressing the borehole by lowering the water level illustrated the dynamic flow potential from the same inflowing fractures.

As part of this geophysical logging program, the Mount Sopris 2SFA-1000 Fluid Temperature / Resistivity probe (FTR) was used to measure the temperature and electrical conductivity of the borehole fluid during both ambient and dynamic (pumping) fluid flowing conditions. This Fluid Temperature / Resistivity probe is part of a combination probe, forming the bottom end of the 3-arm mechanical caliper probe. The probe was checked for functionality prior to shipping to site. Immediately prior to use, the probe was calibrated using two fluids of known conductivity, the first being fluid pumped from the borehole during flushing, and the second being the same fluid diluted with distilled water (0.057 mS/cm and 29.50 mS/cm, respectively). The calibration values are recorded in the pre-use Calibration and Verification Check form in Appendix A.

Prior to geophysical logging, the borehole was flushed with approximately 45,000 litres of water, representing over 4 borehole volumes (volume of the borehole without HQ rods). This was done to improve fluid clarity for the optical televiewer, as well as to replace the existing fluid column in the borehole with fluid of a consistent and known electrical conductivity of 10 mS/m based on final flushing measurements as reported in WP02 (Golder 2021b). The flushing process took approximately 15 hours, after which the rods were removed. Details about the flushing process are discussed in WP02, Borehole Drilling and Flushing (Golder 2021b).

Immediately following flushing and removal of the drill rods, the geophysical equipment was set up as described in Section 3.3. The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and is calculated based on the stickup of the reference point measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications of the probe manuals (Appendix B).

The initial phase of FFEC testing was conducted under static (ambient) flowing conditions, over the course of 861 minutes. A total of seven logs were collected during this phase of testing, including three down logs run at 10 m/min sampling every 5 cm, and four complete up logs run at 20 m/min sampling every 10 cm.

After static testing, the probe was stopped at 80 m and a Grundfos submersible pump was lowered into the borehole to 60 m. FFEC testing was carried out below 80 m, under pumping conditions to stimulate flow from fractures.

As the probe could not be returned to the surface between tests, due to the presence of the Grundfos submersible pump being located above it, the wireline was marked with tape at a reference point on surface when the probe was at a depth of 80.00 m to accurately measure the ASCE for each run.

Sixteen additional FFEC logs were collected during the dynamic testing phase, over the course of ~1,800 minutes, between the pump depth (approximately 60 m) and the bottom of the borehole. These included eight complete down logs, run at 10 m/min sampling every 5 cm, and eight complete up logs, run at 20 m/min sampling every 10 cm. These logs are noted within Table 3.

Table 3 presents the Flowing Fluid Electrical Conductivity (FFEC) logs, including the logging time in minutes since start of testing, the logged depth interval, direction, sampling rate and the recorded After-Survey Depth Error (ASDE). The testing began 147 minutes after the last rods were pulled from the hole. The first 6 logs were acquired during ambient conditions over a 1,000-minute period. The remaining 16 logs were acquired while pumping over a 2,000-minute period.

Table 3: FFEC Logging Details

Log Start Time (mins from start of FFEC)	Interval Top (m)	Interval Bottom (m)	Direction	Speed (m/min)	Sampling Rate (cm)	After -Survey Depth Error (ASDE) (m)
145	1.82	407.92	Down	10	5	0
217	407.92	1.83	Up	20	5	0.01
348	1.82	999.32	Down	10	5	0

Log Start Time (mins from start of FFEC)	Interval Top (m)	Interval Bottom (m)	Direction	Speed (m/min)	Sampling Rate (cm)	After -Survey Depth Error (ASDE) (m)
516	999.32	0.73	Up	20	5	-1.09
631	1.82	999.51	Down	10	5	0
725	999.51	1.87	Up	20	5	0.05
861	1.82	999.53	Down	10	5	0
1283	50.01	999.58	Down	10	5	0
1569	999.37	50.19	Up	20	5	0.18
1712	50	999.48	Down	10	5	0
1928	999.54	81.74	Up	20	5	1.74
2028	80	995.02	Down	10	5	0
2125	995.02	81.16	Up	20	5	1.16
2213	80	995.02	Down	10	5	0
2296	995.02	80.85	Up	20	5	0.85
2375	80	995.04	Down	10	5	0
2453	995.04	81.18	Up	20	5	1.18
2530	80	995.05	Down	10	5	0
2608	995.05	80.75	Up	20	5	0.75
2635	80	995.02	Down	10	5	0
2770	995.02	80.93	Up	20	5	0.93
2845	80	999.31	Down	10	5	0
2950	999.31	81.04	Up	20	5	1.04

During the dynamic (pumping) phase of the FFEC logging, water levels were monitored and are shown on Figure 8. Due to the extremely low recharge rate encountered in the well the pump was only operated periodically to draw down the well to maintain a relatively constant water level.

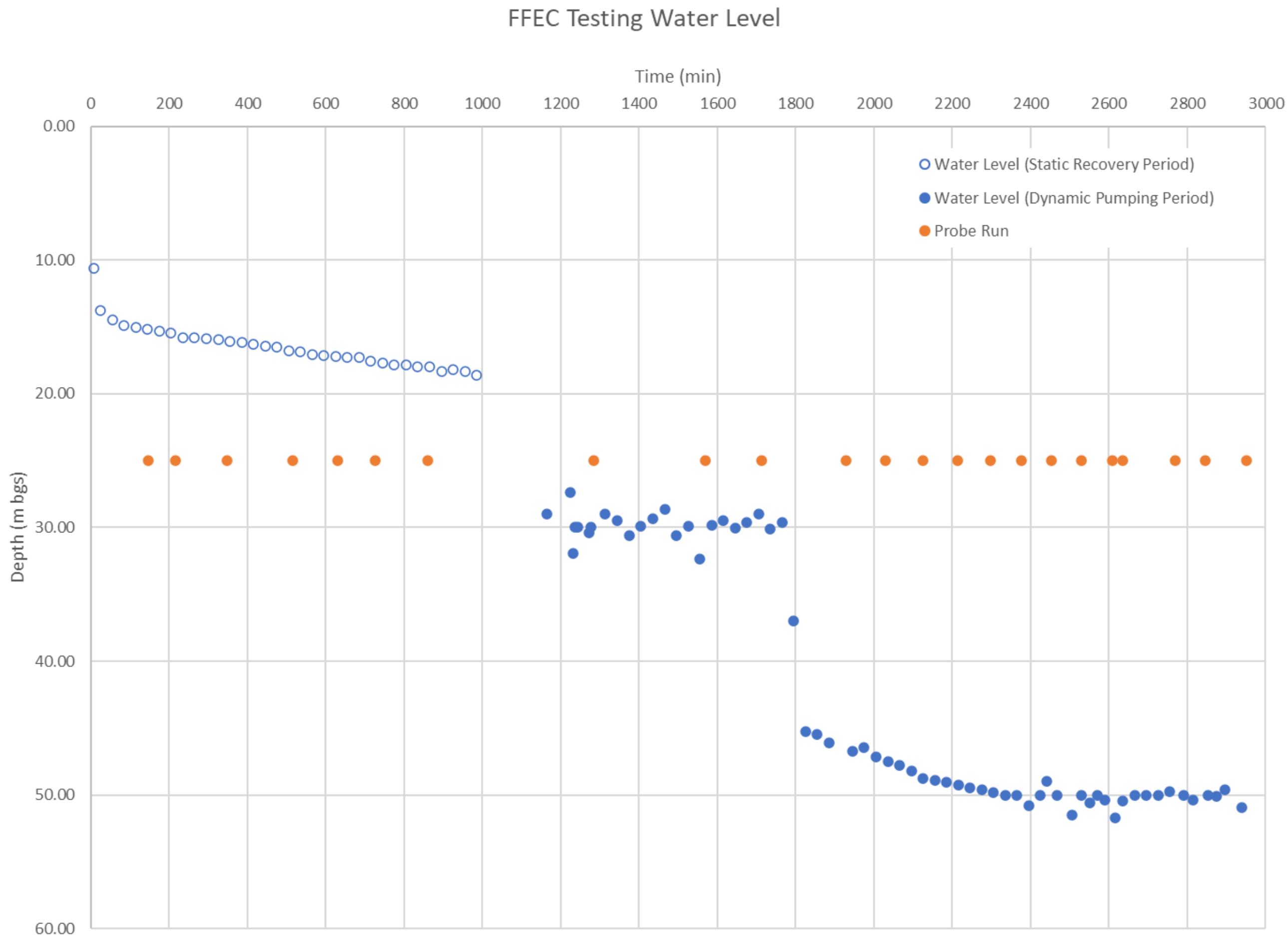

Figure 8: Water Level, measured during FFEC testing, from time of start of testing

Figure 8 shows the timeline of the FFEC testing, with 147 minutes being the beginning of the first test. The static testing phase lasted from 0 minutes to 1000 minutes. After the static testing the pump was lowered to 48 m and water level was lowered to 30 m. The pump was turned on periodically to maintain a relatively constant water level of 30 m in the borehole for testing between 1000 and 1800 minutes. The pump was then lowered to approximately 55 m and water level was then lowered to approximately 50 m and maintained until the completion of the FFEC testing.

The FFEC log data was imported into WellCAD as .TFD files and an interpolation function was applied to remove data spikes and gaps smaller than 1 metre. The logs were shifted to correct for the After-Survey Depth Error (ASDE), as listed in Table 3. A formula was then applied to correct the recorded depth as described in Section 3.4.1.3. The logs, once referenced to the corrected depth, were then exported as .WCA files, one for each logging run.

Each .WCA file was then imported back into one common WellCAD file where they were compared with each other and other geophysical logs, such as the optical televiewer image log. FFEC log depths were matched to common features to further refine their accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, using formulae described in Section 3.4.1.2.

To interpret the FFEC log results a numerical model was generated using multiple fluid conductivity logs under both ambient (static) and dynamic (pumping) conditions. The logs were first used to identify the discrete inflow points, corresponding to the peaks of the conductivity anomalies seen in the static logs. Four such points were identified, and a numerical model, described by Paillet (2012), was applied to simulate different inflow rates, fluid electrical conductivities, and hydraulic transmissivities. The modelling method assumes one-dimensional mass conservation and a constant longitudinal dispersion coefficient, due to the mixing caused by the repeated passage of the probe through the water column. The inflow rate from each point is also taken to be constant for the measurement period. The mixing volume used to model dispersion was 30 cm of borehole length (approximately 0.4 litres) and the modelled time-step was one minute.

Results from the FFEC modelling (see Appendix F) were imported into the same WellCAD file and compared to the Fluid Conductivity logs and optical televiewer Image log. Model injection points were then refined to reflect associated narrow fractured intervals. Final FFEC model values, as well as flow rates, incoming Fluid Electrical Conductivity, and Transmissivity, were displayed alongside field measured values. Representative logs from both static and dynamic pumping phases of the FFEC testing are presented on the Hydrogeology Log in Appendix E. Log times in Appendix F are given in minutes after the start of logging. For clarity, four representative logs were selected from the ambient phase of logging, six from the dynamic phase, and five from the model showing response under modelled dynamic conditions.

The Fluid Conductivity logs are overlaid in the Hydrogeology Log, included in Appendix E, in three groups based on whether they represent static flow (ambient) conditions, dynamic flow (pumping) conditions, or modelled dynamic flow (pumping) conditions. Within these three groups, logs are arranged in descending order of time, from early to late in the testing interval, showing the progression of changes in the conductivity profile with time.

The modelled FFEC logs match well with the observed anomalous pattern of the fluid conductivity logs, where each of the electrical conductivity anomalies can be correlated to a narrow fracture interval observed in the televiewer structural interpretation. There are two injection points considered in the model.

The FFEC model injection values shown in the Hydrogeology log are described in detail in Appendix F and are summarized in Table 4. The results suggest two inflow points, which are interpreted to be located at 580 m and 995 m and have flow rates between 0.11 L/min and 1.25 L/min. The hydraulic transmissivity of these points is estimated between 0.021 and 0.064 m^2/day for the feature at 580 m and between 0.002 and 0.006 m^2/day for the feature at 995 m.

Table 4: FFEC Model Injection Values

Depth (m)	Model Flow (L/min)	Conductivity (mS/m)	Transmissivity (m2/day)
580	1.25 +/- 0.10	159 +/- 15	0.021<T<0.064
995	0.11 +/- 0.08	150 +/- 30	0.002<T<0.006
Total Inflow	1.36 ± 0.03	-	-

3.4.3 Electromagnetic Induction (Apparent Conductivity)

Electromagnetic induction data was acquired using a Mount Sopris Instruments (MSI) 2PIA-1000 probe, also known as an Apparent Conductivity probe. This probe was run to investigate the bulk (formation and fluid) electrical conductivity of the bedrock. Changes in electrical conductivity are used to identify changes in mineralization, such as the presence of conductive sulphides, or clay-bearing fracture zones.

The probe contains a transmitter and receiver coil and measures the apparent bulk conductivity of the borehole wall around the probe, in mS/m. The depth at which the measurement is given is the midway point between the two coils. Since the conductivity probe generates a primary magnetic field, which extends through the air or water within the borehole and into the surrounding formations, it is not necessary for the probe to be centralized in the borehole.

This probe is susceptible to drift in changing temperatures, so to ensure optimal data accuracy, it was acclimatized in the borehole fluid prior to calibration and logging, according to ASTM standard D6726-15 (Section 8.2). The probe was turned on and run in Time Mode to display real-time apparent conductivity values. The probe was then lowered to a point below the static water level and below the casing where it was left to acclimatize for 30 minutes until the real-time apparent conductivity readings had stabilized, which indicated that it had equilibrated to the temperature of the borehole fluid.

The probe was then ascended and removed from the borehole. It was taken away from the drill rig to the conductivity calibration area which was at least 8 m away from the nearest large metal objects. The calibration measurements were completed as soon as possible after the probe was removed from the borehole fluid to minimize temperature changes caused by the cold air outside the logging shelter. The conductivity probe was placed in the calibration ring and probe measurements were carried out using two pre-set conductivity values on the variable dial of the ring (0 mS/m and 102 mS/m). The results were saved into the associated .TOL file and exported as a .TXT file for record keeping. The calibration records were documented in the Record of Geophysical Logging, as well as the Calibration and Verification Check Form, and provided to NWMO.

Following the calibration, the probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction was specific to the tool and was calculated based on the stickup of the reference point above ground surface as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B.

During the descent, the probe was run in Time Mode to display real-time values in order to check the expected conductivity range of the bedrock. Based on the expected range, a range setting of the probe was selected following the procedures outlined in the user manual (Appendix B). The sensitivity range setting for the probe was set to the 0 to 100 mS/m range for increased probe sensitivity. The probe was descended to a depth of 350 m, turned on and the first log was started. The QA/QC log was recorded for 10% of the borehole depth, from 350 m to 450 m. The probe was logged down up at 4.0 m per minute and sampled every 5 cm. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. After reaching the bottom of the borehole, the second file was started, recording up at 4.5 m per minute and sampled every 5 cm.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe had entered the casing in which the readings were affected by the metallic casing, the second file was terminated. The probe was ascended to the level point, where the final level depth was recorded, and the probe was removed from the borehole. The probe was then run in Time Mode and placed back in the calibration ring in the same location as the initial calibration. The two pre-set values were checked and recorded in the Record of Geophysical Logging, and the Calibration and Verification

Check Form. Temperature drift, which is caused by changes in measured values due to changing temperature of the probe’s internal electronics, was calculated, and drift correction applied using a linear data shift based on the difference between initial calibrated values and final check values, assuming the final check values are correct as the probe has had the most time for the internal electronics temperature to stabilize to the borehole fluid temperature.

The .TFD files were imported into WellCAD and the primary log compared favourably to the QA/QC log over the repeated interval from 350 m to 450 m. For the primary log, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. Once ASDE was corrected, the log was exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, resistivity logs, magnetic susceptibility log, and natural gamma log. Apparent Conductivity log depths were matched to common features to further refine the accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, using formulae described in Section 3.4.1.2. The final Apparent Conductivity log is displayed on the Lithology Log, in Appendix E.

Results from the Apparent Conductivity log are measured in milliSiemens per metre (mS/m), ranging from -935.33 mS/m to 4339.5 mS/m. The average value is 12.32 mS/m. The general trend of the apparent conductivity curve is flat, with gradual decrease towards end of the borehole. There are anomalies seen at the location of the metal wedge that was used due to re-alignment of drilling. These are seen at 373 to 382 m and 392 to 399 m.

More localized spikes in apparent conductivity, such as 579 to 581 m, and 624 to 625 correspond with dykes and veins apparent in the optical televiewer log and seen in natural gamma, gamma-gamma density, and neutron logs.

3.4.4 Gamma-Gamma Density

Near- and far-field bulk density data were acquired using the Mount Sopris QL40-DEN focused gamma-gamma probe. The gamma-gamma probe measures the electron density of the bedrock by using a radioactive source, Cesium 137, located on the same plane as the detectors, the surrounding bedrock is bombarded with intermediate gamma rays. The probe contains two CsI (Th) detectors spaced 20 cm and 35 cm from the source to measure “near” and “far” back-scatter of radiation, respectively. The probe is forced against the borehole wall using a single caliper arm ensuring the gamma rays interact with the formation in the correct plane.
The phenomenon of Compton scattering takes place in which the back-scattered gamma rays emerge from the borehole wall and are received by the detectors.

Prior to loading the radioactive source into the probe, the instrument was connected to the wireline and tested for operation at surface. The calibration of the density sensors was verified at DGI’s Operation Centre prior to mobilizing the instrument to site. The calibration utilized an aluminium test block with a known density of 2.6 grams per cubic centimetre (g/cm^3) and a test borehole in rock with a known density of 2.942 g/cm^3. The gamma-gamma density probe achieved calibration status with ±0.08 g/cm^3 in near and far density measurements of the aluminium block and ±0.001 g/cm^3 in measurements of the test borehole.

Once the probe was configured, the probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool in relation to ground surface, in this case bedrock surface. This depth correction was specific to the tool and was calculated based on the stickup of the reference point above ground surface as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator's manuals in Appendix B.

The probe was descended to a depth of 300 m and a single caliper arm was deployed to ensure the probe was forced against the borehole wall, then the first log was started. The QA/QC log was recorded for 10% of the borehole depth, from 300 m bgs to 200 m bgs. The probe was run up at 2.5 m per minute and sampled every 2.5 cm. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. After reaching the bottom of the borehole, the second file was started, recording up at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored to ensure valid telemetry and minimal data errors. The calibration of the caliper arm was checked against the same known diameters, then the probe was deactivated.

The .TFD files were imported into WellCAD. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were then exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they were compared with each other and the QA/QC log, to ensure repeatability. Final Near Density and Far Density logs were then compared to other geophysical logs, such as the optical televiewer Image log, Neutron log, and full waveform sonic velocity logs. Gamma-gamma density log depths were matched to common features to further refine the accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Near Density and Far Density curves are displayed on both the Lithology Log and the Engineering Log, in Appendix E. Both Near and Far Density logs are measured in grams per cubic centimetre (g/cc). The Near Density log ranges from 2.28 g/cc to 3.08 g/cc (below the casing), with an average of 2.76 g/cc. The Far Density log ranges from 2.55 g/cc to 3.10 g/cc (below the casing), and has an average value of 2.72 g/cc. There are two spikes observed in the near and far density logs at the location of the steel wedge with ranges 2.62 g/cc to 2.70 g/cc from 369 to 395m. Additionally, six spikes ranging in thickness from 0.5 to 5.7 m are apparent associated with discrete changes in rock type as observed in optical televiewer logs and through geological core logging, and typically range from 2.28 g/cc to 3.10 g/cc, or 0.07 g/cc to 0.3 g/cc above background.

3.4.5 Televiewer Logging

3.4.5.1 Acoustic Televiewer

The Advanced Logic Technology (ALT) ABI40-2G Acoustic Televiewer probe, also known as the Acoustic Borehole Imager (ABI), was used primarily to image discontinuities (e.g. joints, veins, etc.) intersecting the borehole wall. The ABI40-2G transmits a series of high frequency sonic pulses, reflected off of a rotating mirror, and receives the echo of those pulses from the borehole wall. By analysing the amplitude of the echo relative to the original pulse, as well as the time delay between the original pulse and the return, the ABI40-2G generates a series of thin slices of data which it stacks and translates into a pair of continuous images, the Amplitude and the Travel Time logs. Because of varying hardness, different rocks and minerals absorb or reflect different amounts of the original sonic pulse, thus the ABI40-2G's Amplitude log shows an image of the varying hardness of the borehole wall, plotting these differences using a colour scale. A quartz vein, for example, will reflect more energy than the host shale bed, thus the ABI Amplitude image will show a bright reflection for the quartz and a dimmer reflection for the shale. The ABI40-2G's Travel Time log is an image plotting the differences in echo delay, meaning an open fracture or void into which the sonic pulse had to travel farther before being reflected will appear in contrast to the nearer borehole wall.

Using a depth-dependant fluid velocity log derived from borehole diameter values measured by the mechanical caliper, the average travel time of the pulses at each recorded depth were converted into a distance, producing the Acoustic Caliper log, showing the calculated diameter of the borehole.

In order to translate the travel time of each pulse into distance, and properly analyse the strength of the pulse echoes, the ABI40-2G can only be run in water. Because the ABI40-2G does not use an optical camera, the borehole fluid may be murky without adversely affecting the image quality. Additionally, because of the geometry of the reflections of the pulses, the ABI40-2G must be well centralized in the borehole. Three non-metallic centralizers with a fixed HQ diameter were affixed to the ABI40-2G to maintain centralization of the probe while logging. The use of these centralizers assumes a near-uniform diameter of the borehole.

The ABI40-2G acoustic televiewer contains internal electronics to record tilt, azimuth, and roll of the probe while operating using a 3-axis fluxgate magnetometer and a 3-axis accelerometer. These internal electronics were factory calibrated and the certificate of calibration is included in Appendix A. Prior to shipping and use, the probe was checked for functionality, with the results recorded in the pre-use Calibration and Verification Check form. The magnetometer measurements are susceptible to interference from highly magnetic rock, metallic casing, or geomagnetic interference (e.g. intense auroral activity or solar storms). Under those conditions, the orientation of the probe and its image must be estimated. To ensure no geomagnetic field disturbances, data from NRCAN were obtained prior to logging. Data measured data from the NRCAN magnetic field strength were obtained from the Brandon, Manitoba station for the duration of the field program. No geomagnetic interference was observed during the time of logging.

Once the probe was connected to the wireline, the probe was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. The offset of the probe sensor is outlined in the technical specifications and operator’s manuals in Appendix B.

Acoustic televiewer logging was completed in two stages, with the upper 100 m being logged prior to the drilling of the rest of the borehole. This was done to allow a section of the upper 100 m to be isolated from the rest of the borehole to prevent groundwater from flowing between near-surface and deeper fractures. The procedure for collecting acoustic televiewer in both stages were the same.

The appropriate .TOL file was selected from the tool list, the probe was turned on. The probe was run in Time-Mode, allowing it to transmit real-time images which were monitored by the logging scientist while the ABI40-2G descended the borehole. The depth of casing was noted on the collected data. This depth was later compared as a QA check to the depth of well casing documented during borehole drilling in order to verify the accuracy of the wireline odometer wheel.

The probe was descended the length of the borehole at up to 15 m per minute while the logger monitored the wireline tension and the real-time ABI40-2G images for potential obstructions and image centralization. The QA/QC log was recorded down from 5 m to 995 m. Once the log QA/QC log was finished, the QA/QC file was terminated, and the probe was returned to surface. An additional log was recorded down the entire length of borehole, sampling at 0.05 m to record deviation. Once the probe reached the bottom of the hole, the deviation file was terminated, and the primary file was started. The ABI40-2G was run up the borehole at 2.0 m per minute, sampling every 2.1 mm (millimetres) with 288 ppt (points per turn) azimuthal resolution. A constant logging speed was used throughout entire length of borehole to ensure consistency.

Logs were recorded as a .TFD file and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent. Once the probe had reached the casing, the log was terminated, and the probe deactivated. The probe was then ascended until it was level with the reference point and removed from the borehole. The difference between initial and final depths reported at the reference point, 0.58 m, was recorded as the After-Survey Depth Error (ASDE).

The .TFD files were imported into WellCAD then depth shifted and merged accordingly, including existing ABI logs from the top 100 m section that were provided by NWMO. For the primary log data curves, an interpolation function was applied to remove data spikes and gaps smaller than 0.1 m, while for the Acoustic Amplitude and Travel Time logs, the Interpolate Bad Traces algorithm was run to remove blank traces.

Through calibration to the mechanical caliper a constant fluid velocity of 1,450 m/s was used to calculate the acoustic caliper log.

A high-pass normalization function was applied to the acoustic amplitude log, using a window of 5 degrees and 0.01 m, to improve image quality. A centralization function was applied to the acoustic travel time log to correct for minor offsets in image centralization.

One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2. The acoustic televiewer images are displayed in the Structural Log, included in Appendix E, while the deviation curves are included in the Deviation Log.

3.4.5.2 Optical Televiewer

The Advanced Logic Technology (ALT) OBI40-2G Optical Televiewer probe, also known as the Optical Borehole Imager (OBI), consists of a camera which records images of the surrounding borehole by focusing downward on a conical mirror and lighting the hole with a ring of LED lights. The thin slices of images are stacked to form a continuous 24-bit RGB true colour image of the unwrapped interior of the borehole. Because the image is a 2-dimensional unwrapped cylinder, planar features (e.g. fractures) intersecting the borehole at an angle appear sinusoidal in the OBI40-2G image log.

The OBI logs are useful for observing layering, banding, foliation, fractures, voids and veins, in addition to obtaining information on visual characteristics such as oxidation staining, mineral infilling, alteration, etc. The probe also contains a 3-axis magnetometer and 3-axis accelerometer which records the tilt and azimuth of the hole, as well as the roll of the probe inside the hole. The magnetometer is susceptible to interference from highly magnetic rock, the metallic casing, or geomagnetic interference (such as intense auroral activity or solar storms). To maximize the accuracy of the deviation package, the NRCAN Space Weather Prediction Centres was consulted prior to logging to ensure no geomagnetic field disturbances. Data from the NRCAN magnetic field strength were obtained from the Brandon, Manitoba station for the duration of the field program.

The OBI40-2G optical televiewer probe's deviation package was factory calibrated and the certificate of calibration was provided to NWMO. The probe was also checked for functionality before shipping and before logging, with the results recorded in the pre-use Calibration and Verification Check form, submitted to NWMO. Prior to use, the fidelity of the optical image was verified using a standardized Kodak strip of colour bars in a specialized canister which was placed over the end of the OBI40-2G, while the probe was still on surface. A file showing the colour bars was recorded for QA/QC purposes. A set of three specialized centralizers for HQ sized borehole were affixed to the OBI40-2G probe to maintain centralization of the probe while logging.

Once the probe was connected to the wireline, the probe was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction was specific to the tool and was calculated based on the stickup of the reference point above ground surface as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator's manual in Appendix B.

The appropriate .TOL file was selected from the tool list in the Logger program and the probe was then turned on. The probe was run at 15 m/min in Depth-Down Mode, recording deviation at 0.05 m intervals, and allowing it to transmit real-time images which were monitored by the logging scientist. During the descent, the logging scientist documented the depth to the bottom of well casing. This depth was later compared as a QA check to the depth of well casing documented during borehole drilling (WP02: Golder 2021b) in order to verify the accuracy of the wireline odometer wheel. Once the probe reached the bottom of the borehole, the deviation file was terminated, and a new file was started. The probe was run up from the bottom of the borehole to maintain constant tension on the wireline and thus a consistent logging speed (2 m/min).

All logs were recorded as a .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent. Once the probe was level with the reference point the final level depth was recorded to determine the After-Survey Depth Error (ASDE), the log was terminated, and the probe deactivated and removed from the borehole.

Because the OBI40-2G records and optical image through a camera lens it requires a transparent medium to see through. Data from the initial OBI40-G2 logging indicated the presence of turbid water in the borehole column over the entire length of the borehole.

The .TFD files were imported into WellCAD then depth shifted and merged accordingly, including existing OBI logs from the top 100 m section provided by NWMO. For the primary log data curves, an interpolation function was applied to remove data spikes and gaps smaller than 1 m, while for the Optical Image logs, the Interpolate Bad Traces algorithm was run to remove blank traces. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. The logs, once drift corrected and referenced to the corrected depth, were then exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they compared favourably with the QA/QC log. These logs were then compared and depth-matched to common features of other geophysical logs, such as the acoustic televiewer logs, and Mechanical Caliper log.

One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2. The optical televiewer image is displayed for reference in the Structural Log, Lithology Log, Engineering Log, and Hydrogeology Log, included in Appendix E, while the deviation curves are included in the Deviation Log.

The depth correction process was difficult due to the image quality of the optical televiewer log.

The optical image from the televiewer is particularly useful for identifying lithological and alteration zones based simply on the colour image. In addition, the optical televiewer image was a key dataset used to interpret structural features throughout the length of the borehole. Description of this interpretation is included in Section 3.4.5.3.

3.4.5.3 Televiewer Structural Interpretation

Once the optical and acoustic televiewer logs were finalized, a structural analysis was completed using the structural interpretation module in WellCAD to obtain the depth, apparent dip, and dip direction (i.e., orientations relative to high side) of each interpreted structure (Figure 9).

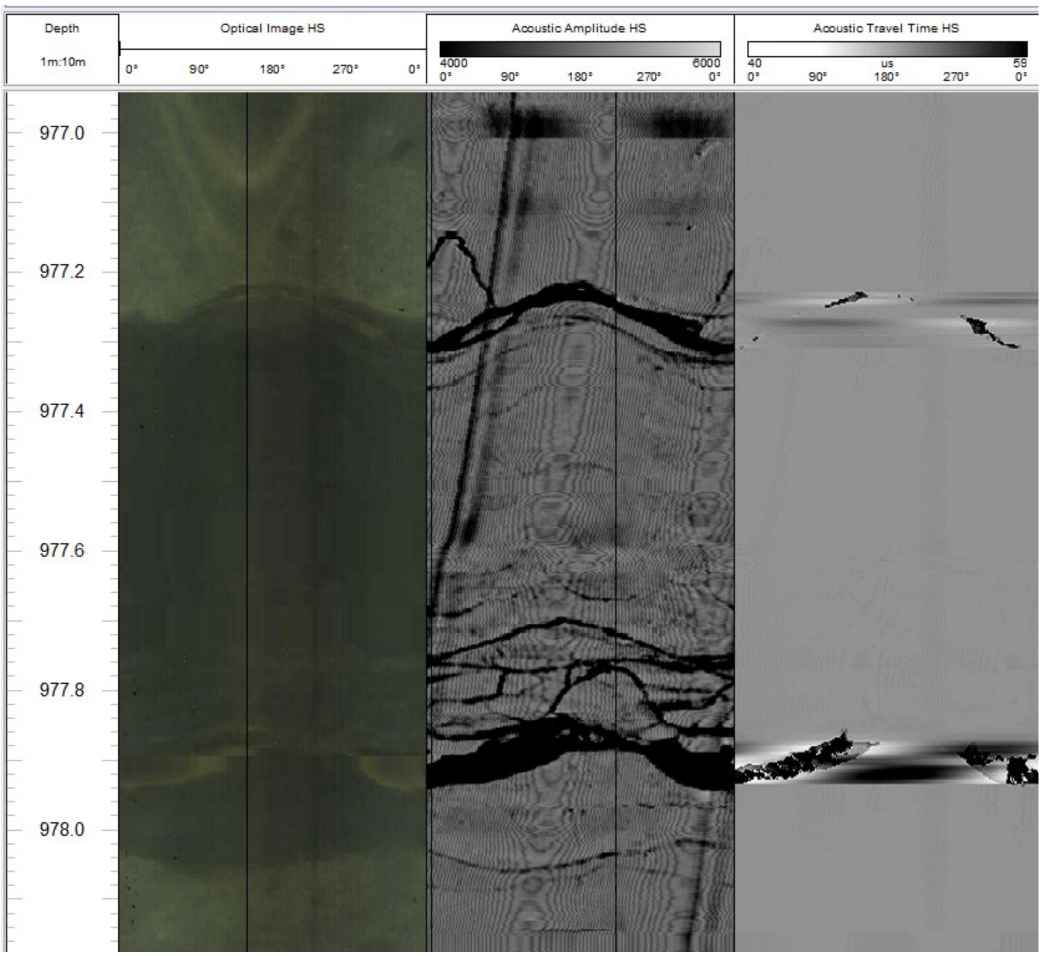

Figure 9: Optical and acoustic televiewer logs showing sinusoidal fracture planes intersecting the borehole wall

To complete the structure analysis a blank structure log was overlain on either televiewer image, switching between data sets as needed, to compare the pick of one feature over multiple images. The Acoustic Caliper log was selected to represent the borehole diameter used to calculate apparent dip, as this log spanned the entire depth of the borehole, including the top 100 m, which was not surveyed with the Mechanical Caliper. The structure dictionary was consistent with the terminology used during geological and geotechnical core logging outlined in WP03. However, only a subset of those structures was applicable to picking from the televiewer images. For each type of structure, a certainty value was assigned to address the clarity of the structure traced in the televiewer image (High, Medium and Low). For structures with a measurable thickness (e.g. veins, joints), apparent apertures were also traced as the width of the structure perpendicular to its orientation (see Figure 10).

Figure 10: WellCAD Structure Dictionary showing used structures

A Breakout log was also created to allow for the picking of the minimal breakouts observed. Breakouts are defined as open vertical or sub-vertical structures in the borehole wall, aligning with the plane of minimum horizontal stress. Breakouts are formed where stresses around the borehole have exceeded the compressive strength of the rock. They can be seen in televiewer logs as pairs of vertical or sub-vertical features, and potentially in mechanical caliper logs as increases in borehole dimeter, depending on their size and orientation relative to the caliper arms. Breakouts can be traced on a breakout log by aligning a feature along the breakout axis and assigning it an aperture. Two breakout zones were observed in the borehole log, between 859.0 and 860.7 m and between 943.8 and 946.7 m, which are shown in Figures 11 and 12.

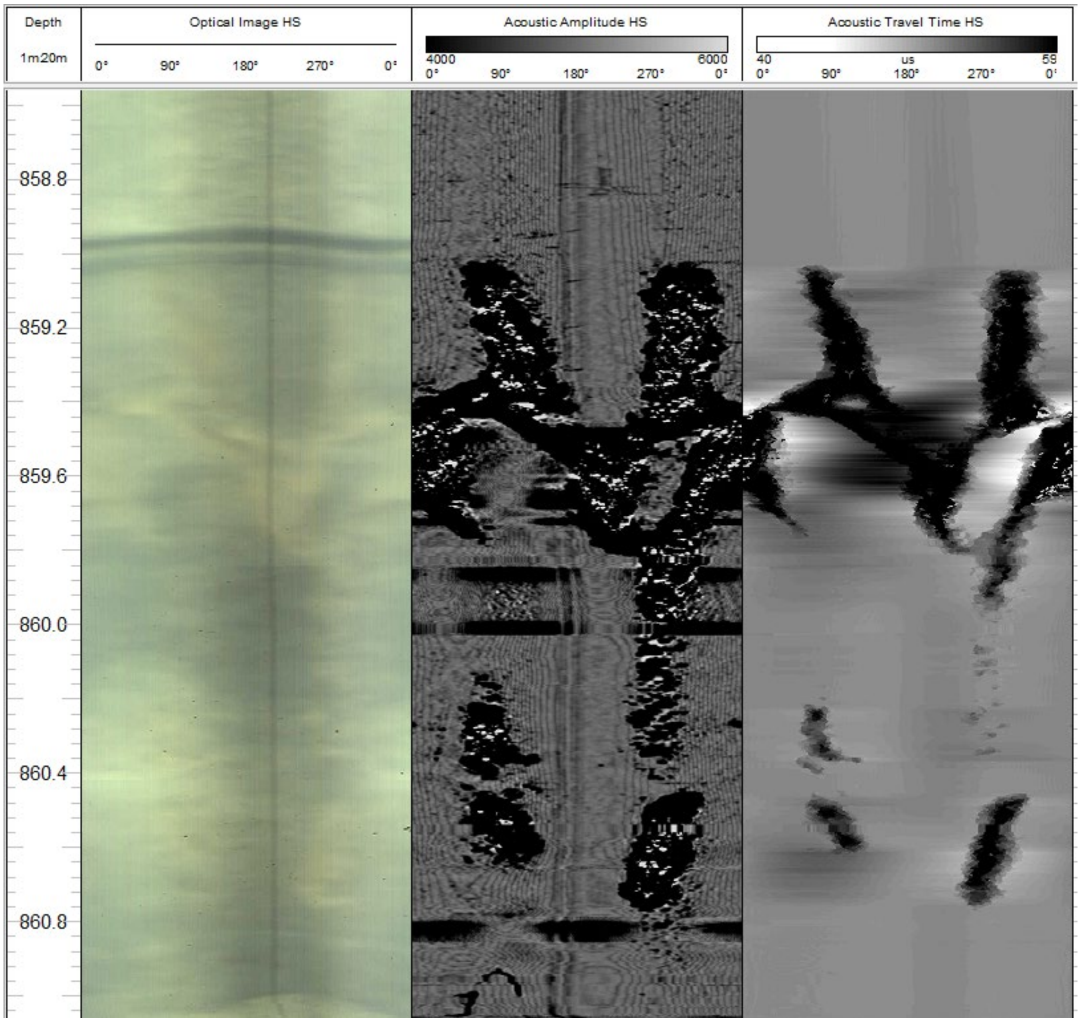

Figure 11: Breakout zone observed between 859.0 and 860.7 m.

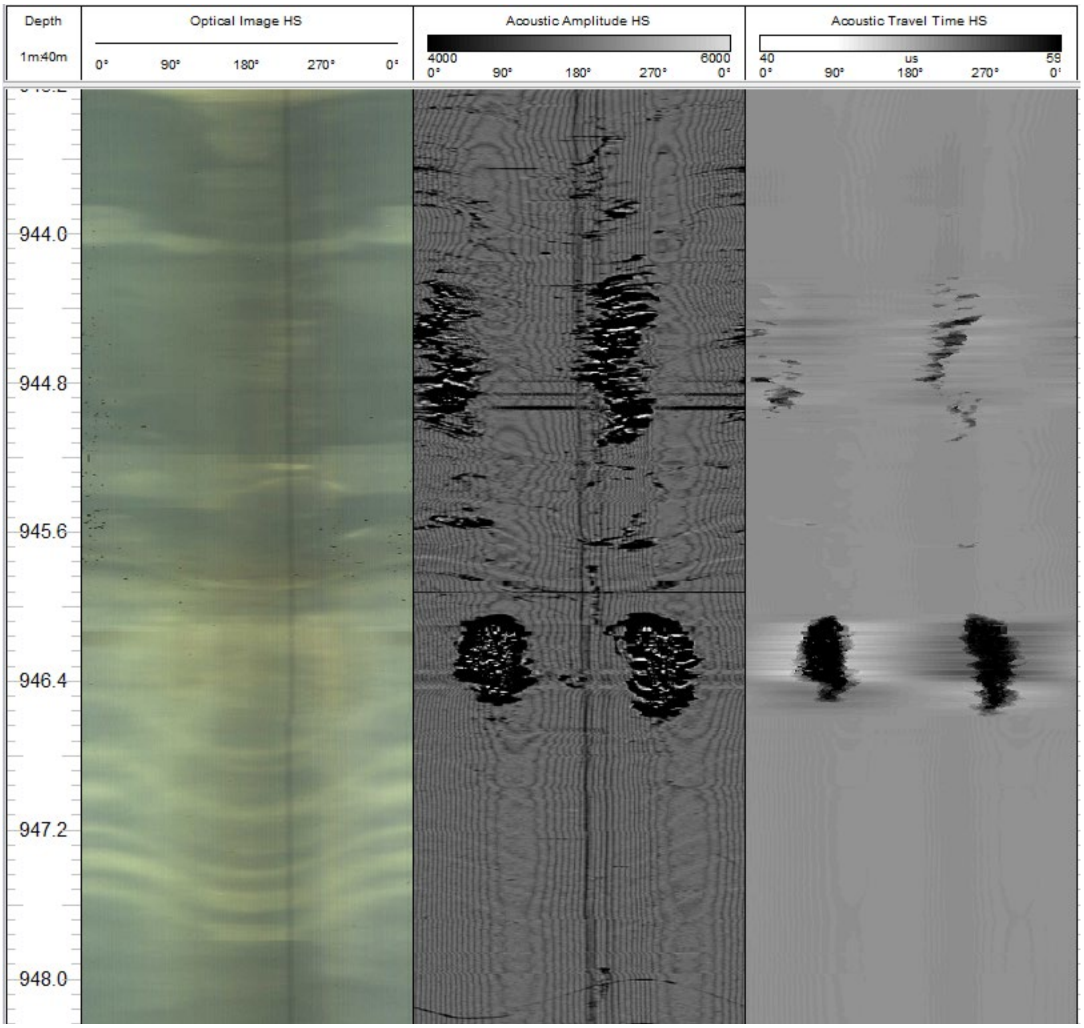

Figure 12: Breakout zone observed between 943.8 and 946.7 m.

Interpreted structure orientations were corrected from apparent dip and dip direction to true dip and dip direction (i.e., relative to true north), using the acoustic televiewer Tilt and Azimuth logs. Final orientations of structures are presented as tadpoles (Tadpoles TD&DD in Appendix E), showing their dip magnitude along the X-axis and the tail showing their azimuth direction. The corrected structure log was then exported as a .CSV file where the Magnetic North azimuths were corrected with the local magnetic declination (1.361°W), as calculated by the Geological Survey of Canada, to yield True North azimuths. The structure types were converted from numerical labels to descriptive labels and the file was saved.

The Tadpoles TD&DD log was used to generate two frequency logs (Joints and Veins), measured in counts per metre. The frequency of Joints ranges from 0 counts/m to 13 counts/m, with an average of 1.36 counts/m. The frequency of Veins ranges from 0 counts/m to 9 counts/m, with an average of 0.78 counts/m.

Five equal-angle (Wulff) stereonets, each spanning 200 m of the borehole were plotted to show the change in dip and dip direction of joints along the borehole. Structures picked from televiewer logs, as well as frequency logs and stereonets, are displayed in the Structural Log, included in Appendix E.

3.4.6 Natural Gamma

In crystalline rock, the gamma log is used principally for lithologic identification based on presence of minerals with natural radioactivity. The Mount Sopris QL40-GR Natural Gamma probe was used to provide a measurement, recorded in counts per second (cps) that is proportional to the natural radioactivity of the bedrock.

The Mount Sopris QL40-GR natural gamma probe uses a scintillation sodium iodide crystal to measure the incoming natural gamma radiation from the borehole walls. The gamma-emitting radio-isotopes that naturally occur in geologic materials are Potassium 40 and nuclides in the Thorium 232 and Uranium 238 decay series. Potassium 40 occurs with all potassium minerals including potassium feldspars. Thorium 232 is typically associated with biotite, sphene, zircon and other heavy minerals. Uranium 238 is typically associated granitoid rocks with uranium mineralization.

Once the probe was connected to the wireline, it was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator's manuals in Appendix B.

As the natural gamma probe was attached to several probe an individual QAQC log was not recorded, rather multiple natural gamma logs were collected along the entire length of the borehole. For logging the probe was descended to the bottom of the borehole and the continuous borehole log was initiated recording up the borehole at 2.25 m per minute, sampling every 2.5 cm.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors, according to ASTM Standard D6274-10 (Section 9). Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe reached the top of the hole and was level with the reference point, the log was terminated, and the probe was deactivated and removed from the borehole.

The .TFD files were imported into WellCAD where the primary log compared favourably to the QA/QC logs. For the primary log, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The log was shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes and exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, spectral gamma total counts log, and apparent conductivity log. Natural gamma log depths were matched to common features to further refine the accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2.

The final Natural Gamma curve is displayed on the Lithology Log, in Appendix E. The data were measured in counts per second in the borehole, ranging from 32.58 cps to 682.82 cps, with an average value is 70.29 cps. The Natural Gamma values are on average 2.5 times higher than the Spectral Gamma total counts values, which is a result of counts falling outside the spectral energy classification window used during spectral gamma acquisition, which filters out counts with energy below 100 keV. Both the Natural Gamma and Spectral Gamma total counts logs match well for their respective ranges, showing the same pattern along the total depth of the borehole. The most apparent anomalies in the data tend to be associated with sharp changes in total counts associated with changes in biotite concentration. A pronounced change can be seen in the Natural Gamma log at the depth intervals between approximately 95 m and 102 m which is associated with casing. There is a gradual increase in Natural Gamma response beginning at 555 m and settling at 676 m. This area has spikes at 616 m and 621 m with maximum values of 682.82 cps which are likely associated with tonalite dykes. Another area of increase is from 747 m to 845 m with a maximum of 147.78 cps. Elsewhere in the borehole more localized anomalies are also associated with intervals that have undergone alteration.

3.4.7 Neutron

The Mount Sopris LLP-2676 Dual Sensor Neutron probe uses an alpha emitting radioactive source, Americium 241 mixed with Beryllium and a single detector, to acquire relative neutron counts principally related to hydrogen ion concentration. Changes in neutron counts can be used to identify changes in rock geology.

Prior to mobilization, the probe was tested for proper calibration at DGI's Operation Centre, using an open-air sample and a test block, in accordance with ASTM standard D6727-16 / D6727M-16. The calibration test passed with an average count of 87.23 cps in open air, and 1734.48 cps in the test block. Values and verification were recorded in the Calibration and Verification Check Form, included in Appendix A.

Once the probe was configured and calibration was verified, it was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator's manuals in Appendix B. The hole was logged in one shift with the log being collected from 990 m to surface. A QA/QC file was also recorded from 300 m to 200 m. The logs were collected in the up direction, with the probe being run at 2.5 m per minute, sampling every 2.5 cm.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe was level with the reference point, the file was terminated and saved to the laptop and backup drive, and the probe was deactivated and removed from the borehole. The neutron source was removed and returned to its protective case.

The .TFD files were imported into WellCAD where the primary logs compared favourably to the QA/QC log. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. A formula was then applied to correct the recorded depth as described in Section 3.4. Once referenced to the corrected depth, the logs were exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they were compared with other geophysical logs, such as the optical televiewer image log, gamma-gamma density log, and natural gamma log. The two primary logs were merged, and common features were matched, to further refine the accuracy. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs described in Section 3.4.

The final Short Sensor (SS) Neutron and Long Sensor (LS) Neutron curves are displayed on the Lithology Log, in Appendix E. The Neutron data is measured in counts per second, with the SS data ranging from 3,731.1 cps to 10,022.1 cps with an average value of 9,217.2 cps. and the LS data ranging from 151.8 cps to 1,492.1 cps, with an average value of 1,080.2 cps. The neutron curve tends to produce anomalies along the borehole length than inversely correlate with anomalies in the gamma-gamma density curve. Several pronounced decreases are present on both LS and SS curves with the six biggest anomalies at 318 m to 321 m, 484 m to 489 m, 575 m to 578 m, 615 m to 622 m, and 904 m to 908 m. This depth intervals are similarly reflected in the gamma-gamma density and total gamma curves. Numerous high-frequency anomalies, reflected as sharp 200 cps to 580 cps decreases in neutron counts, also occur along the borehole and coincide with peaks in the gamma-gamma density log.

A porosity log, calculated based on Neutron log data, is also presented on the Lithology Log, in Appendix E. The Porosity values are displayed in percent, ranging from 0.84% to 67.68%, with an average Porosity of 1.6% in the open rock section of the borehole. The Porosity curve is generally flat with several sharp spikes associated with density and resistivity spikes, as well as with lithology change. The most prominent correlation with average porosity increases of 5% to 67% are shown at depth intervals of 575 m to 577 m, 615 m to 622 m, 904 m to 908 m, 942 m to 947 m, and 976 m to 979 m. Other spikes with an average increase of 2% are also presented along the whole length of borehole and associated with lithology (dykes).

3.4.8 Full Waveform Sonic

Full waveform sonic logs provide data on the compression wave and shear wave velocity of the borehole wall. This data can be used in conjunction with density logs from the gamma-gamma density probe to calculate engineering properties like shear modulus, bulk modulus, young’s modulus, and Poisson’s ratio, which are useful for distinguishing rock types.

The Mount Sopris FWS Full Waveform Sonic probe (FWS) utilizes a sonic transmitter and three receivers to measure the primary (compression) and secondary (shear) wave velocities of the rock formation. The transmitter and receiver portions of the probe are isolated from each other with a flexible sonic isolator which prevents the transmitted sonic pulses from travelling through the probe. As the calculations for wave velocity require a consistent separation from the transmitter and receivers relative to the borehole wall, centralizers are required for this probe.

Once the probe was assembled, affixed with centralizers, checked for functionality, and connected to the wireline, the probe was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B. The probe was descended to 50% of the borehole depth, and a QA/QC log was recorded from 500 m to 400 m. The probe was run at 2.0 m per minute, sampling every 0.05 m. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole and the second file was begun, recording with the same speed and sampling interval. The primary log was recorded from 990 m bgs to 2.92 m bgs.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe was level with the reference point, the tool was deactivated, and the probe was removed from the borehole.

The .TFD files were imported into WellCAD where the primary log compared favourably to the QA/QC log. For the primary log, the Interpolate Bad Traces algorithm was applied to remove any gaps in the data. The log was shifted to correct for the After-Survey Depth Error (ASDE). Once referenced to the corrected depth, the log was exported as .WCA files.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, gamma-gamma density log, and neutron log, and common features were matched to further refine the accuracy.

Compression and shear wave velocities were estimated in WellCAD by computing a semblance plot that evaluates the similarities in the full sonic waveforms across the array of receivers in the probe. Graphically, the FWS Semblance Plot is an image log where individual pixels are assigned a colour based on the amplitude of the semblance between the travel times recorded by each of the FWS receivers. The manually picked slowness curves were adjusted using the WellCAD extremum algorithm, and the logs were inverted to generate Compression Wave Velocity and Shear Wave Velocity logs. These logs were then used to calculate the Poisson's Ratio log, according to the formula (ALT 2011):

$$Poisson's\ Ratio = \frac{\frac{1}{2}\left(\frac{dts}{dtc}\right)^2 - 1}{\left(\frac{dts}{dtc}\right)^2 - 1}$$

where:

$$dtc = Compression\ Wave\ Slowness\ \ (\mu s/sm)$$

$$dts = Shear\ Wave\ Slowness\ (\mu s/sm)$$

The calculated Poisson's Ratio was then used in conjunction with the Shear Modulus to generate the Young's Modulus, according to the formula:

$$Young's\ Modulus\ (MPa) = 2 \times \mu \times (1 + \nu)$$

where:

$$\mu = Shear\ Modulus\ (MPa)$$

$$\nu = Poisson's\ Ratio$$

The Bulk Modulus was calculated according to the formula:

$$Bulk\ Modulus\ (MPa) = \rho_b \times \left(\frac{1}{dtc^2} - \frac{4}{3 \times dts^2}\right)$$

where:

$$\rho_b = Bulk\ Density\ (g/cc)$$

Using the Near Density log in conjunction with the Shear Wave slowness log, the Shear Modulus was calculated according to the relationship (ALT 2011):

$$Shear\ Modulus\ (MPa) = \frac{\rho_b}{dts^2}$$

The Near Density log was also used in conjunction with the Compression Wave Velocity log to calculate the Characteristic Acoustic Impedance, according to the following relationship:

$$Characteristic\ Acoustic\ Impedance\ (Rayls_{MKS}) = \rho_n \times v_P$$

where:

$$\rho_n = Near\ Density\ \ (kg/m^3)$$

$$v_P = Compression\ Wave\ Velocity\ (m/s)$$

One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.

The Full Waveform Sonic (FWS) image log and curves are displayed in the Engineering Log, included in Appendix E. The FWS logs include the Semblance Plot image, the picked Compression Wave and Shear Wave slowness curves, the calculated Compressive Wave Velocity and Shear Wave Velocity curves, the calculated elastic constant curves, and the calculated Characteristic Acoustic Impedance curve. Table 5 lists the FWS logs, along with their units, minimum and maximum values, as well as average values (where applicable).

Table 5: FWS Log Details

Log Name	Units	Min Value	Max Value	Average Value
Compression Wave Slowness	µs/m	154	236	177
Shear Wave Slowness	µs/m	271	422	301
Compression Wave Velocity	m/s	4229	6488	5662
Shear Wave Velocity	m/s	2368	3693	3326
Poisson’s Ratio	-	0.116	0.3634	0.2359
Shear Modulus	MPa	15386	41044	30525
Young’s Modulus	MPa	41083	102132	75441
Bulk Modulus	MPa	26434	72057	47805
Characteristic Acoustic Impedance	Rayls (MKS)	$1.15*10^7$	$1.93*10^7$	$1.56*10^7$

The Semblance Plot is overlaid with the picked Compression Wave and Shear Wave slowness curves, which correspond to the two separate peak values shown in the Semblance Plot image. The corresponding Compression Wave Velocity and Shear Wave Velocity curves are overlaid for comparison. The Poisson’s Ratio curve is displayed next to the three overlain elastic constants curves, Shear Modulus, Young’s Modulus, and Bulk Modulus. Variations in the velocity curves and associated engineering property curves positively correlate to changes in the gamma-gamma density. Five spikes on Compression and Shear Wave Velocity curves correspond to spikes on Near and Far Density curves at 319 m bgs, 575-586 m bgs, 615-623 m bgs and 904-

910 m bgs, 988-991 m bgs where average Compression and Shear Wave Velocities changes 10% to 30%, accordingly. Also, there is a decrease in compression wave velocity at the depth of the metal wedge.

3.4.9 Mechanical Caliper

Caliper data is used to measure the average diameter of the borehole, showing voids, and open joints and fractures. Caliper data is necessary for accurate calculation of apparent structure dips, and for the determination of the borehole fluid velocity for the calculation of the acoustic caliper log.

The Mount Sopris 2PCA-1000 Mechanical Caliper probe uses three spring-driven arms, held against the borehole wall, to measure the average diameter of the borehole with depth. The short caliper arms were used given the diameter of the borehole. The caliper probe is run up from the bottom of the borehole such that the arms will expand into voids or fractures. The caliper probe is a combination tool with the fluid temperature / resistivity probe (FTR). The probe was checked for functionality prior to shipping to site and again once on site prior to use. Records of pre-use checks can be found in the pre-use Calibration and Verification Check Form, provided in Appendix A.

Before descending the probe into the borehole, the caliper was calibrated on surface using an associated calibration jig with two known diameters (6.1 cm and 10.2 cm), in accordance with ASTM standard D6167-11 (Section 8.2). The diameters of the calibration jig were recorded with the probe's response and the results were saved into the associated .TOL file and exported as a .TXT file for record keeping. Calibration values were also recorded in the Calibration and Verification Check Form, provided in Appendix A. Following the calibration, the probe was lowered into the borehole until level with the reference point, and the depth was corrected to report the depth below ground surface of the measurement point of the caliper portion of the combination tool. The probe was then descended the full depth of the borehole. The associated .TOL file was then selected, and the probe was activated. The full boot sequence was allowed, requiring 90 seconds as the caliper arms were opened, before the readings were valid. The probe was logged up from 430 m to 320 m as a QA/QC file. Once the QA/QC file was complete, the file was terminated, the probe arms were closed, and the probe was descended back to the bottom of the borehole. The primary caliper log was run up from the bottom of the borehole to 2.63 m (into the casing), at 2.5 m per minute, sampling every 1 cm.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent.

Once the probe was level with the reference point, it was turned from Depth Up mode to Time Mode and the probe was removed from the borehole with the arms still extended. It was then checked in the calibration jig against the same two known diameter values. Changes in temperature of the probe caused the reported values to drift over the course of the log by -0.02 cm on the high end. These values were used later in the processing stage to correct the caliper curve, by matching points of stable rock wall and casing to known diameter values.

The .TFD files were imported into WellCAD where the primary log compared favourably to the QA/QC log. For the primary log, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The log was shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, and acoustic caliper log. The log was depth matched with common features, to further refine the accuracy. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Mechanical Caliper curve is displayed on the Hydrogeology Log, in Appendix E and is overlaid with the Acoustic Caliper curve for comparison purposes. The borehole was drilled using a HQ drill bit with an outer diameter of 96.1 mm. The Mechanical Caliper log measured in mm through the borehole ranges from 90.18 mm to 108.33 mm, with an average value 98.63 mm. The Mechanical Caliper and Acoustic Caliper logs match well for their ranges, showing the same pattern along the length of the borehole.

3.4.10 Normal Resistivity, Self-Potential and Single Point Resistance

The Mount Sopris QL40 ELOG (resistivity) probe was used to collect a continuous record of the normal electrical resistivity, electrical resistance, and natural electrical potential of the borehole wall. The probe is comprised of 5 separate electrodes which are used to measure normal resistivity at 4 spacings (8 inch, 16 inch, 32 inch, and 64 inch). The tool also measures self-potential (SP), and single point resistance (SPR) between the uppermost electrode on the probe and a remote reference electrode installed at surface, in a shallow pit filled with bentonite mix located approximately 50 cm from the borehole. The resistivity probe is used with an electrically isolating bridle separating the probe from the wireline cable head.

The SP log provides a measure of the natural voltages within the borehole, which can be related to either electrochemical forces, such as differences in fluid electrical conductivities/salinities between the borehole fluid (flushed fluid) and the formation fluid and movement between the two, or electrokinetic forces, such as fluid flow from a fracture resulting in changes in hydraulic gradients. SP is measured between the 64” electrode and the armour of the probe near the wireline cable head.

The SPR log provides a qualitative indication of electrical resistance of the bedrock adjacent to the current electrode. The resistance measured represents the sum of the resistance between the surface reference electrode and the current electrode. Therefore, it is important to minimize the contact resistance of the surface electrode by seating it in a bentonite/clay mud cake and maintaining a constant temperature throughout the logging. The surface electrode was located within the warmed enclosure surrounding the borehole to maintain the temperature throughout the logging.

The QL40 ELOG was tested prior to use and calibrated using the ELOG calibration box with resistivities of 1 Ωm, 100 Ωm, 1,000 Ωm and 10,000 Ωm (ohm-metres). The record of calibration is provided in the Calibration and Verification Check Form.

Once the probe and bridle were connected to the wireline, the probe and bridle were lowered into the casing until the top of the bridle was flush with the reference point and the depth was corrected to report the depth of the bottom of the tool referenced to ground surface. Due to the multiple measurement points on the probe, the .TOL file determined the individual offsets of the electrodes automatically, using pre-determined channel shift values. The depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each electrode on the tool is outlined in the technical specifications and operator’s manuals, in Appendix B, and is recorded in the .STACK file QL40-GAMIP-5579.stack, which is included in Appendix D. The surface electrode was connected to the Matrix logging box. The probe was descended to a depth of 500 m and the tool was turned on, Depth Mode was selected, and the first log was started. The QA/QC log was recorded down from 500 m to 600 m. The probe was run at 3.0 m per minute, sampling every 0.05 m. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. Once the probe reached the bottom of the borehole, the second file was started, recording with the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent.

Once the bridle was level with the reference point, it was turned from Depth Up mode to Time Mode and the probe was removed from the borehole. It was then checked in the calibration box against the same known resistivity values. Changes in temperature of the probe caused minimal drift (<0.1%) over the course of the survey. The post-use calibration check values are recorded in the Calibration and Verification Check Form, in Appendix A.

The .TFD files were imported into WellCAD and the primary logs were compared to the QA/QC log to ensure repeatability. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. A formula was then applied to correct the recorded depth as described in Section 3.4. Once referenced to the corrected depth, the logs were exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they were compared with other geophysical logs, such as the optical televiewer image log, magnetic susceptibility log, and apparent conductivity log. The resistivity logs were depth matched with common features, to further refine the accuracy. The logs were merged into final Self Potential, Single-Point Resistivity, and 8”, 16”, 32”, and 64” Resistivity logs. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Resistivity, Self-Potential, Single Point Resistance curves are presented in the Lithology Log, included in Appendix E. The Self-Potential and SP Resistance curves are overlaid with the Apparent Conductivity curve for comparison purposes, while the 8”, 16”, 32”, and 64” Resistivity curves are displayed in logarithmic scale and overlaid with each other. The logs are shown in Table 6, along with their units, minimum and maximum values, as well as average and estimated background values (where applicable).

In general, the resistivity curve shows a steady decrease with depth, with numerous discrete downward spikes correlating to changes in lithology (e.g. 275-279 m, 575-586 m, 615-622 m, 905-908 m, 960-963 m, and 976-979 m) as observed in televiewer logs and core logging. Several of these spikes correlate with low neutron counts and high gamma-gamma density counts throughout the borehole. Also, there are downward spikes at the location of the metal wedge.

The self-potential curve shows variability over much of the borehole, with a general decreasing trend. Sudden spikes in the self-potential often correlate to changes in lithology, with a primary example at 277 m and 571-596 m. There are downward spike associated with the metal wedge.

Single-point resistance tends to decrease down the hole with small variations associated with slight decreases in resistivity. The metal wedge caused decreases in the measured resistance.

Table 6: ELOG Log Details

Log Name	Units	Min Value	Max Value	Average Value
Self-Potential	mV	-243	375	-5.94
Single Point Resistance	Ω	205	23,346	2,766
8” Resistivity	Ωm	275	25,613	6,275
16” Resistivity	Ωm	515	38,931	11,003
32” Resistivity	Ωm	1,174	86,083	19,326
64” Resistivity	Ωm	2,183	157,055	16,567

3.4.11 Spectral Gamma

The Mount Sopris 2SNA-1000 Spectral Gamma probe was used to measure the naturally occurring gamma radiation of distinct energy levels being emitted by the host rock, in order to derive the concentrations of Potassium (K), Uranium (U) and Thorium (Th) as well as their decay products. The logs are used for the identification of lithology, mineralogy and alterations. The probe consists of a scintillation sodium iodide crystal, which measures the incoming natural gamma radiation from the borehole walls and is resolved into a spectrum of energy levels associated with the specific radionuclides of Potassium, Uranium and Thorium. The gamma-emitting radio-isotopes that naturally occur in geologic materials are Potassium 40 and nuclides in the Thorium 232 and Uranium 238 decay series. Potassium 40 occurs with all potassium minerals including potassium feldspars. Thorium 232 is typically associated with biotite, sphene, zircon and other heavy minerals. Uranium 238 is typically associated granitoid rocks with uranium mineralization.

The spectral gamma probe was checked for functionality prior to shipping. The results of the functionality test are recorded in the pre-use Calibration and Verification Check Form, included in Appendix A.

Once the tool was connected to the wireline, the probe was powered up and checked for valid data. The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B.

The probe was descended to a depth of 400 m and turned on and the first log was started. The QA/QC log was recorded down 10% of the borehole depth, from 400 m to 500 m. The probe was run at 2.25 m per minute, sampling every 2.5 cm. Once the QA/QC log was complete, the first file was terminated, and the probe was descended to the bottom of the hole. The second file was started, logging up into the borehole at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe was level with the reference point, the second file was terminated, and the probe was deactivated and removed from the borehole.

The .TFD files were imported into WellCAD and the primary logs were compared to the QA/QC log to ensure repeatability. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes Once referenced to the corrected depth, the logs were exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where the logs were compared with other geophysical logs, such as the optical televiewer image log, and natural gamma log. The logs were depth matched with common features, to further refine the accuracy.

The K, U, and Th curves were generated through the WellCAD procedure for spectrum stacking over a 2-metre window, and a 10-metre window. To generate the individual curves an energy window of 1,360 keV to 1,560 keV was used for the K band, an energy window of 1,660 to 1,860 keV was used for the U band, and an energy window of 2,520 keV to 2,720 keV was used for the Th band, as described in the user’s manual for the probe (Appendix B) and which captures energy 100 keV either side of the peak associated with the band.
One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The Spectral Gamma curves are presented in the Lithology Log, included in Appendix E. The Spectral Gamma total counts curve is overlaid with the Natural Gamma curve for comparison purposes, while the stacked Potassium, Thorium, and Uranium counts logs are overlaid on each other. The Spectral Gamma logs are listed in, Table 7 along with their units, minimum and maximum values, as well as average and estimated background values (where applicable).

Table 7: Spectral Gamma Log Details

Log Name	Units	Min Value	Max Value	Average Value
Spectral Gamma	total cps	3.31	291.91	28.67
K – Stacked – 2m	cps	0.10	1.44	0.51
Th – Stacked – 2m	cps	0.00	0.20	0.03
U – Stacked – 2m	cps	0.00	0.54	0.13
K – Stacked – 10m	cps	0.29	1.01	0.51
Th – Stacked – 10m	cps	0.00	0.08	0.03
U – Stacked – 10m	cps	0.03	0.33	0.13

The Natural Gamma and Spectral Gamma total counts logs match well for their ranges, showing the same trends, spikes, and plateaus. The Natural Gamma values are on average 2.5 times higher than the Spectral Gamma total counts values, which is a result of counts falling outside the spectral energy classification window used during spectral gamma acquisition, as the Spectral Gamma probe filters out any counts with an energy level less than 100 keV. Trends in both the Natural Gamma and Spectral Gamma total counts logs match well for their respective ranges, showing the same pattern along the total depth of the borehole. In general, the total gamma counts curve is negatively correlated with the presence of biotite in the host tonalite, with interpreted biotite-rich layers appearing as relatively low gamma plateaus. Overall, the uranium and thorium curves show very low concentrations, however, the potassium curve appears to represent the bulk of the radioactive response.

3.4.12 Fluid Temperature and Resistivity

The Mount Sopris 2SFA-1000 Fluid Temperature / Resistivity probe (FTR) is part of a combination probe, forming the bottom end of the 3-arm mechanical caliper probe. The FTR is run down the borehole within the fluid and records the fluid temperature and electrical resistivity as the fluid passes through the tool.

Immediately prior to use, the probe was calibrated using two fluids of known resistivity (8.5 Ωm and 88.5 Ωm). The calibration values are recorded in the Calibration and Verification Check form, as well as the exported calibration text file, provided to NWMO.

The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point above ground surface, as measured during setup. The offset of the measurement point of each tool is provided in the probe specific .TOL file, and outlined in the technical specifications and operator's manuals in Appendix B.

Data logging began at the top of casing to obtain a complete profile of the borehole. Starting the log data in the air ensured that it recorded the transition between the air-filled portion and the fluid-filled portion of the borehole; a sharp change in resistivity and temperature indicates the top of static water level in the borehole. Temperature data in the air-filled portion reflects the ambient air temperature, however fluid resistivity values above the static water level are not valid. The primary log was recorded down at a speed of 4 m per minute, sampling every 5 cm.

As multiple logs for this probe were run there was no QA/QC log collected and data from various runs were compared for QA/QC purposes.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent. Once the probe was level with the reference point the recording mode was switched from Depth Down mode to Time Mode and removed from the borehole.

The probe was then checked in the same two fluids of known resistivity and the results recorded in the Calibration and Verification Check form. The probe values drifted by an average of 1 Ωm over the course of testing.

The .TFD files were imported into WellCAD where the primary logs compared favourably to the QA/QC log. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. Once referenced to the corrected depth, the logs were exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where the logs were compared with other geophysical logs, such as the optical televiewer image log, and FFEC logs. The logs were depth matched with common features, to further refine the accuracy. The Fluid Resistivity log was inverted to present Fluid Conductivity for comparison to FFEC logs. Fluid Resistivity Gradient and Temperature Gradient logs were created using the standard WellCAD formula. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, using formulae described in Section 3.4.1.2.

The final Fluid Temperature, Fluid Resistivity, and Static Fluid Conductivity curves are displayed on the Hydrogeology Log, in Appendix E. The FTR curves are overlaid with each other and are presented next to the FFEC logs, with log start time in minutes, for comparison purposes. The FTR logs are listed in Table 8, along with their units, minimum and maximum values, as well as average values. The Fluid Temperature curve shows a steady increase from approximately 10.6°C at the water table, to 15.5°C at the bottom of the borehole.

Table 8: FTR Log Details

Log Name	Units	Min Value	Max Value	Average Value
Fluid Temperature (T=516min)	°C	9.35	15.47	10.47
Fluid Resistivity (T=516min)	Ωm	5.13	117.10	61.34
Static Fluid Conductivity (T=516min)	mS/m	-0.21	194.85	47.79

3.4.13 Magnetic Susceptibility

Magnetic susceptibility data was collected to measure the magnetic susceptibility of the rock. The HM 320 Magnetic Susceptibility probe contains a two coil system and is used to measure the dimensionless magnetic susceptibility constant *K* of the rock mass, which indicates the degree to which it can be magnetized in the presence of a magnetic field.

The probe calibration was verified prior to use using the manufacturer-supplied calibration block of known magnetic susceptibility (0.02262×10^{-3} SI Units) and the null value in air. The results of the calibration are recorded in the Calibration and Verification Check form.

Once the probe's calibration was verified it was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point above ground surface, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator's manuals in Appendix B. The probe was descended to a depth of 400 m, turned on and the first log was started. The QA/QC log was recorded up the borehole for 10% of the borehole depth, from 400 m to 300 m. The probe was run at 4.5 m per minute, sampling every 5 cm. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. Once the probe reached the bottom of the borehole, the first file was terminated, and the second file was started, recording up at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent. Once the probe was level with the reference point, the final log was terminated, and the probe was turned from Depth Up mode to Time Mode and removed from the borehole.

The probe was then checked in the calibration block and in air and the results recorded in the Calibration and Verification Check form. The probe values drifted by an average of 0.65×10^{-3} SI Units over the course of testing.

The .TFD files were imported into WellCAD where the primary logs compared favourably to the QA/QC log. For the primary logs, an interpolation function was applied to remove data spikes and gaps larger than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes, and the noted depth loss from the odometer wheel error was corrected based on the short repeat log. Once referenced to the corrected depth, the logs were exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where the logs were compared with other geophysical logs, such as the optical televiewer image log, natural gamma log, apparent conductivity log, and resistivity logs. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Magnetic Susceptibility curve is presented in the Lithology Log, included in Appendix E. Magnetic susceptibility is presented as SI unitless values), and ranges from -3.47×10^{-3} SI to 40.43×10^{-3} SI, with an average value of 0.58×10^{-3} SI.

In general, the magnetic susceptibility curve is flat, with sharp positive spikes associated with lithology change. The most prominent spikes associated with high biotite tonalites and amphibolite lenses at depth intervals of 489 to 595 m, 704 to 722 m, 722 to 738 m, 748 m, 856 to 870 m. The metal wedge also causes drastic swings in values.

3.4.14 Heat-Pulse Flowmeter

Fluid flow along borehole is useful for inferring where changes in hydraulic head are occurring, where water-bearing fractures are located, and whether systems of joints and fractures are hydraulically connected in proximity to the borehole. The Mount Sopris HFP-2293 Heat-Pulse Flow Meter probe (HPFM) was used to measure the vertical rate of fluid flow in a borehole by collecting data at discrete points along the borehole while the probe is motionless in the water column. The probe uses a rubber skirt to divert all flow at one horizon in the water column through the annulus of the probe, which it marks with a pulse of heat. Two thermistors, one located above and one below the annulus, are used to calculate the velocity and direction of motion of the heated water. This velocity is converted, using a calibration formula, into a flow rate. The probe is factory calibrated and is re-calibrated in the event it is sent for repair. The HPFM is designed to measure low flow conditions, from 0.113 to 3.785 litres per minute. The probe specifications note that the accuracy of the probe is within 5% of the actual flow rate in the mid measuring range, and within 15% at the extremes of the measuring range.

The HPFM was checked for functionality prior to shipping and again prior to use while on site. The pre-use checks are recorded in the pre-use Calibration and Verification Check form. The probe was also tested in the borehole under pumping conditions to simulate flow of known magnitude, and the results of the test are recorded in the Calibration and Verification Check form. All pre-use test results are reported in Appendix A.

An HQ diverter and centralizer were attached to the probe and it was connected to the wireline. The Matrix Heat software was started and the associated .TOL file was selected. The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Matrix Heat program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point above ground surface, as measured during setup. The offset of the measurement point of each tool was outlined in the technical specifications and operator's manuals in Appendix B. The probe was then descended below the static water level and powered up. When the static water level was above the bottom of the casing, two measurements were taken within the casing to ensure good response in a zero-flow condition.

The initial HPFM testing was conducted under static conditions. A standardized measurement interval of 20 m was used to sample the flow in the borehole. Three separate records of 45 seconds each were gathered from each depth to ensure repeatability. After static testing, a Grundfos submersible pump was lowered into the borehole to 48.0 m bgs. A drawdown to 35 m was created to conduct the HPFM testing under pumping/dynamic conditions. A standardized measurement interval of 20 m was used to sample the flow in the borehole; however, sampling interval was reduced to 10 m and 5 m and 1 m at the depth where any flow would occur to better locate the source of the potential flow. Measurement of flow while pumping with the HPFM in the casing was used to check the operation of the HPFM and ensure the diverters were working properly to divert flow through the probe.

Responses observed outside the first 45 seconds can be attributed to the thermal movement of the heated slug of water and are not considered true flow measurements. The MatrixHeat manual (Appendix B) indicates that there is generally no useable data beyond 25 seconds.

Data was recorded as .MH files (ALT proprietary format). Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the data had been gathered, the file was saved in Matrix Heat and the probe was powered down and ascended to the next measurement depth.

All the data files (.MH) were reviewed for consistency in pulse time picks, then the depths and flow values were exported as .CSV files. The .CSV file was reviewed manually to remove duplicate entries, which were the result of small (mm) changes in reported probe depth. Flow rates were converted from US gallons per minute to litres per minute. The separate .CSV files were combined to generate one single file.

The .CSV file was then imported into one common WellCAD file where the log was compared with other geophysical logs, such as the optical televiewer image log, FFEC logs, and modelled dynamic flow values. Flow values ranged from 0.32 L/min to 0.99 L/min to a depth of 600 m. After 600 m no flow was detected. The final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2.

The final Heat-Pulse Flow Meter (HPFM) data is presented in the Hydrogeology Log, included in Appendix E. It is presented as the Heat-Pulse Static Flow curve, in litres per minute, with indicators at each discrete sample depth. In testing of the open portion of the borehole no static flow was detected with the HPFM run, thus the curve is set to 0 L/min. The Heat Pulse Static Flow curve is overlaid on the FFEC Model Dynamic Flow curve for comparison purposes.

3.4.15 Borehole Deviation

To be able to correct apparent structures to true dip and dip direction, as well as to understand the overall tilt and azimuth of the borehole, multiple deviation logs were collected. These logs were compared to each other to identify and mitigate possible sources of error.

Borehole deviation data were recorded in IG_BH04 using tilt and azimuth information from the optical and acoustic televiewer logs. The tilt and azimuth logs were collected with the same setup procedure as outlined in Section 3.4.5.2, logging the complete borehole down at 15 m per minute, sampling every 5 cm, as well as up at 4 m per minute, sampling every 1.6 mm. In total there were two acoustic and two optical televiewer logs created and used to calculate the trajectory of the borehole from ground surface to the bottom of hole (Table 9). The average azimuth and tilt for the upper 100 m of the borehole were provided by NWMO and also used to create a complete average of the values for the length of the borehole.

The individual Tilt and Azimuth logs were filtered using a 3-point moving window filter to remove data spikes and interpolated over gaps less than 1 m to remove data blanks. Distortion of the azimuth logs caused by the metallic casing was trimmed.

For the interval between 100 m and the bottom of the borehole, tilt and azimuth logs from each of the completed televiewer runs were combined into a single set of logs by calculating an average of the logs on a point-by-point basis. Once the average deviation logs for the interval from 100 m to the bottom of the borehole were generated, they were merged with the upper 100 m deviation logs to produce a continuous set of deviation logs. The final Azimuth log was rotated 1.361° to correct for the local magnetic declination, in order to reference it to True North.

The averaged Tilt and Azimuth (True North referenced) logs were used to calculate approximate Easting and Northing displacement of the hole from the collar, as well as the True Vertical Depth below ground surface. These values were used to plot the preliminary trajectory of the borehole shown in a Bull's Eye plot in the header of the Deviation Log included in Appendix E. The individual logs are listed in Table 9, along with their logging direction, sampling rates, units, minimum and maximum values, as well as average values (where applicable).

Table 9: Deviation Log Details

Log Name	Sampling Rate (m)	Units	Min Value	Max Value	Average Value
ABI Azimuth 10-7	0.05	Deg	99.07	116.04	108.59
OBI Azimuth 09-3+09-04	0.032	Deg	99.69	115.45	107.78
OBI Azimuth 09-05	0.016	Deg	101.35	113.49	107.99
ABI Azimuth 10-08+10-09+10-10	0.002	Deg	100.80	115.70	110.06
Wood Average Azimuth	0.1	Deg	109.76	113.21	111.74
ABI Tilt 10-7	0.05	Deg	19.60	28.38	24.79
OBI Tilt 09-3+09-04	0.032	Deg	19.49	28.55	24.89
OBI Tilt 09-05	0.016	Deg	19.78	28.46	24.94
ABI Tilt 10-08+10-09+10-10	0.002	Deg	20.01	28.40	25.03
Wood Average Tilt	0.1	Deg	20.75	21.46	21.06

The Deviation curves are presented in the Deviation Log, included in Appendix E. The various azimuth and tilt curves are overlaid with each other for comparison. The averaged azimuth log, corrected from High Side to True North (TN), and the averaged tilt log are also presented (Table 10). From the Average Azimuth TN and Tilt Average logs the Northing, Easting and True Vertical Depth (TVD) logs are calculated and presented in Table 11. The TVD log is used to calculate the Elevation log and the two are presented as depth column logs. The Easting and Northing logs are overlaid and presented beside curves showing the semi-major axis of the error ellipses calculated by WellCAD, based on the tilt and azimuth uncertainty values (±0.5° of tilt, ±1.2° of azimuth) found in the user manual for the televiewer probes, included in Appendix B. Error ellipses, also known as footprints, are an expression of the uncertainty of the measurement on the calculation of position along the borehole. The WellCAD algorithm is based on a probabilistic approach, meaning that the higher sampling of orientation measurements leads to less overall uncertainty and smaller ellipses, denoted by small semi-major axis values.

Table 10: Details of the Averaged Deviation Log

Log Name	Units	Min Value	Max Value	Average Value
Azimuth Average TN	Deg	102.37	113.21	108.92
Tilt Average	Deg	19.91	28.22	24.84

Table 11: Results of Eastings, Northings, and True Vertical Depth (TVD) Recorded at Bottom of Borehole

Log Name	Units	Total Value
Easting	m	392.47
Northing	m	-144.27
TVD	m	904.51

3.4.16 Posiva Flow

The Posiva Flow logging was completed by Posiva under the supervision of Golder.

The Posiva Flow Log uses a flowmeter that incorporates a flow guide and can be used to obtain relatively quick measurements of hydraulic conductivity and equivalent freshwater hydraulic head of fractures/fractured zones in boreholes.

The applied section lengths of the flow guide were 5 m and 0.5 m. Flow into the borehole or from the borehole to the bedrock was measured within the section length. The measurements were carried out in pumped and in natural (i.e. un-pumped) conditions. The transmissivity (T) and equivalent freshwater hydraulic head (h) of zones were calculated from the obtained flow and pressure results.

Four water flowing fractures were identified during the Posiva Flow Logging. Fractures were identified at depths of 113.7m, 580.9 m, 616.5m and 620.6 m along the borehole. The largest flow was encountered at a depth of 580.9m, where flow was 1,900 mL/hr in unpumped conditions and 44,700 mL/hr while pumped drawdown was approximately 13 metres in the borehole. The highest transmissivity, also at a depth of 580.9m, was calculated to be $9.97*10^{-7}$ m^2/s. The complete Posiva report presenting the testing, interpretation and results is provided in Appendix G.

4.0 REFERENCES

ALT (Advanced Logic Technology), 2011. WellCAD User Manual Section 4.1.8 Computing Rock Mechanical Parameters

ASTM D5753-18, 2018. Standard Guide for Planning and Conducting Geotechnical Borehole Geophysical Logging, ASTM International, West Conshohocken, PA, www.astm.org.

ASTM D6167-11, 2011. Standard Guide for Conducting Borehole Geophysical Logging: Mechanical Caliper, ASTM International, West Conshohocken, PA, www.astm.org.

ASTM D6274-10, 2010. Standard Guide for Conducting Borehole Geophysical Logging - Gamma, ASTM International, West Conshohocken, PA, www.astm.org.

ASTM D6726-15, 2015. Standard Guide for Conducting Borehole Geophysical Logging—Electromagnetic Induction, ASTM International, West Conshohocken, PA, www.astm.org.

ASTM D6727 / D6727M-16, 2016. Standard Guide for Conducting Borehole Geophysical Logging—Neutron, ASTM International, West Conshohocken, PA, www.astm.org.

Blackburn, C.E. and Hinz, P., 1996. Gold and base metal potential of the northwest part of the Raleigh Lake greenstone belt, northwestern Ontario-Kenora Resident Geologist's District; in Summary of Field Work and Other Activities 1996, Ontario Geological Survey, Miscellaneous Paper 166, p.113-115.

DesRoches, A., Sykes, M., Parmenter, A. and Sykes, E., 2018. Lineament Interpretation of the Revell Batholith and Surrounding Greenstone Belts (Nuclear Waste Management Organization). No. NWMO-TR-2018-19.

Golder (Golder Associates Ltd.) 2021a. Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06, Ignace Area. Borehole Characterization Plan for IG_BH04. NWMO APM-REP-01332-0369.

Golder (Golder Associates Ltd.), 2021b. Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06, Ignace Area. WP02 Data Report - Borehole Flushing for IG_BH04. NWMO APM-REP-01332-0278

Golder (Golder Associates Ltd.), 2022a. Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06, Ignace Area. WP06 Data Report - Hydraulic Testing for IG_BH04. NWMO APM-REP-01332-0280.

Golder (Golder Associates Ltd.), 2022b. Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06, Ignace Area. WP07 Data Report – Opportunistic Groundwater Sampling for IG_BH04. NWMO APM-REP-01332-0281.

Golder (Golder Associates Ltd.) and PGW (Paterson Grant and Watson Ltd.), 2017. Phase 2 Geoscientific Preliminary Assessment, Geological Mapping, Township of Ignace and Area, Ontario.

OGS (Ontario Geological Survey), 2011. 1:250 000 scale bedrock geology of Ontario, Ontario Geological Survey, Miscellaneous Release Data 126 - Revision 1.

Paillet Frederick L., 2012.A mass-balance code for the quantitative interpretation of fluid column profiles in ground-water studies. Computers and Geosciences Volume 45 (2012), pages 221 to 228.

Paillet, Frederick L., Williams, John H., Romanowicz, Edwin A., 2010. Comparison of Borehole Flow Measurements Obtained by Heat Pulse Flowmeter and Dilute Logging in Fractured Bedrock Aquifer. Published in the Proceedings of the 23rd Symposium on the Application of Geophysics to Engineering and Environmental Problems, 2010.

Parmenter, A., Waffle, L. and DesRoches, A., 2020. An updated bedrock geology map and geological database for the northern portion of the Revell batholith (No. NWMO-TR-2020-08). Nuclear Waste Management Organization.

SGL (Sander Geophysics Limited), 2015. Phase 2 Geoscientific Preliminary Assessment, Acquisition, Processing and Interpretation of High-Resolution Airborne Geophysical Data, Township of Ignace, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06145-0002.

SRK (SRK Consulting, Inc). and Golder, 2015. Phase 2 Geoscientific Preliminary Assessment, Observation of General Geological Features, Township of Ignace, Ontario. Prepared for Nuclear Waste Management Organization. NWMO Report Number: APM-REP-06145-0004.

Stone, D., 2009. Geology of the Bending Lake Area, Northwestern Ontario; in Summary of Field Work and Other Activities 2009. Ontario Geological Survey. Open File Report 6240.

Stone, D., 2010a. Geology of the Stormy Lake Area, Northwestern Ontario; in Summary of Field Work and Other Activities 2010. Ontario Geological Survey, Open File Report 6260.

Stone, D., 2010b. Precambrian geology of the central Wabigoon Subprovince area, northwestern Ontario. Ontario Geological Survey, Open File Report 5422.

Stone, D., Halle, J. and Chaloux, E., 1998. Geology of the Ignace and Pekagoning Lake Areas, Central Wabigoon Subprovince; in Summary of Field Work and Other Activities 1998, Ontario Geological Survey, Misc. Paper 169.

Stone, D., Davis, D.W., Hamilton, M.A. and Falcon, A., 2010. Interpretation of 2009 Geochronology in the Central Wabigoon Subprovince and Bending Lake Areas, Northwestern Ontario, in Summary of Field Work and Other Activities 2010, Ontario Geological Survey, Open File Report 6260

APPENDIX A

Calibration and Verification Forms, Data Quality Confirmation Forms, Pre-Use Check Forms

----
CALIBRATION REPORT : MSI1-GAM_FTC_6327

Name : EHT
Source : GR
Alias : EHT
Units : Volts
Calibration Date : 25/02/21 12:52
Calibration Type : Linear - 2 pts
CalA : -3.95513
CalB : 0
Reference1 : 0
Reference2 : -1093
Value1 : -0
Value2 : 276.35

Name : GR
Source : MChProc
Alias : GR
Units : cps
Calibration Date :
Calibration Type : GR
CalA : 1
CalB : 0
Reference1 : Background
Reference2 : Background + 0 cps
Value1 : 0
Value2 : 0

Name : Vinj
Source : FTC
Alias : Vinj
Units : V
Calibration Date : 09/02/17 14:26
Calibration Type : Linear - 2 pts
CalA : 1.16491e-006
CalB : -0.0139841
Reference1 : 9.258
Reference2 : 0
Value1 : 7.9594e+006
Value2 : 12004.4

Name   : Iinj
Source : FTC
Alias   : Iinj
Units   : mA
Calibration Date   : 09/02/17 12:37
Calibration Type   : Linear - 2 pts
CalA   : 7.51732e-006
CalB   : -0.000768271
Reference1   : 89.9
Reference2   : 0
Value1 : 1.19592e+007
Value2 : 102.2

Name   : DV1
Source : FTC
Alias   : DV1
Units   : V
Calibration Date   : 09/02/17 12:37
Calibration Type   : Linear - 2 pts
CalA   : 5.49207e-007
CalB   : -0.000161385
Reference1   : 3.105
Reference2   : 0
Value1 : 5.6539e+006
Value2 : 293.851

Name   : DV2
Source : FTC
Alias   : DV2
Units   : V
Calibration Date   : 09/02/17 12:37
Calibration Type   : Linear - 2 pts
CalA   : 5.45127e-007
CalB   : -3.67688e-005
Reference1   : 3.094
Reference2   : 0
Value1 : 5.67581e+006
Value2 : 67.45

Name   : Temp
Source : FTC

```
Alias   : Temp
Units   : 'C
Calibration Date        : 09/02/17 14:26
Calibration Type        : Linear - 2 pts
CalA    : 0.00389412
CalB    : -277.873
Reference1      : 7.3
Reference2      : 73.6
Value1  : 73231.7
Value2  : 90257.4
------------------------------------------------------------------------

Name    : Cond
Source  : MChProc
Alias   : Cond
Units   : uS/cm
Calibration Date        : 09/02/17 14:26
Calibration Type        : Linear - 2 pts
CalA    : 1.56809
CalB    : -2.39163
Reference1      : 5220
Reference2      : 122
Value1  : 3330.41
Value2  : 79.3267
------------------------------------------------------------------------

Name    : Cond25C
Source  : MChProc
Alias   : Cond25C
Units   : uS/cm
Calibration Date        : 25/01/16 10:53
Calibration Type        : Linear - 2 pts
CalA    : 1
CalB    : 0
Reference1      : 1
Reference2      : 0
Value1  : 1
Value2  : 0
------------------------------------------------------------------------
```

CALIBRATION REPORT : MSI1-GAM_FTC_6327

Name : EHT
Source : GR
Alias : EHT
Units : Volts
Calibration Date : 29/04/21 18:44
Calibration Type : Linear - 2 pts
CalA : -3.95513
CalB : 0
Reference1 : 0
Reference2 : -1093
Value1 : -0
Value2 : 276.35

Name : GR
Source : MChProc
Alias : GR
Units : cps
Calibration Date :
Calibration Type : GR
CalA : 1
CalB : 0
Reference1 : Background
Reference2 : Background + 0 cps
Value1 : 0
Value2 : 0

Name : Vinj
Source : FTC
Alias : Vinj
Units : V
Calibration Date : 09/02/17 14:26
Calibration Type : Linear - 2 pts
CalA : 1.16491e-006
CalB : -0.0139841
Reference1 : 9.258
Reference2 : 0
Value1 : 7.9594e+006
Value2 : 12004.4

Name : Iinj
Source : FTC
Alias : Iinj
Units : mA
Calibration Date : 09/02/17 12:37
Calibration Type : Linear - 2 pts
CalA : 7.51732e-006
CalB : -0.000768271
Reference1 : 89.9
Reference2 : 0
Value1 : 1.19592e+007
Value2 : 102.2

Name : DV1
Source : FTC
Alias : DV1
Units : V
Calibration Date : 09/02/17 12:37
Calibration Type : Linear - 2 pts
CalA : 5.49207e-007
CalB : -0.000161385
Reference1 : 3.105
Reference2 : 0
Value1 : 5.6539e+006
Value2 : 293.851

Name : DV2
Source : FTC
Alias : DV2
Units : V
Calibration Date : 09/02/17 12:37
Calibration Type : Linear - 2 pts
CalA : 5.45127e-007
CalB : -3.67688e-005
Reference1 : 3.094
Reference2 : 0
Value1 : 5.67581e+006
Value2 : 67.45

Name : Temp
Source : FTC

Alias : Temp
Units : 'C
Calibration Date : 29/04/21 18:44
Calibration Type : Linear - 2 pts
CalA : 0.00329627
CalB : -230.75
Reference1 : 8
Reference2 : 36
Value1 : 72430.4
Value2 : 80924.8

Name : Cond
Source : MChProc
Alias : Cond
Units : uS/cm
Calibration Date : 29/04/21 18:27
Calibration Type : Linear - 2 pts
CalA : 1.56809
CalB : -2.39163
Reference1 : 57
Reference2 : 29500
Value1 : 37.8751
Value2 : 18814.2

Name : Cond25C
Source : MChProc
Alias : Cond25C
Units : uS/cm
Calibration Date : 25/01/16 10:53
Calibration Type : Linear - 2 pts
CalA : 1
CalB : 0
Reference1 : 1
Reference2 : 0
Value1 : 1
Value2 : 0

```
-----------------------------------------------------------------------
CALIBRATION REPORT : 2PCA-F Caliper S/N: 5032
-----------------------------------------------------------------------

Name    : Caliper
Source  : MChProc
Alias   : Caliper
Units   : cm
Calibration Date        : 02/05/21 14:24
Calibration Type        : Linear - 2 pts
CalA    : 0.00880204
CalB    : -27.0873
Reference1      : 10.2
Reference2      : 15.2
Value1  : 4236.21
Value2  : 4804.26
-----------------------------------------------------------------------
```

NWMO IGNACE DRILLING - DATA QUALITY CONFIRMATION (REV 0)

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DAILY INSTRUMENT CALIBRATION FORM FOR WP05
20253946 (4050)
Form No.: NWMO-IGNACE-20253946-WP02-F007

Borehole	IG_BH04

Calibration by: P.Leith
Calibration date and time: 2021-05-04 22:02

Calibration Details

Instrument / Serial Number	Parameter	Units	Calibration Standard		Measured Value	Calibration Required?	Calibration Performed?	Measured Value after Calibration
			Lot No. / Exp. Date	Target Measurement				
AquaFluor	Fluorescein Concentration	ppb	1F0652 Sept-2022	-	-	-	-	-
Horiba U-52	pH	-	0GH332 Aug-2021	4	3.97	N	Y	4
	Conductivity	mS/cm	0GH332 Aug-2021	4.49	4.9	N	Y	4.5
	Turbidity	NTU	0GH332 Aug-2021	0	0	N	Y	0
Hydrometer	Density	API Gravity	-	-	-	-	-	-
Analytical Scale	Mass	mg	-	-	-	-	-	-
Refrigerator	Temperature	°c	-	-	-	-	-	-

Horiba requires manual calibration (Y/N)? N If yes and not performed under WP07, see WP02 Horiba Calibration Form.

Notes (include any additional instrument calibration checks):
Monitor refrigerator temperature throughout day-shift and night-shift

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EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*MECHANICAL CALIPER*
Serial Number	*2649*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
cm	15.2	15.25	0.02
cm	10.2	10.28	0.08

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked using calibration jig. 2PCA_Caliper_2649_03112021.tfd Caliper cal file: Caliper_2649_Calibration_03112021.txt

Olga Fomenko	OAFomenko	March 11, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*MECHANICAL CALIPER*
Serial Number	*4354*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
cm	15.2	15.2	0
cm	10.2	10.05	0.15

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked using calibration jig. 2PCA_Caliper_4354_03112021.tfd Caliper cal file: Caliper_4354_Calibration_03112021.txt

Olga Fomenko	OAFomenko	March 11, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*MECHANICAL CALIPER*
Serial Number	*5032*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
cm	15.2	15.18	0.02
cm	10.2	10.2	0

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked using calibration jig. 2PCA_Caliper_5032_03112021.tfd Caliper cal file: Caliper_5032_Calibration_03112021.txt

Olga Fomenko	OAFomenko	March 11, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2PGA NATURAL GAMMA*
Serial Number	*2622*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
CPS	n/a - air	18-25	n/a
CPS	n/a - bentonite clay	50-60	n/a

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench. Background response and bentonite clay bag response. 2PGA 2622_03112021.tfd

OAFomenko

Olga Fomenko		March 11, 2021
Calibration Operator	Signature	Date

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EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2PIA2PGA STACK NATURAL GAMMA+ APPARENT CONDUCTIVITY*
Serial Number	*2622+2618*
Date	*MARCH 23, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
mS	0	-7	-7
mS	463	456	7

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench using calibration ring. App Conductivity check, Probe was not acclimatized in water. 2PGA2PIA_2618_Conductivity_03232021.tfd

OAFomenko

Olga Fomenko		March 23, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2PIA APPARENT CONDUCTIVITY*
Serial Number	*2618*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
mS	0	-10	-10
mS	1752	1739	13

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench using calibration ring. 2PIA_2618_03112021.tfd 2PIA_Conductivity_2618_03112021.txt cal file

Olga Fomenko	OAFomenko	March 11, 2021
Calibration Operator	Signature	Date

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EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2SFA FLUID TEMPERATURE/ RESISTIVITY*
Serial Number	*4380*
Date	*APRIL 7, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
OHM*M	19.8	19.4	0.4
OHM*M	87.71	86.69	1.02
C DEG	16.01	12.7	3.31

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench using 2 conductivity solutions and horiba. (Horiba checked: conductivity solution 0.503 mS/cm Conductivity solution 0.114mS/cm) 2SFA_4380_Calibration_04072021.txt Temperature not calibrated

Olga Fomenko	OAFomenko	April 7, 2021
Calibration Operator	Signature	Date

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada
T: +1 905 567 4444 F: +1 905 567 6561

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2SNA SPECTRAL GAMMA*
Serial Number	*4116*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
CPS	n/a - air	4-10	n/a
CPS	n/a - bentonite clay	18-23	n/a

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench . Background response and bentonite clay bag response. 2SNA_4116_03112021.tfd

Olga Fomenko — OAFomenko — March 11, 2021

Calibration Operator — Signature — Date

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EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*ABI 2G ACOUSTIC TELEVIEWER*
Serial Number	*190404*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
DEG ROLL / AZI	0	0.2 / 359.8	0.2 / -0.2
DEG ROLL / AZI	180	179.2 / 181.6	0.8 / 1.6
DEG ROLL	270	271.2 / 271.3	1.2 / 1.3
DEG TILT	0	1.1	1.1
DEG TILT	90	90.1	0.1

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked using calibration jig on bench.

OAFomenko

Olga Fomenko		March 11, 2021
Calibration Operator	Signature	Date

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EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*NORMAL RESISTIVITY, INDUCED POTENTIAL ELOG/IP*
Serial Number	*5579*
Date	*APRIL 19, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
Ohm*m	1	0.3-0.9	0.7-0.1
Ohm*m	100	103-106	3-6
Ohm*m	1000	1019	19
Ohm*m	10000	10003	3

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
QL_IP_5579_Normal_Res.tfd IP_5579_calibration_190421.txt

Olga Fomenko	OAFomenko	April 19, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*QLGAM ATV STACK*
Serial Number	*6752+190404*
Date	*APRIL 7, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
cps	n/a - air	33.7	n/a
cps	n/a - bentonite clay	51.68	n/a

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench. Background response and bentonite clay bag response. Factory (MSI) calibrated. QLGR6752_ATV190404_Gamma_040721.tfd

Olga Fomenko — OAFomenko — April 7, 2021

Calibration Operator — Signature — Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*QL40 HMI INDUCTION MAGNETIC SUSCEPTIBILITY*
Serial Number	*6766*
Date	*APRIL 7, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
mS/m	1000	983.81	-16.19
mS/m	200	223.67	23.67

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench Inside the building, not acclimatized in water. Factory (MSI) cal on march 22,2021. Could not check MagSusc properly as there is a lot of metal around. HMI_6766_Conductivity.tfd HMI_6766_Mag Sus.tfd

Olga Fomenko	OAFomenko	April 7, 2021
Calibration Operator	Signature	Date

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EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*OBI 2G OPTICAL TELEVIEWER*
Serial Number	*160403*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
DEG ROLL / AZI	90	90.3 / 93.1	0.3 / 0.1
DEG ROLL / AZI	180	180.1 / 182.4	0.8 / 0.4
DEG ROLL	270	270.4 / 268.7	1.2 / -1.3
DEG TILT	0	0.9	0.9
DEG TILT	90	90.1	0.1
Image Colour	Colour Wheel	Recorded File	n/a – Image quality passed

Calibration Results: ☒ Passed Check

☐ Needs Recalibration

Testing Notes
Probe checked using calibration jig on bench and colour wheel. Files saved for each of the tests for reference.

Olga Fomenko	OAFomenko	March 11, 2021
Calibration Operator	Signature	Date

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada T: +1 905 567 4444 F: +1 905 567 6561

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*4MXC-1000*
Serial Number	*1699*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
METERS	0.00	0.00	0
METERS	1.00	1.00	0

Calibration Check Results: ☒ Passed Check

☐ Needs Recalibration

Testing Notes
Winch was inspected and odometer checked by spooling out 1m of cable, as measured using a tape measure, and compared to values measured through software.

Olga Fomenko	OAFomenko	March 11, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*4MXC-1000*
Serial Number	*2323*
Date	*MARCH 11, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value	Difference
METERS	0.00	0.00	0
METERS	1.00	1.00	0

Calibration Check Results: ☒ Passed Check

☐ Needs Recalibration

Testing Notes
Winch was inspected and odometer checked by spooling out 1m of cable, as measured using a tape measure, and compared to values measured through software.

Olga Fomenko		March 11, 2021
Calibration Operator	Signature	Date

d:_golder files\calibration\calibration check - winch 4mxc-1000 sn2323 11mar2021.docx

Certificate of Calibration: Mount Sopris Instruments

Tests performed by: Steve Phung

Probe Identification: HFP-2

Company Name: TerraPlus

Calibration Numbers for HFP-2293 Serial Number 4736

LINE	Delta Time	Delta Time	Flow	Flow
UP	10.0	.800	.03	1.0
DN	10.95	.700	-.03	-1.0

08-20-2020

TOOL CERTIFICATE

Advanced Logic Technology

Product type : QL40-FWSM-1TX-4RX

Serial Number : 210306

Build date : Feb-2021

Sonic sensors		
Serial Numbers :	Spacer :	210211
	Tx :	203918
	Rx1 :	203913
	Rx2 :	203920
	Rx3 :	203919
	Rx4 :	203917
Test :	Tool accoustic conduction	

Cartridge			
Serial Number :	210306		
Tests :	Current consumption :	40 mA	
	Main voltage input :	120 V	

Final test			
Tests :	Burn-in (1 night)		
	Telemetry tests on reference winch :	Cable Length	Baud rate
	Mono Cond. 1/8"	1500m	125kb/s
	4 Cond 3/16"	480m	500kb/s
	Field test		
	Open hole :	Velocity analysis	
	Cased hole :	CBL	

Calibration Responsible :

Validation by :

Date : 08.02.2021

ALT sa. Bâtiment A, Route de Niederpallen, L-8506 Redange-sur-Attert Luxembourg
T:(352)23 649 289 F:(352)23 649 364 e-mail: sales@alt.lu RCS:2001-22 10559 VAT: LU18773332

MOUNT SOPRIS
INSTRUMENTS

MOUNT SOPRIS INSTRUMENTS
4975 East 41st Avenue
Denver, CO 80216
Phone: 303-279-3211

TOOL CERTIFICATE

Product type : QL40-HM-453

Build date : 3/22/2021

Probe			
Serial Number :	6766		
Model :	QL40-HM-453		
Part Number :	Q40IND-1000		
Tele PSU Firmware :	Version 1.8		
Gen CPU Firmware :	Version 1.50		
Tests :	Current consumption	35 mA (NOM)	☑
	Voltage at test	120 V	☑
	Pressure test	200 bar (2900 psi)	☑

Receiver Coils	
Receiver Spacing from Tip (cm)	Mag Sus: 32
	Induction: 118

Tests :		Mag Sus			Conductivity	
		0	5.6*10^-3		Low Conductivty Ring (mS/m)	High Conductivity Ring (mS/m)
		Low Mag-Sus Puck	High Mag-Sus puck		200	1000
	CPS	529.58	1314.33	CPS	1287.13	4285.16

Final Test				
Burn-in (24 hours)			☑	
Telemetry tests on reference cable	***Cable length***		***Baud rate***	
Mono Cond. 1/8"	1500	meters	☑ 41.6 kb/s	☑ 166 kb/s
4 Cond. 3/16"	1850	meters	☑ 41.6 kb/s	☑ 166 kb/s
Logged in MSI test well			Yes / No	
Logged in offsite test location			Yes / No	
Probe stack configurations:	QL40GR + QL40HMI			

Calibration By: NGOC NGUYEN Date: 3/23/21

Validation By: Steve Phung Date: 3/23/2021

MOUNT SOPRIS
INSTRUMENTS

MOUNT SOPRIS INSTRUMENTS
4975 East 41st Avenue
Denver, CO 80216
Phone: 303-279-3211

TOOL CERTIFICATE

Product type : QL40-GR
Build date : 2/23/21
ASTM Standard: *Calibrated in general accordance with ASTM Standard D6274-10*

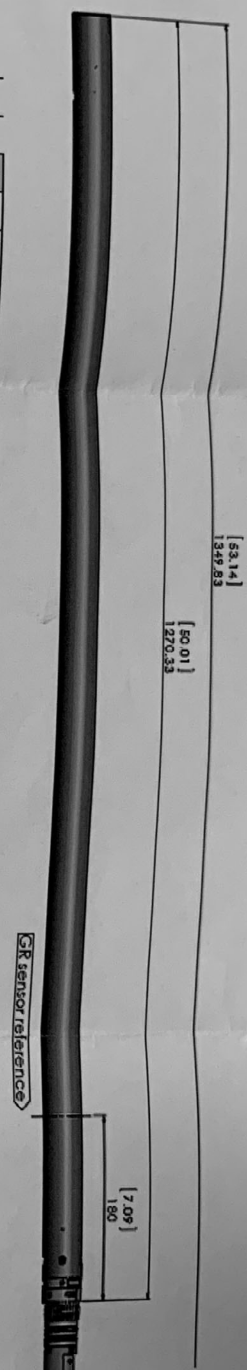
Probe	
Serial Number :	6752
Model :	QL40-GR
Part Number :	Q40GRA-1000
Tele PSU Firmware :	Version 1.8
Gen CPU Firmware :	Version 1.50

Tests :	Current consumption	35 mA (NOM)	☑
	Voltage at test	120 V	☑
	Pressure test	200 bar (2900 psi)	☑

Gamma Detectors	
Serial Number (Crystal) :	111420F
Serial Number (PMT) :	103283

Tests :	Calibration of the GR - Coefficient (CPS to API)		Performed by:	
	Crystal Type	NaITI	Dimension	2.2 x 7.6 cm (0.875 x 3 in)
	Uranium source high CPS test (SN: 2)	49,837 cps		
	High voltage plateau setting	- 1085 VDC		
	Thorium source API test (SN: 2015)	API		

Final Test			
Burn-in (24 hours)		☑	
Telemetry tests on reference cable	***Cable length***	***Baud rate***	
Mono Cond. 1/8"	1500 meters	☑ 41.6 kb/s	☑ 166 kb/s
4 Cond. 3/16"	1800 meters	☑ 41.6 kb/s	☑ 166 kb/s
Logged in MSI test well		Yes / No	
Logged in offsite test location		Yes / No	
Probe stack configurations: GR-TCP			
CAL-GR-TCP			



Calibration By: Jake Mott Date: 03/01/21

Validation By: Steve Phung Date: 03/09/2021

Stonehenge Calibration report

Tool ID	4028
Calibration setup	Stonehenge (4π semi-infinite homogeneous source of known activity and density)
Date of calibration	2019-04-11
Version of report	1.0
Commissioned by	Golder Associates Inc.

Calibration by

Ir. M.Tijs
(Medusa Radiometrics BV)

Validation by

Dr. E.J. van der Graaf
(University of Groningen)

MEDUSA Radiometrics BV
PO box 623
9700 AP Groningen,
The Netherlands

www.medusa-radiometrics.com

Parts of this work were performed in collaboration with the Nuclear Accelerator Facility of the University of Groningen, The Netherlands

Contents

Fact sheet

General information	
Tool ID	4028
Model	2SNA-1000-S
Crystal type	NaI
Crystal dimensions	0.875" x 3"
Application	Borehole measurements
Calibration setup	Stonehenge (4π semi-infinite homogeneous source of known activity and density)
Read-out	ALT Matrix logger
Calibration duration	Approximately 2 hours
Date of calibration	2019-04-11
Commissioned by	Golder Associates Inc.

Calibration results	
Energy resolution @662 keV	10.8%
Overall scaling factor	84.7%
Energy scaling factors	
	a_0: -5.800
	a_1: 0.581
	a_2: 0.000
Standard spectra created	^{40}K, ^{232}Th and ^{238}U
Calibration file(s)	1) 4028_0.875x3NaI_11-04-19_KUTh.b2320.mcf

1 Summary

This report describes the calibration of a tool for the measurement of natural gamma radiation from soils and rock formations. The tool under consideration is a NaI “spectra gamma tool”, and does support energy-resolved measurement of radiation. The tool was calibrated against the Stonehenge setup, a semi-infinite cube of brick of density 2.32 kg/l.

The measurements were carried out on 2019-04-11, using the Stonehenge setup at the Medusa facility in Groningen, The Netherlands.

The results of the calibration are:

- The energy resolution of the system is 10.8% @ 662 keV (^{137}Cs);
- The overall scaling factor for the system is 84.7%. This implies that the system provides 84.7% of the theoretical maximum efficiency;
- The energy scaling factors of the system are (a_0=-5.800, a_1=0.581; a_2=0.000).

2 Assignment

The goal of the calibration is to retrieve a set of *standard spectra*; response curves of the tool against a source of unity activity and given geometry. In this case, the tool is calibrated against the Medusa Stonehenge facility.

2.1 Tool description

The tool is a 0.875" x 3" NaI detector and is intended for borehole measurements. The device was readout using ALT Matrix logger.

2.2 Tool drawings

No tool drawings were supplied by the client.

2.3 Measurement setup

The tool was inserted into the Stonehenge setup at the Medusa facility in Groningen, The Netherlands. Inside the setup, the tool was set to log in “time mode”, and during a period of approximately 2 hours, the system recorded gamma spectra.

3 Calibration

3.1 Stonehenge calibration setup

Figure 1. The Stonehenge calibration setup

The tool was calibrated using the Stonehenge calibration setup. Stonehenge is a brick castle (outer dimensions: 120x120x120 cm^3) with a horizontal square (20x20 cm^2) opening at the front in which a detector under test may be entered. The opening was closed on the front and the end by 20 cm thick blocks leaving only a 6x6 cm^2 square opening. The radionuclide concentrations of the bricks were measured using gamma ray spectrometry and are presented in Table 1.

Table 1. Radionuclide concentrations in Stonehenge bricks.

Radionuclide	Concentration (Bq/kg)	Concentration (ppm or %)	Concentration as oxides (ppm or %)
^{232}Th	52	13 ppm Th	14.64 ppm ThO_2
^{238}U	41	3.33 ppm U	3.94 ppm U_3O_8
^{40}K	535	1.69% K	2.08% K_2O

The Stonehenge calibration facility has been modeled using a Monte Carlo Simulation code (MCNPX). In the simulations, the bricks were assumed to be pure SiO_2 with a density of 2.32 kg dm^{-3}. Air was taken as a mixture of N_2 (79 % mass) and O_2 (21% mass) with a density of 1.293 kg m^{-3}.

3.2 Monte Carlo Models

Using the Monte Carlo code, a model was created for the 0.875" x 3" NaI crystal present in the tool. The model also includes most other components of the tool which may have an influence on the spectrum being collected.

For the model, response curves were simulated assuming 1 Bq/kg sources of ^{40}K, ^{238}U and ^{232}Th in the Stonehenge geometry. Such a response curve is called a pure spectrum or *standard spectrum* and represents the spectrum one would measure in the hypothetical situation of a tool inside a Stonehenge-type geometry having an activity of 1 Bq/kg.

3.3 Calibration procedure

The next step in the calibration of a tool is to measure a gamma spectrum inside the Stonehenge setup. The spectrum measured is subsequently energy stabilized, normalized and approximated by the Monte Carlo calculated unbroadened histograms. In this approximation procedure, the following steps are applied:

1. Determination of the spectral resolution of the tool; the unbroadened response histograms are energy-broadened to fit the spectral resolution of the detector;

2. Determination of a general scaling factor describing the difference between a theoretical tool response (response without losses) and the actual response;

3. Determination of a function mapping the “raw” multichannel spectral data to an energy-calibrated spectrum. This procedure basically determines the function needed to map a channel in the MCA spectrum to energy in the energy spectrum. In most cases a quadratic mapping function is used, described by three parameters a_0, a_1 and a_2. These a-factors are the coefficients of the 2^{nd} order function translating the channel numbers into energy.

    - a_0 represents the channel offset present in the multichannel system

    - a_1 represents the (temperature dependent) linear scaling factor;

    - a_2 represents an alinear correction to the channel-energy scaling

    In an ideal multi-channel system, the factors a_0 and a_2 would be zero and a_1 varies solely with the temperature of the system (c.f. Hendriks *et al*, 2001);

These steps are described in detail in Van der Graaf *et al*, 2008. The result of the calibration procedure is a set of standard spectra that can be used in Full Spectrum Analysis to analyze gammaray data measured in the field. The output of the calibration procedure is a Medusa Calibration File (MCF) that can be used in the Medusa spectral analysis software.

3.4 Calibration results

The spectra recorded were summed and analyzed according to the procedure listed above.

The results of the calibration are the following;

- The energy resolution of the system is 10.8% @ 662 keV (^{137}Cs);
- The overall scaling factor for the system is 84.7%. This implies that the system provides 84.7% of the theoretical maximum efficiency;
- The energy scaling factors of the system are (a_0=-5.800, a_1=0.581; a_2=0.000).

The figures below show the measured spectrum along with the unbroadened response histograms and the standard spectra.

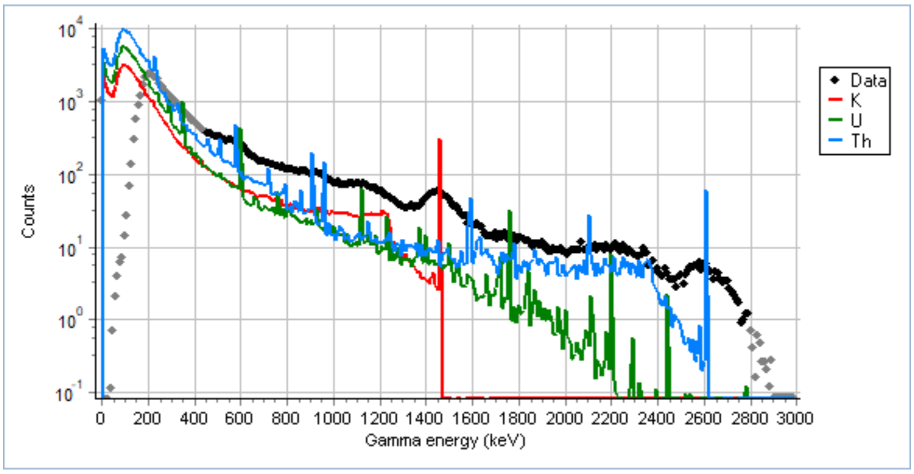


Figure 2. Unbroadened response histograms calculated using MCNPX for the 0.875" x 3" NaI system. The curves represent the response to a ^{40}K source (red curve), a ^{238}U source (green curve) and a ^{232}Th source (blue curve) respectively. Note the huge numbers of decay lines for the U and Th series. ^{40}K has a single decay line at E=1460 keV.

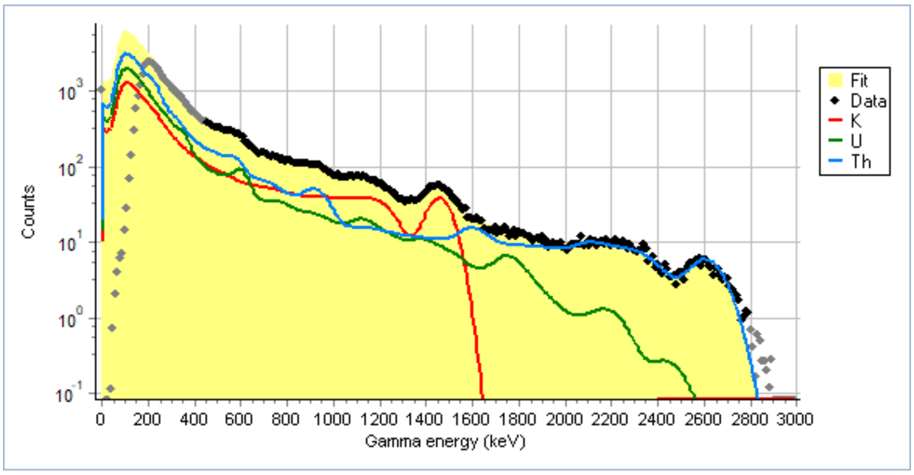


Figure 3. Spectrum measured inside Stonehenge (black dots), standard spectra (red, green and blue for ^{40}K, ^{238}U and ^{232}Th respectively) and resulting fit (yellow surface). The standard spectra are the broadened versions of the lines in the figure above.

3.5 Remarks

1. The overall scaling factor of 84.7% is good;

2. The offset and alinearity of the tool (factors a_0 and a_2) are well within the quality limits for a spectral gamma tool;

3. A few channels in the spectrum had an unexpectedly high number of counts resulting in an artificial peak (see figure 4 below). The origin of these counts is possibly an electronics issue.

   During the calibration process, data was collected in time mode, at an interval of either 1 or 10 seconds. With the interval set to 10 seconds, the peak was less distinct. The additional count rate attributed to the peak was 1.14 counts per second and 0.04 counts per second for a 1 second and a 10 second interval respectively (on a total of 48 counts per second for the complete spectrum).

   When putting a 10 kBq ^{22}Na source next to the tool, the count rate over the complete spectrum increases significantly, which resulted in a smooth spectrum without a visible peak, even for a 1 second interval.

   In the calibration process as described in this report, the 10 second interval spectra were used, where the additional counts were removed manually.

   It is not known if the channels with unexpected high count rates would also be present when the tool is operated in depth mode.

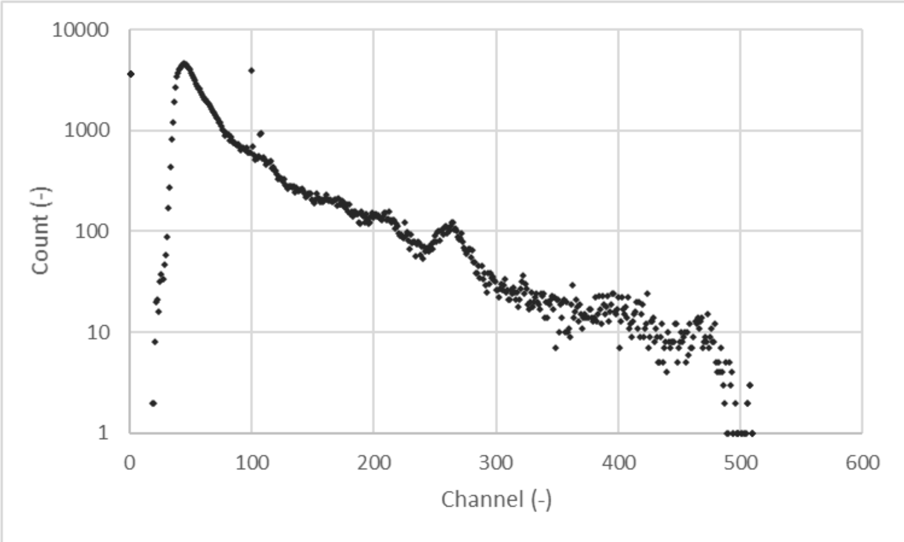


Figure 4. Spectrum measured inside Stonehenge in time mode with a 1 second interval. The unexpected counts are visible around channel 100 – 110.

4 Definition of calibration parameters

Energy resolution

The resolution of the spectrum describes the width of the photo peaks. The resolution is calculated as the full width at half maximum (FWHM) for a ^{137}Cs photo peak at 662 keV. The resolution depends on the configuration and electronics, but it is largely determined by the intrinsic properties of the scintillation crystal.

During the calibration, the resolution has been determined over the complete spectrum. The FWHM depends on the energy of the photo peak and is presented in this report for 662 keV.

Overall scaling factor

A Monte Carlo model has been created to describe the spectrometer to be calibrated. The Monte Carlo model is used to generate the histograms which describe the response of the system to the calibration set-up. Aside from the crystal itself, materials and dimensions of all other system parts may have an effect on the response of the system and need to be included into the model as well. The Monte Carlo model never perfectly describes the system and even systems from the same series may differ slightly. As a result, there is often a slight difference between the measured spectrum and the generated spectrum, which can be corrected for by applying a scaling factor. The scaling factor is typically close to 100%.

Energy spectrum

An energy spectrum consists of 300 channels with 10 keV per channel. An energy spectrum describes a range from 0 to 3000 keV.

Standard spectrum

The standard spectrum describes the response of the calibrated system for 1 unit of activity. Normally, the unit is provided in Bq/kg of a radionuclide in the geometry for which the system has been calibrated. A standard spectrum is also an energy spectrum.

A calibration file (MCF file) contains a set of standard spectra, one for each radio nuclide in the file.

a_0, a_1 and a_2 parameters

The a_0, a_1 and a_2 parameters are the coefficients of a 2nd order function translating the channel numbers of a measured spectrum into energy.

- a_0 represents the channel offset present in the multichannel system;
- a_1 represents the (temperature dependent) linear scaling factor;

- a_2 represents an alinear correction to the channel-energy scaling.

In an ideal system, the factors a_0 and a_2 would be zero and a_1 varies solely with the temperature of the system (c.f. Hendriks et al, 2001). In practice, most systems show some offset ($a_0 <> 0$) and/or some alinearity ($a_2 <> 0$).

The a_0, a_1 and a_2 parameters are independent of the length of the measured spectrum and always transfer a 512 channel measured spectrum into a 300 channel energy spectrum.

Each channel in the measured spectrum describes an energy range in the energy spectrum, the lower bound of which can be calculated using:

$$S_{lower}(i) = a_0 + f a_1 i + f^2 a_2 i^2$$

Here S_{lower} is the lower bound in the energy spectrum for channel i in the measured spectrum. f is a scaling parameter defined as 512 divided by the number of channels in the measured spectrum (for a measured spectrum with 256 channels, f would be 2). Note that the upper boundary of the energy range for channel i is equal to the lower boundary of the next channel:

$$S_{upper}(i) = S_{lower}(i + 1)$$

Gamman and the GammaBase DLL use a highly optimized version of the equations above to convert the measured spectrum to an energy spectrum.

5 References

Hendriks, P.G.H.M. 2003. *In-depth gamma-ray studies: Borehole measurements*. PHD-thesis, University of Groningen, Groningen, 189 pp.

Hendriks, P.H.G.M., Limburg, J. and de Meijer, R.J. 2001. Full-spectrum analysis of natural [gamma]-ray spectra. *Journal of Environmental Radioactivity*, **53**: 365-380.

Hendriks, P.H.G.M., Maucec, M. and de Meijer, R.J. 2002. MCNP modelling of scintillation-detector [gamma]-ray spectra from natural radionuclides. *Applied Radiation and Isotopes*, **57**: 449-457.

Pelowitz, D. B., ed., 2005. MCNPX User's Manual, Version 2.5.0, Los Alamos National Laboratory report LA-CP-05-0369.

Van der Graaf, E., J. Limburg, R.L. Koomans and M. Tijs. 2011.Monte Carlo based calibration of scintillation detectors for laboratory and in situ gamma ray measurements. Journal of Environmental Radioactivity, **102**: 270-282.

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2PGA2PCA*
Serial Number	*3493_3513*
Date	*MAY 04, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO IG BH04 SITE*

Calibration Units	Calibration Value	Measured Value	Difference
cps	Background air	55-57	n/a
cps	DGI Neutron source in the box AM241Be	2882-2980	n/a

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench. Background response and bentonite clay bag response. Factory (MSI) calibrated. 2PGA2PCA_3493_3513_Gamma_Preuse check_06Shift.tfd

Olga Fomenko	OAFomenko	May 04, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2SFA FLUID TEMPERATURE/ RESISTIVITY*
Serial Number	*6327*
Date	*APRIL 29, 2021*
Operator	*OLGA FOMENKO, PETER LEITH*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
mS/cm	0.057	0.053	0.004
mS/cm	29.50	29.51	0.01
C DEG	8	8.3	0.3
C DEG	36	36	0

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes	
Probe checked on the bench using 2 conductivity solutions and two temperature solutions with Horiba.	
(Horiba checked: conductivity solution 0.057 mS/cm Conductivity solution 29.5 mS/cm)	
2FSA_6327_Cond_calibration_01Shift.txt	Conductivity cal txt file
2FSA_6327_Temperature_calibration_01Shift.txt	Temperature cal txt file

Olga Fomenko — OAFomenko — April 29, 2021

Calibration Operator — Signature — Date

Peter Leith — April 29, 2021

Calibration Operator — Signature — Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*QLGAM*
Serial Number	*5598*
Date	*MAY 04, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO IG BH04 SITE*

Calibration Units	Calibration Value	Measured Value	Difference
cps	Background air	75-88	n/a
cps	DGI Neutron source in the box AM241Be	2300-2326	n/a

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench. Background response and bentonite clay bag response. Factory (MSI) calibrated. QLGAM 5598_Gamma_PreuseCheck_06Shift.tfd

Olga Fomenko	OAFomenko	May 04, 2021
Calibration Operator	Signature	Date

```
-----------------------------------------------------------------------
CALIBRATION REPORT : MSI_BR_GR5598-IP5579-PL
-----------------------------------------------------------------------

Name    : EHT
Source  : GRA
Alias   : EHT
Units   : Volts
Calibration Date        : 06/05/21 16:50
Calibration Type        : Linear - 2 pts
CalA    : -3.24249
CalB    : 0
Reference1      : 0
Reference2      : -1285
Value1  : -0
Value2  : 396.3
-----------------------------------------------------------------------

Name    : GR
Source  : MChProc
Alias   : GR
Units   : CPS
Calibration Date        : 23/03/12 15:52
Calibration Type        : Linear - 2 pts
CalA    : 1
CalB    : 0
Reference1      : 0
Reference2      : 1
Value1  : 0
Value2  : 1
-----------------------------------------------------------------------

Name    : VSP
Source  : IP
Alias   : VSP
Units   : mV
Calibration Date        : 08/03/17 10:39
Calibration Type        : Linear - 2 pts
CalA    : 0.603015
CalB    : -8.44221
Reference1      : 0
Reference2      : 120
Value1  : 14
Value2  : 213
-----------------------------------------------------------------------
```

```
Name     : VSPR
Source   : IP
Alias    : VSPR
Units    : V
Calibration Date        : 08/03/17 10:39
Calibration Type        : Linear - 2 pts
CalA     : 1.21022e-006
CalB     : -0.227609
Reference1       : 15.734
Reference2       : 0.574
Value1   : 1.3189e+007
Value2   : 662366
--------------------------------------------------------------------------

Name     : I
Source   : IP
Alias    : I
Units    : mA
Calibration Date        : 08/03/17 10:39
Calibration Type        : Linear - 2 pts
CalA     : 5.87176e-005
CalB     : -0.00517009
Reference1       : 490
Reference2       : 0
Value1   : 8.34512e+006
Value2   : 88.0501
--------------------------------------------------------------------------

Name     : V16
Source   : IP
Alias    : V16
Units    : V
Calibration Date        : 08/03/17 10:39
Calibration Type        : Linear - 2 pts
CalA     : 1.19869e-006
CalB     : -0.0678421
Reference1       : 2.775
Reference2       : 0.114
Value1   : 2.37162e+006
Value2   : 151701
--------------------------------------------------------------------------

Name     : V64
Source   : IP
```

Alias : V64
Units : V
Calibration Date : 08/03/17 10:39
Calibration Type : Linear - 2 pts
CalA : 1.29334e-006
CalB : -0.0753723
Reference1 : 0.671
Reference2 : 0.041
Value1 : 577089
Value2 : 89978.1

Name : V8
Source : IP
Alias : V8
Units : V
Calibration Date : 08/03/17 10:39
Calibration Type : Linear - 2 pts
CalA : 1.21499e-006
CalB : -0.0913257
Reference1 : 5.93
Reference2 : 0.203
Value1 : 4.95586e+006
Value2 : 242245

Name : V32
Source : IP
Alias : V32
Units : V
Calibration Date : 08/03/17 10:39
Calibration Type : Linear - 2 pts
CalA : 1.25467e-006
CalB : -0.0705678
Reference1 : 1.343
Reference2 : 0.0655
Value1 : 1.12665e+006
Value2 : 108449

Name : SPR
Source : MChProc
Alias : SPR
Units : Ohm
Calibration Date : 08/03/17 10:39

Calibration Type : Linear - 2 pts
CalA : 1
CalB : 0
Reference1 : 1
Reference2 : 0
Value1 : 1
Value2 : 0

Name : N16
Source : MChProc
Alias : N16
Units : Ohm.m
Calibration Date : 06/05/21 16:50
Calibration Type : Linear - 2 pts
CalA : 1
CalB : 0
Reference1 : 100
Reference2 : 10000
Value1 : 100
Value2 : 10000

Name : N64
Source : MChProc
Alias : N64
Units : Ohm.m
Calibration Date : 06/05/21 16:50
Calibration Type : Linear - 2 pts
CalA : 1
CalB : 0
Reference1 : 100
Reference2 : 10000
Value1 : 100
Value2 : 10000

Name : N8
Source : MChProc
Alias : N8
Units : Ohm.m
Calibration Date : 06/05/21 16:50
Calibration Type : Linear - 2 pts
CalA : 1
CalB : 0

```
Reference1      : 100
Reference2      : 10000
Value1  : 100
Value2  : 10000
-----------------------------------------------------------------------

Name    : N32
Source  : MChProc
Alias   : N32
Units   : Ohm.m
Calibration Date        : 06/05/21 16:50
Calibration Type        : Linear - 2 pts
CalA    : 1.09608
CalB    : -4.80423
Reference1      : 100
Reference2      : 10000
Value1  : 95.6173
Value2  : 9127.8
-----------------------------------------------------------------------
```

PROTECTED WHEN COMPLETED

DENSITY PROBE CALIBRATION CHECK - BENCH TEST #1

Date:	April 13-16, 2021
Operator:	Shane Davidson
Probe model:	QL40 DEN – Compensated Dual Density
Probe Serial Number (SN):	6366
Radioactive Source Type & Activity:	Cs137; 3.7GBq
Radioactive Source SN:	Q1246
Probe Resolution and Accuracy:	0.05 g/cc resolution and 0.1 g/cc accuracy

Test #1 - Aluminum Block

Aluminum Block (g/cc):	**2.6**

Test File Name: **QLDEN-6366--Q1246-Aluminum-T1_20210416**

Near Density	g/cc	Far Density	g/cc
Min:	2.554	**Min:**	2.553
Max:	2.728	**Max:**	2.701
Average:	2.640	**Average:**	2.631
Difference:	0.040	**Difference:**	0.031

Total number of sample data points: 502

Test Results:

- ☑ Passed
- ☐ Needs Re-calibration

Test #2 - Hardy Test Hole 38-277m

Reference Average (g/cc):	**2.856**

Test File Name: **000_QLDEN_6366_Q1246_u1_041321, 000_QLDEN_6366_Q1246_u2_041321**

Near Density	g/cc	Far Density	g/cc
Average:	2.852	**Average:**	2.852
Difference Average Values:	-0.003	**Difference Average Values:**	-0.004

Total number of sample data points: 2399

Test Results:

- ☑ Passed
- ☐ Needs Re-calibration

S. Davidson	Andrew Torgerson	Roxanne Leblanc
Test Operator	Operation Center Supervisor	Senior Data Analyst

```
------------------------------------------------------------------------
CALIBRATION REPORT : MSI1-GR5598-HMI453
------------------------------------------------------------------------

Name    : EHT
Source  : GRA
Alias   : EHT
Units   : Volts
Calibration Date        : 03/10/12 13:01
Calibration Type        : Linear - 2 pts
CalA    : -3.24249
CalB    : 0
Reference1      : 0
Reference2      : -1285
Value1  : -0
Value2  : 396.3
------------------------------------------------------------------------

Name    : GR
Source  : MChProc
Alias   : GR
Units   : CPS
Calibration Date        : 23/03/12 15:52
Calibration Type        : Linear - 2 pts
CalA    : 1
CalB    : 0
Reference1      : 0
Reference2      : 1
Value1  : 0
Value2  : 1
------------------------------------------------------------------------

Name    : MagSus
Source  : MChProc
Alias   : MagSus
Units   : 10e-3 SI units
Calibration Date        : 22/03/21 11:26
Calibration Type        : Multi-linear
Reference1      : 0 10e-3 SI units
Reference2      : 0.6 10e-3 SI units
Reference3      : 5 10e-3 SI units
Reference4      : 5.6 10e-3 SI units
Value1  : 529.576
Value2  : 621.112
Value3  : 1223.01
```

```
Value4  : 1314.33
-----------------------------------------------------------------------

Name    : Conductivity
Source  : MChProc
Alias   : Conductivity
Units   : mS/m
Calibration Date        : 22/03/21 11:26
Calibration Type        : Multi-linear
Reference1      : 0 mS/m
Reference2      : 200 mS/m
Reference3      : 1000 mS/m
Value1  : 336.884
Value2  : 1287.13
Value3  : 4285.16
-----------------------------------------------------------------------
```

DGI GEOSCIENCE INC.

PROTECTED WHEN COMPLETED

NEUTRON CHECK - BENCH TEST #1

Date:	April 13-16, 2021
Operator:	C. Crawford
Probe model:	Dual Neutron
Probe Serial Number (SN):	6650
Radioactive Source Type & Activity:	Am241Be
Radioactive Source SN:	71-1-1409G

Test #1 - Water

Porosity Value (%):	**100**

Test File Name: **000_100%_MSDDN_6650_71-1409G_031920.tfd**

Neutron	SS Neu cnts	LS Neu cnts	Porosity
Min Counts:	3838.000	0.000	90.228
Max Counts:	4420.000	32.064	111.367
Average Counts:	4115.912	12.545	100.144
Standard Deviation:	85.841	4.972	3.302

Total number of sample data points: 3721

Test Results:

☑ Passed

☐ Needs Re-calibration

Test #2 - Hardy Run

Average Hardy Porosity (%):	**10.408**

Test File Name: **LH-20_QLSNN_6650_71-1-409G_u2.tfd**

Neutron	SS Neu cnts	LS Neu cnts	Porosity
Min Counts:	4797.230	51.567	2.074
Max Counts:	9266.870	915.296	68.303
Average Counts:	8401.018	457.770	10.447
Standard Deviation:	372.950	136.991	6.110

Total number of sample data points: 3237

Test Results:

☑ Passed

☐ Needs Re-calibration

C. Crawford	Andrew Torgerson	Roxanne Leblanc
Test Operator	Operation Center Supervisor	Senior Data Analyst

DGI GEOSCIENCE INC.

Data QA/QC Record Sheet

Project: _______L-675 NWMO – Golder 2021_____________________________

Client: ___________________Golder__________________

Date: _________________03/05/21_____________________

Reviewed by: _________________Roxanne Leblanc______________

PARAMETER:	
Probe (model/sn)	QL Density 6366
Source (sn)	Cs137_Q1246
Survey File Name:	
Depth Start zero	
Depth Start data	
Depth End Data	
Depth End Zero	
Data Point Errors (%)	
QA/QC File Name	IG_BH04_WP05_GAMDEN_04_02_050221.tfd
Depth Start zero	2.68
Depth Start data	300.18
Depth End Data	199.23
Depth End Zero	2.55
Data Point Errors (%)	0.024
Data Repeats (Survey vs QA/QC)	Yes | No
Depth Shift Acceptable (Start Zero vs End Zero)	Yes | No
Data points errors below 1%	Yes | No

Comments:
Data point errors are below 1%.

DGI GEOSCIENCE INC.

Data QA/QC Record Sheet

Project: _______L-675 NWMO – Golder 2021_____________________________

Client: ___________________Golder__________________

Date: _________________03/05/21_____________________

Reviewed by: _________________Roxanne Leblanc______________

PARAMETER:	
Probe (model/sn)	Dual Neutron 6650
Source (sn)	Am241Be 71-1409G
Survey File Name:	
Depth Start zero	
Depth Start data	
Depth End Data	
Depth End Zero	
Data Point Errors (%)	
QA/QC File Name	IG_BH04_WP05_GAM2NEU_04_01_050221.tfd
Depth Start zero	2.35
Depth Start data	303.03
Depth End Data	199.98
Depth End Zero	2.29
Data Point Errors (%)	0.0
Data Repeats (Survey vs QA/QC)	Yes | No
Depth Shift Acceptable (Start Zero vs End Zero)	Yes | No
Data points errors below 1%	Yes | No
Comments:	

DGI GEOSCIENCE INC.

Data QA/QC Record Sheet

Project: _______L-675 NWMO – Golder 2021_____________________________

Client: ___________________Golder__________________

Date: _________________04/05/21_____________________

Reviewed by: _________________Roxanne Leblanc______________

PARAMETER:	
Probe (model/sn)	Dual Neutron 6650
Source (sn)	Am241Be 71-1409G
Survey File Name:	IG_BH04_WP05_GAM2NEU_05_01_050321.tfd
Depth Start zero	2.35
Depth Start data	990.00
Depth End Data	1.30
Depth End Zero	1.67
Data Point Errors (%)	0.04
QA/QC File Name	IG_BH04_WP05_GAM2NEU_04_01_050221.tfd
Depth Start zero	2.35
Depth Start data	303.03
Depth End Data	199.98
Depth End Zero	2.29
Data Point Errors (%)	0.0
Data Repeats (Survey vs QA/QC)	Yes | No
Depth Shift Acceptable (Start Zero vs End Zero)	Yes | No
Data points errors below 1%	Yes | No

Comments:

TOOL CERTIFICATE

Advanced Logic Technology

Product type :	**QL40-FWSM-1TX-4RX**
Serial Number :	**210306**
Build date :	**Feb-2021**

Sonic sensors

Serial Numbers :	Spacer :	**210211**
	Tx :	**203918**
	Rx1 :	**203913**
	Rx2 :	**203920**
	Rx3 :	**203919**
	Rx4 :	**203917**
Test :	Tool accoustic conduction	

Cartridge

Serial Number :	**210306**		
Tests :	Current consumption :	**40 mA**	
	Main voltage input :	**120 V**	

Final test

Tests :	Burn-in (1 night)		
	Telemetry tests on reference winch :	Cable Length	Baud rate
	Mono Cond. 1/8"	**1500m**	**125kb/s**
	4 Cond 3/16"	**480m**	**500kb/s**
	Field test		
	Open hole :	**Velocity analysis**	
	Cased hole :	**CBL**	

Calibration Responsible :

Validation by :

Date : 08.02.2021

ALT sa. Bâtiment A, Route de Niederpallen, L-8506 Redange-sur-Attert Luxembourg
T:(352)23 649 289 F:(352)23 649 364 e-mail: sales@alt.lu RCS:2001-22 10559 VAT: LU18773332

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2SFA FLUID TEMPERATURE/ RESISTIVITY*
Serial Number	*6327*
Date	*MAY 04, 2021*
Operator	*PETER LEITH*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
mS/cm	0.09	1.17	-1.080
mS/cm	26.8	24.15	2.650
C DEG	4.99	6.78	-1.790
C DEG	19.25	22.31	-3.060

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench using 2 conductivity solutions and two temperature solutions with Horiba.
(Horiba checked: conductivity solution 0.09 mS/cm Conductivity solution 26.8 mS/cm)
IG_BH04_WP05_2SFA_Cond_PreUse_06Shift.tfd
IG_BH04_WP05_2SFA_Temp_PreUse_06Shift.tfd
FTC_6327_Cond_calibration_290421.txt cal file
FTC_6327_temp_calibration_290421 cal file

Peter Leith		May 04, 2021
Calibration Operator	Signature	Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*OBI 2G OPTICAL TELEVIEWER*
Serial Number	*160403*
Date	*May 9, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
DEG ROLL / AZI	0	0.1	0.1
DEG ROLL / AZI	90	90.7	0.7
DEG ROLL / AZI	180	180.3	0.3
DEG ROLL / AZI	270	270.2	0.2

Calibration Results: ☒ Passed Check

☐ Needs Recalibration

Testing Notes
Probe checked on bench, rolling by hand. Files saved for each of the tests for reference. IG_BH04_WP05_GAMABI_PreUseCeck_10Shift.tfd

Olga Fomenko	OAFomenko	May 9, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*NORMAL RESISTIVITY, INDUCED POTENTIAL ELOG/IP*
Serial Number	*5579*
Date	*MAY 06, 2021*
Operator	*OLGA FOMENKO*
Location	*MISSISSISSAUGA LAB*

Calibration Units	Calibration Value	Measured Value					Difference				
		N8	N16	N32	N64	SPR					
Ohm*m	1	0.82	0.81	-4.35	-0.71	1.13	0.18	0.19	5.35	1.71	-0.13
Ohm*m	100	96.30	97.58	99.91	93.58	106.53	3.7	2.42	0.09	6.42	-6.53
Ohm*m	1000	963	974	1053	944	1058	37	26	-53	56	-58
Ohm*m	10000	9092	9223	9999	9997	10020	908	777	1	3	-20

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
IG_BH04_WP05_IP_PreUseCheck_08Shift.tfd Calibration_IP_5579_08Shift.txt

Olga Fomenko — OAFomenko — May06, 2021

Calibration Operator — Signature — Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*QL40 HMI INDUCTION MAGNETIC SUSCEPTIBILITY*
Serial Number	*6766*
Date	*MAY 05, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
mS/m	1000	1041.52	-41.52
mS/m	200	206.10	-6.1
mS/m	air	0.23	na
SI*10-3	air	4.42	na
SI*10-3	0.6	1.04	-0.44
SI*10-3	5	5.41	-0.41
SI*10-3	5.6	6.04	-0.44

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench Inside the building, acclimatized in water at 115.7depth for 30 min. HMI_Calibration_factory_220321.txt Factory (MSI) cal on march 22,2021. IG_BH04_WP05_GAMHMI_Acclimatization_07Shift.tfd IG_BH04_WP05_GAMHMI_Cond_PreUseCheck_07Shift.tfd IG_BH04_WP05_GAMHMI_Mag_PreUseCheck_07Shift.tfd

Olga Fomenko	OAFomenko	May 05, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*OBI 2G OPTICAL TELEVIEWER*
Serial Number	*160403*
Date	*May 8, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
Image Colour	Colour Wheel	Recorded File	n/a – Image quality passed

Calibration Results: ☒ Passed Check

☐ Needs Recalibration

Testing Notes
Probe checked on bench, rolling by hand. Colour wheel was used for Image colour check. Files saved for each of the tests for reference. IG_BH04_WP05_OBI_PreColourCeck_09Shift.tfd

Olga Fomenko	OAFomenko	May 9, 2021
Calibration Operator	Signature	Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*MECHANICAL CALIPER*
Serial Number	*5032*
Date	*May 02, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
cm	15.2	15.21	0.01
cm	10.2	10.2	0.00

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe PostUse checked using calibration jig. IG_BH04_WP05_2PCA_PreUseCheck_04Shift.tfd Caliper cal file: 2PCA_5032_Calibration_04Shift.txt

Olga Fomenko	OAFomenko	May 02, 2021
Calibration Operator	Signature	Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*QLATV*
Serial Number	*201201*
Date	*MAY 03, 2021*
Operator	*PETER LEITH*
Location	*NWMO IG BH04 SITE*

Calibration Units	Calibration Value	Measured Value	Difference
TILT, DEG	90	89.4	0.6
TILT, DEG	0	0.2	0.2
ROLL, DEG	0	0.0	0.0
ROLL, DEG	270	270.1	0.1
ROLL, DEG	180	180.1	0.1
ROLL, DEG	90	90.0	0.0

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench, rotating by hand, not square jig IG_BH04_WP05_ABI_201201_PreRoll_05Shift.tfd IG_BH04_WP05_ ABI_201201_PreTilt _05Shift.tfd floor is not 90 deg tilt

Olga Fomenko	OAFomenko	May04, 2021
Calibration Operator	Signature	Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*QLGAM ATV STACK*
Serial Number	*6752_190404*
Date	*MAY 03, 2021*
Operator	*COLIN LANGFORD*
Location	*NWMO IG BH04 SITE*

Calibration Units	Calibration Value	Measured Value	Difference
TILT, DEG	90	90.4	
TILT, DEG	0	1.5	
ROLL, DEG	0	0.1	0.1
ROLL, DEG	270	270.2	0.2
ROLL, DEG	180	180.3	0.3
ROLL, DEG	90	90.3	0.3

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench, rotating by hand, not square jig IG_BH04_WP05_GAMABI_PreTilt_04Shift.tfd IG_BH04_WP05_GAMABI_PreRoll_04Shift.tfd

Olga Fomenko	OAFomenko	May03, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*2SFA FLUID TEMPERATURE/ RESISTIVITY*
Serial Number	*6327*
Date	*MAY 05, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
mS/cm	0.055	0.0553-0.0556	0.00
mS/cm	25.8	21.48-22.078	3.72
C DEG	2.46	4.90	-2.44
C DEG	23.0	24.05	-1.05

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench using 2 conductivity solutions and two temperature solutions with Horiba.
(Horiba checked: conductivity solution 0.055 mS/cm Conductivity solution 25.8 mS/cm)
IG_BH04_WP05_2SFA_Cond_PostUse_06Shift
IG_BH04_WP05_2SFA_Temp_PostUse_06Shift
FTC_6327_Cond_calibration_290421.txt cal file
FTC_6327_temp_calibration_290421 cal file

Olga Fomenko	OAFomenko	May 04, 2021
Calibration Operator	Signature	Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*OBI 2G OPTICAL TELEVIEWER*
Serial Number	*201202*
Date	*May 9, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
DEG ROLL / AZI	0	0.3	0.3
DEG ROLL / AZI	90	90.1	0.1
DEG ROLL / AZI	180	180.22	0.22
DEG ROLL / AZI	270	207.6	0.6

Calibration Results: ☒ Passed Check

☐ Needs Recalibration

Testing Notes
Probe checked on bench, rolling by hand. Files saved for each of the tests for reference. IG_BH04_WP05_GAMABI_PostRollCeck_10Shift.tfd

Olga Fomenko	OAFomenko	May 9, 2021
Calibration Operator	Signature	Date

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*NORMAL RESISTIVITY, INDUCED POTENTIAL ELOG/IP*
Serial Number	*5579*
Date	*MAY 07, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value					Difference
		N8	N16	N32	N64	SPR	
Ohm*m	1	0.83	0.81	-4.65	-0.69	1.13	
Ohm*m	100	96.14	97.37	92.32	93.49	106.47	
Ohm*m	1000	962.51	974.90	981.93	944.40	1059.95	
Ohm*m	10000	9105.48	9222.18	9369.12	8944.06	10039.37	

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
IG_BH04_WP05_IP_PostUseCheck_08Shift.tfd Calibration_IP_5579_08Shift.txt

Olga Fomenko — OAFomenko — May07, 2021

Calibration Operator — Signature — Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*OBI 2G OPTICAL TELEVIEWER*
Serial Number	*160403*
Date	*May 8, 2021*
Operator	*OLGA FOMENKO*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
DEG ROLL / AZI	0	0.1	0.1
DEG ROLL / AZI	90	90.1	0.1
DEG ROLL / AZI	180	180.6	0.6
DEG ROLL / AZI	270	270.6	0.6
Image Colour	Colour Wheel	Recorded File	n/a – Image quality passed

Calibration Results: ☒ Passed Check

☐ Needs Recalibration

Testing Notes
Probe checked on bench, rolling by hand. Colour wheel was used for Image colour check. Files saved for each of the tests for reference. IG_BH04_WP05_OBI_PostColourCeck_09Shift.tfd IG_BH04_WP05_GAMOBI_PostRollCheck_09Shift.tfd

Olga Fomenko	OAFomenko	May 9, 2021
Calibration Operator	Signature	Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*MECHANICAL CALIPER*
Serial Number	*5032*
Date	*May 02, 2021*
Operator	*COLIN LANGFORD*
Location	*NWMO_IG_BH04 site*

Calibration Units	Calibration Value	Measured Value	Difference
cm	15.2	14.78	0.42
cm	10.2	9.82	0.38

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe PostUse checked using calibration jig. IG_BH04_WP05_2PCA_PostUseCheck_04Shift.tfd Caliper cal file: 2PCA_5032_Calibration_04Shift.txt

Olga Fomenko	OAFomenko	May 03, 2021
Calibration Operator	Signature	Date

GOLDER
MEMBER OF WSP

EQUIPMENT CALIBRATION CHECK SHEET

Equipment Model	*QLATV*
Serial Number	*201201*
Date	*MAY 03, 2021*
Operator	*COLIN LANGFORD*
Location	*NWMO IG BH04 SITE*

Calibration Units	Calibration Value	Measured Value	Difference
TILT, DEG	90	89.6	0.4
TILT, DEG	0	1.2	1.2
ROLL, DEG	0	0.2	0.2
ROLL, DEG	270	270.5	0.5
ROLL, DEG	180	180.2	0.2
ROLL, DEG	90	89.9	-0.1

Calibration Check Results: ☒ Check Passed

☐ Needs Recalibration

Testing Notes
Probe checked on the bench, rotating by hand, not square jig IG_BH04_WP05_ABI_201201_PostRoll_05Shift.tfd IG_BH04_WP05_ ABI_201201_PostTilt _05Shift.tfd FLOOR IS NOT 90DEG TILT

OAFomenko

Olga Fomenko		May04, 2021
Calibration Operator	Signature	Date

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	April-29-2021 - Shift 01
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAM2FSA_01-01.TFD	04/30/21	CL	1.82	407.92	406.1	04/30/21	CRP	Acceptable
IG_BH04_WP05_GAM2FSA_01-02.TFD	04/30/21	CL	407.92	1.83	406.09	04/30/21	CRP	Acceptable
IG_BH04_WP05_GAM2FSA_01-03.TFD	04/30/21	CL	1.82	395.40	393.58	04/30/21	CRP	Acceptable
IG_BH04_WP05_GAM2FSA_01-04.TFD	04/30/21	CL	395.40	999.32	603.92	04/30/21	CRP	Acceptable
IG_BH04_WP05_GAM2FSA_01-05.TFD	04/30/21	CL	999.32	975.44	23.88	04/30/21	CRP	Acceptable
IG_BH04_WP05_GAM2FSA_01-06.TFD	04/30/21	CL	999.38	714.10	285.28	04/30/21	CRP	Acceptable

Print name	Signature	Date
Olga Fomenko	OAFomenko	April 30, 2021

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:		**Verified by:**	Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-01-2021 - Shift 02
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAM2SFA_02-01.tfd	Apr-30	OF	714.10	0.73	713.37	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-02.tfd	Apr-30	OF	1.82	999.51	997.69	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-03.tfd	Apr-30	OF	999.51	1.87	997.64	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-05.tfd	Apr-30	OF	1.82	999.53	997.71	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-11.tfd	Apr-30	PL	50.01	999.58	949.57	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-15.tfd	May-01	CDL	999.37	50.19	949.18	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-17.tfd	May-01	CDL	50.00	768.88	718.88	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-18.tfd	May-01	CDL	730.00	999.48	269.48	May-01	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_02-20.tfd	May-01	CDL	999.54	81.74	917.80	May-01	CRP	Acceptable

Olga Fomenko	OAFomenko	May 1, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:		**Verified by:**	Christopher Phillips

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-01-2021 - Shift 03
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAM2SFA_03-01.tfd	May-1	OF	80.00	995.02	915.02	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-02.tfd	May-1	OF	995.02	81.16	913.86	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-03.tfd	May-1	OF	80.00	995.02	915.02	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-04.tfd	May-1	OF	995.02	80.85	914.17	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-05.tfd	May-1	PL	80.00	995.04	915.04	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-06.tfd	May-1	PL	995.04	81.18	913.86	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-07.tfd	May-1	PL	80.00	995.05	915.05	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-08.tfd	May-1	PL	995.05	80.75	914.30	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-09.tfd	May-1	PL	80.00	995.02	915.02	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-10.tfd	May-1	PL	995.02	80.93	914.09	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-11.tfd	May-1	PL	80.00	999.31	919.31	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_03-12.tfd	May-1	CDL	999.31	81.04	918.27	May 2, 2021	CRP	Acceptable
IG_BH04_WP05_2PCA_03-13.tfd	May-1	CDL	429.44	319.44	110.00	May 13, 2021	CRP	Acceptable

Olga Fomenko	OAFomenko	May 2, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-02-2021 - Shift 04
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAM2NEU_04-01.tfd	May-02	DGI	300.03	199.98	100.05		DGI	
IG_BH04_WP05_GAMDEN_04-02.tfd	May-02	DGI	300.18	199.23	100.95		DGI	
IG_BH04_WP05_2PCA_04-03.tfd	May-02	PL	999.47	938.05	61.42	May 3	CRP	Acceptable
IG_BH04_WP05_2PCA_04-04.tfd	May-02	PL	945.00	2.63	942.37	May 3	CRP	Acceptable
IG_BH04_WP05_GAMABI_04-06.tfd	May-03	CDL	2.49	415.03	412.54	May 3	CRP	Acceptable – ATV run at 144 not 288 points but good for QA/QC run

Olga Fomenko	OAFomenko	May 3, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-03-2021 - Shift 05
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAM2NEU_05-01.tfd	May-03	DGI	990.00	2.35	988.33		DGI	
IG_BH04_WP05_GAMABI_05-02.tfd	May-03	PL	2.49	289.30	286.81		DGI	
IG_BH04_WP05_ABI_05-04.tfd	May-03	PL	994.52	960.00	34.52	May 4	CRP	Acceptable
IG_BH04_WP05_ABI_05-05.tfd	May-03	PL	970.02	872.00	98.02	May 4	CRP	Acceptable
IG_BH04_WP05_ABI_05-06.tfd	May-03	CDL	877.00	527.00	350.00	May 4	CRP	Acceptable
IG_BH04_WP05_ABI_05-07.tfd	May-04	CDL	532.03	359.97	172.06	May 4	CRP	Acceptable

Olga Fomenko	OAFomenko	May 4, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-04-2021 - Shift 06
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAMDEN_06-01.tfd	May-04	DGI	990.00	746.85	243.15		DGI	
IG_BH04_WP05_GAMDEN_06-02.tfd	May-04	DGI	751.98	2.09	749.89		DGI	
IG_BH04_WP05_2PGA2PIA_06-03.tfd	May-04	PL	110.00	350.00	240.00	May 5	CRP	Acceptable
IG_BH04_WP05_2PGA2PIA_06-04.tfd	May-04	PL	350.00	450.08	100.08	May 5	CRP	Acceptable
IG_BH04_WP05_2PGA2PIA_06-05.tfd	May-04	PL	450.08	999.52	549.44	May 5	CRP	Acceptable
IG_BH04_WP05_2PGA2PIA_06-06.tfd	May-04	PL	999.52	99.00	900.52	May 5	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_06-07.tfd	May-04	CDL	1.66	700.00	698.34	May 5	CRP	Acceptable
IG_BH04_WP05_GAM2SFA_06-08.tfd	May-04	CDL	680.00	999.40	319.40	May 5	CRP	Acceptable

Olga Fomenko	OAFomenko	May 5, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-05-2021 - Shift 07
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAM2SFA_06-09.tfd	May-05	CDL/OF	999.45	1.39	998.06	May 6	CRP	Acceptable
IG_BH04_WP05_GAMHMI_07-03.tfd	May-05	OF	400.10	299.83	100.27	May 6	CRP	Acceptable
IG_BH04_WP05_GAMHMI_07-05.tfd	May-05	OF	999.21	95.01	904.20	May 6	CRP	Acceptable
IG_BH04_WP05_2SNA_07-07.tfd	May-05	PL	400.00	423.11	23.11	May 6	CRP	Acceptable
IG_BH04_WP05_2SNA_07-08.tfd	May-05	PL	423.11	479.74	56.63	May 6	CRP	Acceptable
IG_BH04_WP05_2SNA_07-09.tfd	May-05	PL	475.00	500.01	25.01	May 6	CRP	Acceptable
IG_BH04_WP05_2SNA_07-10.tfd	May-05	PL	999.59	386.37	613.22	May 6	CRP	Acceptable
IG_BH04_WP05_2NSA_07-11.tfd	May-05	CDL	392.02	-0.13	392.15	May 6	CRP	Acceptable – Zero out of range so will collect a 50m overlap section to properly zero

Olga Fomenko	OAFomenko	May 6, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-06-2021 - Shift 08
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_FWS_08-01.tfd	May-06	OF	500.41	399.99	100.42	May 7	CRP	Acceptable
IG_BH04_WP05_FWS_08-02.tfd	May-06	OF	999.10	895.98	103.12	May 7	CRP	Acceptable
IG_BH04_WP05_FWS_08-04.tfd	May-06	OF	920.05	2.92	917.13	May 7	CRP	Acceptable
IG_BH04_WP05_GAMIP_08-06.tfd	May-06	PL	500.00	600.00	100.00	May 7	CRP	Acceptable
IG_BH04_WP05_GAMIP_08-09.tfd	May-07	CDL	999.52	89.17	910.35	May 7	CRP	Acceptable

Olga Fomenko	OAFomenko	May 7, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	May-07-2021 - Shift 09
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi		
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_HFP_09-01.tfd	May-07	OF	40.00	992.50	952.5	May 8	CRP	Acceptable
IG_BH04_WP05_HFP_09-02.tfd	May-07	PL	992.50	70.00	922.5	May 8	CRP	Acceptable
IG_BH04_WP05_GAMOBI_09-03.tfd	May-07	CDL	2.35	124.05	121.7	May 8	CRP	Acceptable
IG_BH04_WP05_GAMOBI_09-04.tfd	May-07	CDL	114.93	997.26	882.33	May 8	CRP	Acceptable
IG_BH04_WP05_GAMOBI_09-05.tfd	May-08	CDL	995.90	29.10	966.8	May 8	CRP	Acceptable

Olga Fomenko	OAFomenko	May 8, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn Mostafa Khorshidi	**Date / Shift:**	May-08-2021 - Shift 10
		Work Package:	WP05 – Borehole Geophysical Logging
CC:	George Schneider		
		Distributed By:	Email

Borehole Geophysical Logs:

Log Name	Log Date	Logged By	From (m)	To (m)	Total Length (m)	Review Date	Reviewed By	Data Quality
IG_BH04_WP05_GAMOBI_10-2.tfd	May 8	OF	522.02	379.09	142.93	May 9	CRP	Acceptable
IG_BH04_WP05_GAMOBI_10-4.tfd	May 8	OF	996.92	709.61	287.31	May 9	CRP	Acceptable
IG_BH04_WP05_GAMOBI_10-5.tfd	May 8	OF	620.00	520.70	99.30	May 9	CRP	Acceptable
IG_BH04_WP05_GAMOBI_10-6.tfd	May 8	OF	295.00	247.50	47.50	May 9	CRP	Acceptable
IG_BH04_WP05_GAMABI_10-7.tfd	May 8	OF	5.13	995.68	990.55	May 9	CRP	Acceptable
IG_BH04_WP05_GAMABI_10-8.tfd	May 8	OF/PL	994.99	742.10	252.89	May 9	CRP	Acceptable
IG_BH04_WP05_GAMABI_10-9.tfd	May 8	PL	755.00	692.85	62.15	May 9	CRP	Acceptable
IG_BH04_WP05_GAMABI_10-10.tfd	May 8	PL/CDF	696.00	30.93	665.07	May 9	CRP	Acceptable
IG_BH04_WP05_2SNA_10-12.tfd	May 8	CDF	200.00	89.33	110.67	May 9	CRP	Acceptable

Olga Fomenko	OAFomenko	May 9, 2021
Print name	Signature	Date

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

APPENDIX B

Probe Manuals

2PFA-1000 Fluid Resistivity/ Temperature Probe (2SFA,B-1000, 2WQA,B,C-1000)

Mount Sopris Instrument Co., Inc.
Golden CO, U. S. A.
November 29, 2001

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General Information

Overview

The 2PFA-1000, combination temperature/fluid resistivity probe, provides valuable information for the hydrologist and groundwater scientist concerning borehole fluid character and flow. The 2PFA-1000 is configured as a “Poly” probe, with a quick-connect probe top that allows it to be easily attached to either a Poly gamma probe or fitted with a probe top adapter to run in stand alone mode. A second version of this probe, called the 2WQA, B, or C-1000 is a stand-alone probe with, a Mount Sopris single conductor, four-conductor, or GO/I four-conductor top. Finally, it is also available as a factory-mounted sub that is mounted permanently to the bottom of the Poly Electric or Poly Caliper probes.

Theory of Operation

The 2PFA and its various configurations include a seven electrode mirrored Wenner array for measuring borehole fluid resistivity and a temperature sensor based on a fast response semiconductor device whose output voltage changes linearly with temperature. The resistivity array is an internal cylindrical array open at the bottom of the probe. Borehole fluid passes by the array as the probe is lowered in the hole. The array is completely shielded from the outside borehole, so that only fluid resistivity is measured. The temperature sensor is located at the top of the sensor body, in the center of the three exit ports where the borehole fluid returns to the well bore. The “K” factor for the Wenner array is empirically derived, and is approximately 12, when checked for fluid resistivity ranging from 3 to 78 ohmmeters.

Specifications

Diameter	1.5 inches	38 mm
Length	depends on configuration (2WQA-1000 is 22inch, or 56cm)	
Weight	depends on configuration (2WQA-1000 is 5 lbs or 2.3 kg)	
Range		
Fluid Resistivity	0-100 Ohm-meters	
Temperature	-20 to +80 degrees Celsius	
Resolution		
Fluid Resistivity	0.05%	
Temperature	0.1 degrees Celsius	
Accuracy	Better than 1% (both sensors)	

Installation

The 2PFA-1000 uses the tapered lead 6-ring connector common to the Poly family of probes. It is connected to the Poly Gamma or the optional single conductor adapter by simply unscrewing the bull plug (CCW) and screwing the 2PFA-1000 CW onto the mating connector. A firm hand tight connection is all that is required. A layer of electrical tape can be applied if desired.

The 2SFA,B-1000 subs are installed at the factory, and should not be removed in the field unless proper procedures are available and performed by a qualified electronics technician.

The 2WQA,B,C -1000 versions use MSI single conductor, MSI 4 conductor, or Gearhart 4 conductor tops, ready to connect to their respective mating cable heads.

Operating Procedure

Operation

Operation of the 2PFA and its siblings requires that the probe be connected to the cable head. *Make sure that probe power is off before connecting or disconnecting the probe to avoid the chance of electrocution or damage to the equipment.* Normally, **no calibrations are necessary, as the probes are calibrated at the factory**. If re-calibration is desired, see below. Instructions for logging vary depending on your equipment. Follow the appropriate instructions below.

Logging Instructions for MSLog with the MGX II

1. Select the correct tool driver from the Tool panel selection box. If the correct one is not available, run MSLConfig to install it.
2. In the Tool panel, click the Power On button. **It is advisable to power the probe while it is in the hole for a few minutes to warm up the electronics before logging for optimum accuracy**.
3. Place the tool in the borehole and position the top of the tool at the zero depth point. Click the Depth panel upper right corner icon. Click Zero Tool. If you can not place the tool top at depth reference (perhaps the bridle will not go through a sheave), press the Change Depth button and enter the depth of the bottom of the tool.
4. If you wish to fill out the header, in the Acquisition panel click Header button.
5. In the Acquisition panel, click Record and select a file name.
6. Place the probe at the beginning of the interval to be logged. Usually, temperature – fluid resistivity logs are run from the top to the bottom to avoid disturbing the water column before measurement.
7. Turn on the desired, Depth Sampling mode.
8. If you are printing, turn on the printer in MCHCurve.
9. Log to the desired interval as normal. Refer to the MSLog manual for additional information on logging.
10. When done, in the Acquisition panel, click Stop.
11. In the Tool panel, click the Power Off button before removing the probe.

Logging Instructions for Logshell with the MGX II

1. Select the proper probe from the LOG menu. If the correct one is not available, use the CONFIGURE menu item to install it.
2. Use the DATA FILE menu option to name the output file.
3. When you select LOG from the LOG menu, the acquisition program will begin and power will be applied to the tool. **It is advisable to power the probe while it is in the hole for a few minutes to warm up the electronics before logging for optimum accuracy**.
4. Place the tool in the borehole and position the top of the tool at the zero depth point. Set the depth to zero using the SYSTEM CONTROL menu. If you can not place the tool top at depth reference (perhaps the bridle will not go through a sheave), enter the depth for the top of the probe.
5. Place the probe at the beginning of the interval to be logged. Usually, temperature – fluid resistivity logs are run from the top to the bottom to avoid disturbing the water column before measurement.
6. Turn on the output file using the DATA FILE menu item.
7. If you are printing, turn on the printer using the PLOT MENU.
8. Log to the desired interval as normal. Refer to the Logshell manual for additional information on logging.
9. When done, select the EXIT/POWER OFF menu item.

Logging Instructions for Logshell with the MGX

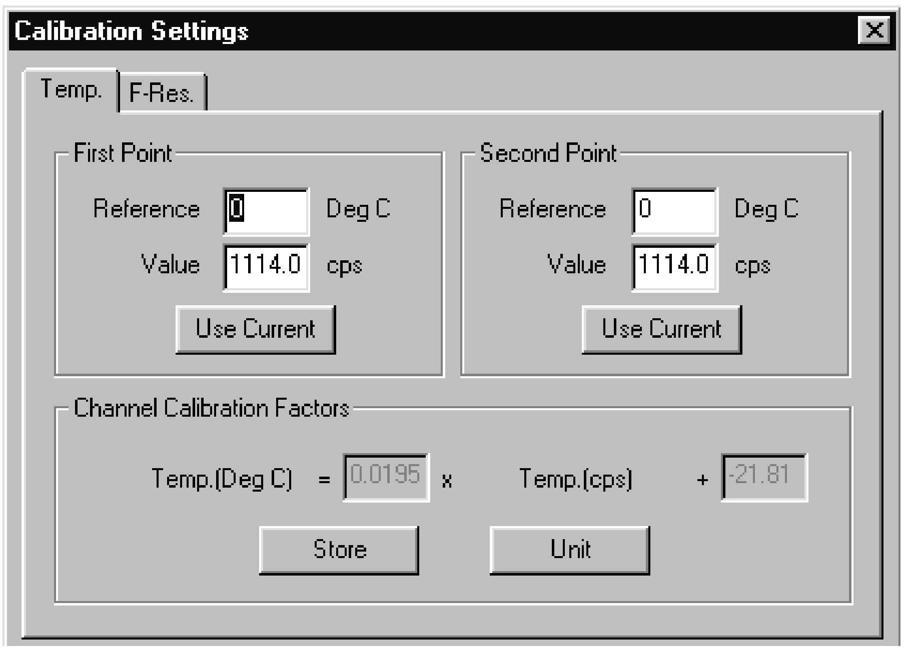
1. Select the proper probe from the LOG menu. If the correct one is not available, use the CONFIGURE menu item to install it.
2. Use the DATA FILE menu option to name the output file.
3. Place the tool in the borehole and position the depth reference point on the tool zero depth point. Set the depth to zero using the DEPTH menu. If you can not place the tool's depth reference at zero depth, enter the depth for reference point on the tool.
4. When you select LOG from the LOG menu, the acquisition program will begin. Place the PROBE SELECT switch in the PULSE 2 position. Place the PROBE POWER switch in the ON position. **It is advisable to power the probe while it is in the hole for a few minutes to warm up the electronics before logging for optimum accuracy**.
5. Place the probe at the beginning of the interval to be logged. Usually, temperature – fluid resistivity logs are run from the top to the bottom to avoid disturbing the water column before measurement.
6. Turn on the output file using the F6 key.
7. If you are printing, turn on the printer using the F7 key. Then start the plot using the F9 (logging down) or Alt-F9 (logging up) keys.
8. Log to the desired interval as normal. Refer to the Logshell manual for additional information on logging.
9. When done, place the PROBE POWER switch in the OFF position.

Performance Checks and Calibrations

The 2PFA series of probes and subs may be re-calibrated in the field, if desired. An accurate thermometer and fluid conductivity/resistivity cell is needed. A good temperature bath is also required, to allow a large mass of water to stabilize at a known temperature. Be sure that the thermometer is placed very close to the sensor to minimize errors. Standard chemical solutions can be purchased from lab supply vendors to calibrate the resistivity array. Contact Mount Sopris for details. Salt-water solutions can be mixed for this procedure, but changes in temperature during mixing can make true resistivity of such solutions difficult to measure.

Calibration Instructions for MSLog

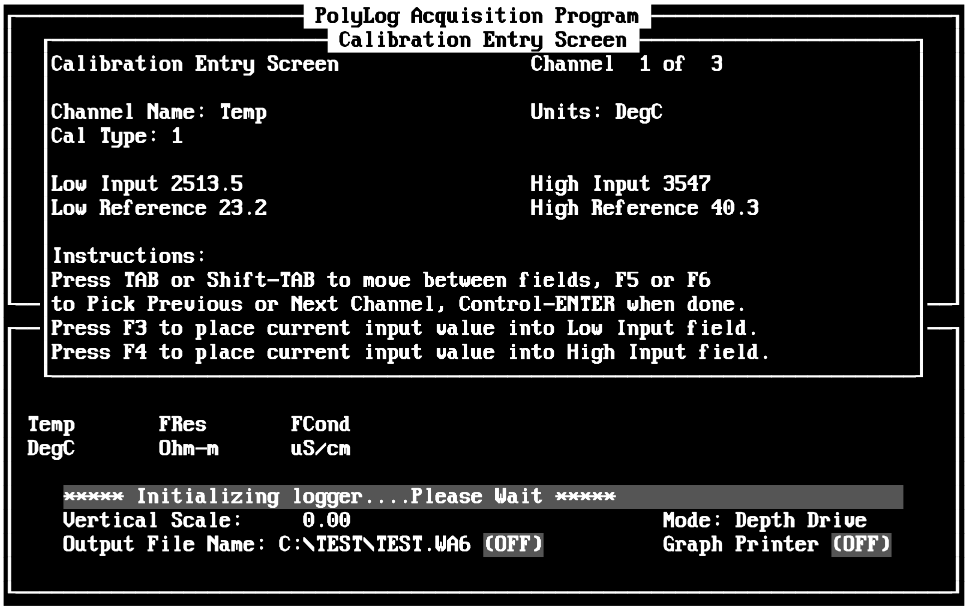
1) Turn Probe power On.
2) Turn Sampling to Time and On.
3) Connect a calibration standard as described above.
4) Allow to warm up for 10-15 minutes.
5) Right click on MCHNum.
6) Uncheck Use calibration
7) Right click on the MCHNum title bar.
8) Click Calibration Settings.
9) Enter the value of the calibration standard (i.e. 5 ohm-m) in the Reference edit box for the first point.



10) Press the First Point Use Current button to capture the raw tool output for the first calibration point.
11) Connect a different calibration standard as described above.
12) Enter the value of the second calibration standard (i.e. 200 ohm-m for a 10 ohm calibration resistor connected to the 64 inch normal electrode) in the Reference edit box for the first point.
13) Press the Second Point Use Current button to capture the raw tool output for the second calibration point.
14) Press Store to save the values to the tool driver file.
15) Press the X in the upper right corner of the browser to close the dialog.
16) On the MSLog Browsers and Processors menu press Close all.
17) Select each Browser or Processor from the menu individually and press the Start button. Wait until the browser or processor Connects then select the next one in the list, press Start and so on until all the processors and browsers are running. This is necessary so that the browsers and processors can read the new calibration information stored in the tool driver file in step 12 above.

Calibration Instructions for Logshell with the MGX II

1) Turn Probe power On.
2) Connect a calibration standard as described above.
3) Allow to warm up for 10-15 minutes.
4) Select the CALIBRATE function in the POLYLOG menu. A screen will appear as follows:

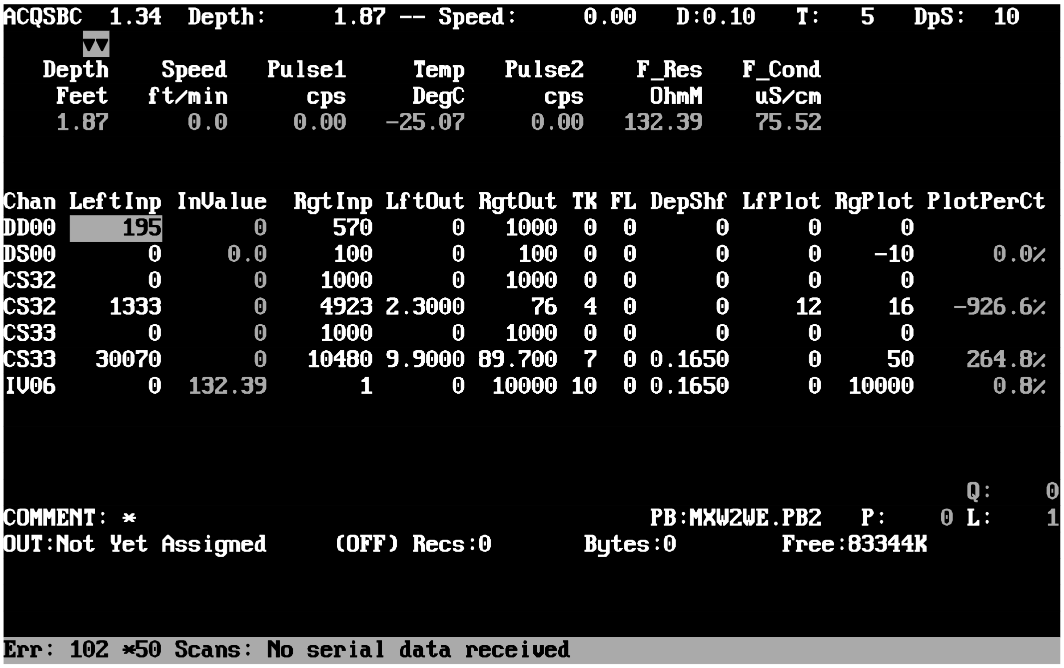


MGX II Example

5) Select either Fluid Resistivity or Temperature (F5 or F6 to toggle between selections). The Low and High Reference fields should be updated by the user, to display the measured low and high values, from your precision thermometer and resistivity meter.
6) Use the F3 (low end) and F4 (high end) keys to write the digital values corresponding to the actual values into the probe file. Check the calibration values several times to verify that they are stable.
7) Then press CONTROL ENTER to exit, and SAVE CALIBRATIONS to save. The new calibration values will be written into the probe file in the active directory. If the new calibration is to be used globally for all new logs, copy the probe file into the directory where LOGSHELL is installed to over-write the old probe file (*.PB4)

Calibration Instructions for Logshell with the MGX

1) Turn Probe power On.
2) Connect a calibration standard as described above.
3) Allow to warm up for 10-15 minutes.
4) Bring up the ACQUIRE Status screen (text screen) in the LOG mode, and you will see the following information:



MGX Example

5) The example shows the ACQSBC status screen for a probe calibrated with the following values:

	LftInp	RgtInp	LftOut	RgtOut
Temperature (2nd line CS32)	1333 cps	4923 cps	2.30 deg. C	76 deg. C.
Fluid Resistivity (2nd line CS33)	30070 cps	10480 cps	9.90 ohm-m	89.7 ohm-m

6) The Inp values are the values sent up the cable by the probe, measured in cps (counts per second). The sensors send the data as DC pulses (positive for temperature and negative for fluid resistivity). The logger counts the pulses and sends them to the PC where they are displayed in the InValue column. The current value for a given temperature or fluid resistivity value is copied into the calibration field (LftInp or RgtInp) by pressing the F3 or F4 key. F3 copies the current value into the low end (LftInp) field and F4 key copies the current value into the high end (RgtInp) field. The values in these fields correspond to the real values measured with the calibration standards (precision thermometer and fluid resistivity meter).
7) The values read from the standards must be entered into the LftOut and RgtOut fields by highlighting these fields with the cursor and typing in the new values and hitting <enter>.
8) To save the calibration data, press F2. The newly calibrated file will be saved in the current directory. If this file is to be used for subsequent logging, copy to the directory where LOGSHELL was installed. You cannot calibrate the Fluid Conductivity channel (IV06) as it is derived mathematically from CS33.

Preventive Maintenance

The only maintenance required for the 2PFA probe series is to be sure to thoroughly clean the interior of the sensor array (electrodes and temperature sensor) with soft brush and clean fresh water and allow to dry before storing. All threads should be cleaned and greased, and all o-ring surfaces and o-rings should be cleaned and coated with silicone grease. Clean logging equipment provides trouble-free logging.

Schematics

Drawing Number	500S-2100.S01	Title	Pwr. Sup. and Temp. Cir.
Drawing Number	500S-2100.S02	Title	Current Generator Circuit
Drawing Number	500S-2100.S03	Title	Voltage Measuring Circuit
Drawing Number	500S-2100.S04	Title	Anti-Co and Pulse Driver Cir.
Drawing Number	Wiring Diagram	Title	2PFA-1000 Wiring Diagram
Drawing Number	Wiring Diagram	Title	2WQA-1000 Wiring Diagram
Drawing Number	Wiring Diagram	Title	2SFA-1000 Wiring Diagram
Drawing Number	Wiring Diagram	Title	2SFB-1000 Wiring Diagram

2PCA-1000 PolyCaliper Probe
and
2CAA-1000 Caliper Probe

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
July 23, 2001

Table of Contents

General Information

Overview

The 2CAA-1000 Caliper and the 2PCA-1000 PolyCaliper probes measure borehole diameter with three linked arms operating a single resistive sensor. The 3 Arm Caliper data can be scaled and calibrated in inches or in centimeters. The output of the caliper has been optimized with a microprocessor generated linearization scheme to improve the accuracy of the probe over the full range of motion. The output from the probe is an anti-coincidence pulse train that has been a Mount Sopris single conductor standard for many years. The 2CAA-1000 Caliper probe requires 60-65 volts D. C. at 85 mA max. and the 2PCA-1000 requires 80-85 volts D. C. at 85 mA max. The probe can be operated with an MGX or MGXII series logger. The MGX requires operator selection of probe power. The MGX II manages the power requirements automatically.

Options

The 2PCA-1000 PolyCaliper probe can be equipped with a fluid resistivity - temperature extension (2SFB-1000) allowing the tool to be logged down measuring the fluid resistivity and temperature and then logged up measuring caliper and gamma using the 2PGA-1000 PolyGamma probe. The PolyCaliper probe can also be run without the gamma probe by using the 2ADP-1000 Poly probe to MSI single conductor adapter. Without this adapter, the PolyCaliper probe can only be run with the PolyGamma probe on the MGXII logging system. Using the 2ADP-1000 adapter the 2PCA-1000 can be operated on the older MGX logging systems.

The 2CAA-1000 Caliper probe can also be equipped with a fluid resistivity temperature extension (2SFB-1000). This system can be run with the older MGX version or the newer MGXII logging systems.

The fluid resistivity - temperature extension is a factory-installed option. Contact factory for details.

Caliper arm extensions are available for measuring holes larger than 17”. The caliper arm can be unscrewed from the short pivot arm and can be replaced with an extension. The arms are then screwed on to the end of the extension. This will allow the caliper to measure up to 30 inches. The minimum hole diameter in which the caliper can be run with the extension arms is 2.25”.

Theory of Operation

The caliper measurement is made with arms attached to a mechanical assembly that drives a linear potentiometer. A constant reference voltage is applied across the potentiometer. The D. C. output voltage from the wiper of the potentiometer is converted to a frequency. A microprocessor applies a quadratic correction to this frequency so that the frequency is linearly related to borehole diameter. Depending on the polarity of the probe power, the microprocessor selects two frequencies to be transmitted up the cable line. The frequencies correspond to the caliper and natural gamma measurements (when 2PGA-1000 is attached), or the temperature and fluid resistivity measurements (when the 2SFB-1000 is attached). The processor controls the pulse driver circuit that sends positive pulses up the cable line for the first frequency, and negative pulses for the second frequency. An anti-coincidence circuit insures that a positive and negative pulse will not occur simultaneously. The microprocessor also controls the motor that opens and closes the caliper mechanism. The mechanism opens or closes as appropriate when power is applied.

Specifications

	2CAA-1000		2PCA-1000 w/2ADP adapter (no Gamma)	
Length:	59.5”	151 cm	60.5"	153 cm
Diameter:	1.5"	38.1mm	1.5"	38.1mm
Weight:	13.0 lbs.	5.9 Kg	13.0lbs	5.9 Kg

The PolyGamma probe adds about 6 lbs (2.72Kg) and 24” (61cm)
The temperature - fluid resistivity extension adds 3 lbs (1.36Kg) about 12.25” (31cm)

Caliper measurement: 1.5" to 17"
38.1mm to 431.8mm

Operating Procedure With the MGX logger

Operation

> **Caution!** Never lower the probe in the hole with the arms open. Caliper logs must be made while logging up, as moving the probe in the down direction with the arms open can damage the caliper mechanism.

Probe File (driver) selection

Name	Measurement	Reference
2CAA-1000 Caliper	3-Arm Caliper	4.55 Ft (or 1.39M) from Top

If the probe is to be operated with a system other than the MGX series loggers consult the factory for proper operating procedures. If the fluid resistivity - temperature extension has been installed and you wish to make these measurements while descending select the **2CAA-1000/F Temp. F. Res** probe file. Apply power to the probe by moving the probe select switch to Pulse 2 and the probe power to - (Closed). A startup cycle time of 2 minutes must elapse before the probe will be ready to log. Log the probe. Reference the Logshell documentation for additional information.

To log the caliper up the hole select the proper probe file **2CAA-1000 Caliper**. Follow the LOGSHELL instructions to execute the logging program, and either calibrate the probe (see below) or proceed to the bottom of the hole. The system must be in the log acquisition mode to be able to measure depth while descending. When bottom is reached, move the MGX Probe Select to the Pulse 2 (MOTOR) position and put the Probe Power switch in the OPEN position. This will open the caliper arms, which will take approximately 2 minutes. Notice the Probe Current light is on while the arms are opening or closing until the arms are fully opened or closed. When the Probe Current light dims or goes out, a confirmation frequency will be sent for a few seconds. This frequency will be 500 Hz after opening and 1000 Hz after the arms are closed. The probe will then begin sending caliper data as the probe is logged up the hole. Recommended logging speed is 15-20 fpm (4-6 mpm). Always slow down when entering casing to avoid possible damage to the casing shoe or the caliper.

Once logging has been completed turn off the data acquisition recording capabilities and exit the file. Place the Probe Power switch to the CLOSE position. This will close the caliper arms in about a minute and a half, indicated by the Probe Current becoming dimmer.

Calibrations

The 2CAA-1000 calibrations should be checked through the LOGSHELL software before logging. Follow the procedure above for opening the caliper, and see the section in the LOGSHELL manual for calibrations. Calibration rings should be selected which bracket the range for the log. The normal operating mode of the MGX system updates data each time the probe moves past a given depth interval. When calibrating a caliper on the surface, it is not necessary to operate the winch to update the data, as this is automatically done every 5 seconds, the default, whether the probe is moving or not. In LOG mode (as if you were getting ready to log the hole), place the small ring on the caliper and allow the arms to centrally locate within the ring. Wait about 15 seconds for the reading to stabilize. Move the cursor in the ACQSBC status screen to LftOut and type in the value (in inches or mm) that corresponds to the small ring diameter. Press F3 to copy the current value from the A/D into the LftInp column. This sets the low-end calibration value in real units to the low-end frequency generated by the probe. Next place the large ring on the probe, center the arms, and wait about 15 seconds for the reading to stabilize. Move the cursor to RgtOut, type in the value for the large ring, and press F4 to copy the current A/D value into the RgtInp column. You may wish to repeat this a few times to check the calibration. When you are satisfied that the calibrations are accurate and repeatable, Press F2 to save the cal values in the probe file. This file will be saved in the current directory, and after logging you will need to copy it to the ACQ directory to update the original probe file values that came with the LOGSHELL program. The fluid resistivity measurements should not need to be calibrated. They can be checked with fluid of known resistivity & temperature. Note that the resistivity of the fluid changes as a function of temperature.

Operating Procedure With the MGXII logger

Operation

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Caution! Never lower the probe in the hole with the arms open. Caliper logs must be made while logging up, as moving the probe in the down direction with the arms open can damage the caliper mechanism.

Probe File (driver) selection

Select the appropriate probe file for the configuration to be operated as listed below. The required Probe files need to have been previously installed via the Logshell Configuration Menu.

To measure caliper

Name	**Measurement**	**Reference**
2PCA-1000 PolyCaliper w/ Gamma	Caliper, Gamma	Probe Top
2PCA-1000 Caliper*	Caliper	Probe Top
2CAA-1000 Caliper	Caliper	Probe Top

To measure Fluid resistivity

Name	**Measurement**	**Reference**
2PCA-1000/F PolyCaliper*	Temp, F_Res	Probe Top
2PCA-1000/F PolyCaliper w/ Gamma	Temp, F_Res	Probe Top
2CAA-1000/F Caliper	Temp, F_Res	Probe Top

- *Requires 2ADP-1000 Polyprobe to MSI single conductor adapter.

Follow the LOGSHELL instructions to execute the logging program, and either calibrate the probe (see below) or proceed to the bottom of the hole. Refer to the Logshell documentation for procedures on opening the probe (see Special Functions section) Once the arms are open the probe may be logged.

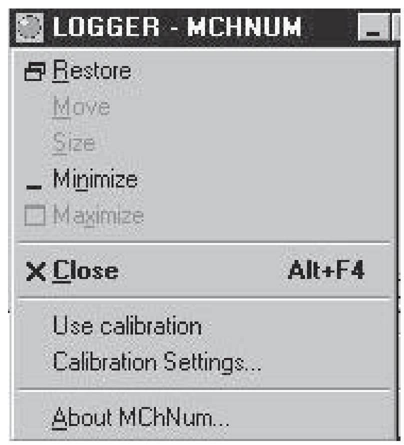
Calibrations

The 2PCA-1000 will need to be calibrated through the LOGSHELL or MSLog software before logging. Follow the procedure above for opening the caliper, and see the sections in either the LOGSHELL or MSLog manuals for calibrations. The normal operating mode of the MGX II system updates data each time the probe moves past a given depth interval. When calibrating a caliper on the surface, it is not necessary to operate the winch to update the data, as this is automatically done when using Logshell every 1 second, which cannot be changed, whether the probe is moving or not. If MSLog is used the user will need to place the acquisition in the Time Mode.

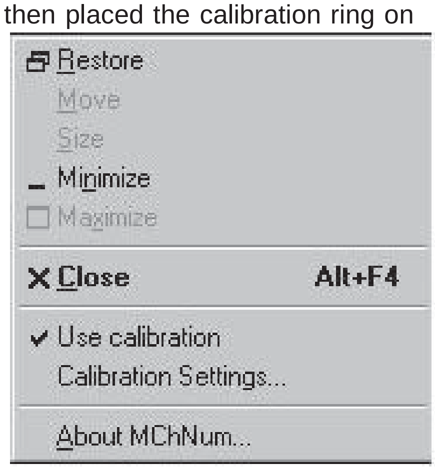
The probe is shipped with a small and a large diameter calibration ring available for calibrating the caliper. **For Logshell users;** In LOG mode (as if you were getting ready to log the hole), place the small ring on the caliper and allow the arms to centrally locate within the ring. Select the Calibrate menu item on the Main PolyLog Menu. Select the EDIT VALUES menu item and enter the values for the Low Reference and High Reference in their respective fields. These values should represent the size of your calibration rings in the engineering units you have chosen (usually inches or centimeters). You move between fields using the TAB key (Shift TAB to move back). Place the small ring on the caliper and center it between the three arms. Press F3 to write the current value of the A/D into the Low Input field. Replace the small ring with the larger ring, and Press F4 to write the current value of the A/D into the High Input field. You may wish to check each ring a few times to verify the calibration. It will take 1 second for the data to update in this mode, so be sure to wait long enough for the value to stabilize. When you are satisfied that the calibrations are accurate and repeatable, Press <Control Enter> to exit the menu and Select the SAVE VALUES bar to save the cal values in the probe file. This file will be saved in the current directory, and after logging may want to copy it to the LS directory to update the original probe file values that came with the LOGSHELL program.

The fluid resistivity and temperature measurements can be calibrated as described in the users manual for this probe extension. They can be checked with fluid of known resistivity & calibrated thermometer. Note that the resistivity of the fluid changes as a function of temperature.

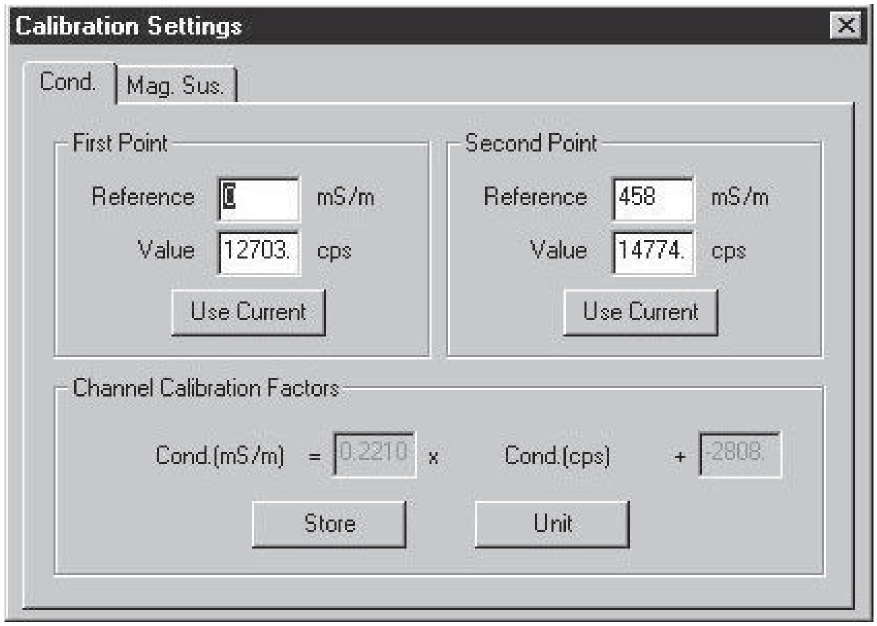
Calibration Settings for MSLog Users



Be sure that the Use Calibration ✔is OFF before proceeding! Click on the Calibration Settings line. In this dialog box, the user can select the channel to calibrate, enter the appropriate calibration values, and then store the entered values in the TOL file. The example on the following page shows a screen for an EM probe calibration, where the user placed the probe in a zero conductivity medium and pressed the button marked “Use Current Value” to set one end of the calibration, and then placed the calibration ring on the probe with a 458 mS/m response and pressed the “Use Current Value” button to set the other end of the calibration. Similar calibrations can be performed for a caliper probe, using two different known calibration ring sizes. When finished with a channel, the user should press the Store button. After finishing the calibration, the user should close the window, and **CLICK on Use Calibration, so the ✔is checked.** If another browser, like MCHCURVE, is running, the user will have to Stop and Start the browser again to make it read the new calibrated values.



Sample Calibration Screen



Caution: The user must follow the above procedures to the letter to ensure accurate and correct calibrations. Pay close attention to the reference to the check mark (✔) setting in front of USE Calibrations. It is OFF during calibration and ON during logging.

Preventive Maintenance

The 2CAA-1000 should provide long life with only minor maintenance required to the mechanical end of the probe. Before and after each usage of the probe, using a standard automotive grease gun and M6 x 1thread fittings (replacement P.N. 28-957-001), apply grease to the two grease ports. These are located immediately above and below the arm pivot point. Close the arms to apply grease to the upper fitting and open the arms to apply grease to the lower fitting. Remove the two grease fittings and install M6 X 6 SS Set Screws (replacement P.N. 28-185-549) as plugs in the holes before operating the probe in a well. After each log, when possible, clean and flush mud and or contaminants out of the caliper arm assembly. When the caliper arms are open inspect the mechanism on the arms to see if there is adequate grease for lubrication. If not re apply grease.

We recommend Dow Corning DC-111 silicone grease for use in water wells. DC-111 is approved for incidental contact with food. There are a number of other greases that will work. High resistance to water washout and temperature range being the prime considerations in their selection. Any grease used should be compatible with the Buna N o-rings. Buna N o-rings are recommended for: Petroleum oils and fluids, cold water, silicone greases and oils, Di-ester base lubricants (MIL-L-7808), Ethylene glycol base fluids (Hydrolubes). It is not recommended for: Halogenated hydrocarbons (nitrobenzene, aniline), Nitro hydrocarbons (nitorbenzene, aniline), Phosphate ester hydraulic fluids (Skydrol, Fyrquel, Pydraul), Ketones (MEK, acetone), strong acids, ozone, and automotive brake fluid.

Keep all thread and o-ring surfaces clean and dry. Re-apply grease or silicone compound (o-rings) on a regular basis. If 2SFB-1000 is attached always flush and clean the fluid resistivity/temperature sensor section after each use, and dry thoroughly before storage to insure accurate measurements.

If electronic troubleshooting becomes necessary it should only be performed by qualified persons or someone that is comfortable with the task.

To access the inside of the probe, the probe top can be removed from the main housing. For the 2CAA-1000, three screws are removed by rotating them counter (anti) clockwise using an M3 hex wrench. For the 2PCA-1000, the three captive screws are rotated clockwise, using an M4 hex head wrench, until they clear the outer housing.

WARNING: The three screws in the 2PCA-1000 Poly top are tight when they are fully counter (anti) clockwise. If they are turned to far clockwise the 2PCA-1000 probe housing will disconnect from the Poly top and can then fall off. **Before disassembling the probe, contact the factory for assistance.**

Next the housing can be unscrewed from the lower section of the probe. The PCB is located at the top end of the inner housing with the motor just below the PCB. In the middle of the PCB are rods, which drive measurement circuits and sensors for control switches that control the open and close positions. Just above where the housing threads are located is the linear potentiometer. When required, feed through wiring is then carried to the bottom of the probe for the 2SFB-1000.

Common electronic problems are a broken or shorted wire. A visual inspection of the wiring should be performed before further testing is done.

If electronic testing is to be done a copy of the schematics is highly recommended before proceeding any further. Depending on the nature of the problem checking things like regulator voltages and pulse outputs is recommended to locate the problem.

Schematics

Drawing Number	Title
0500S-2097 - 1	Poly Caliper power supply
0500S-2097 - 2	Poly Caliper limit switch & v/f
0500S-2097 - 3	Poly Caliper processor & driver circuit

Appendix

Suggested QA Procedure

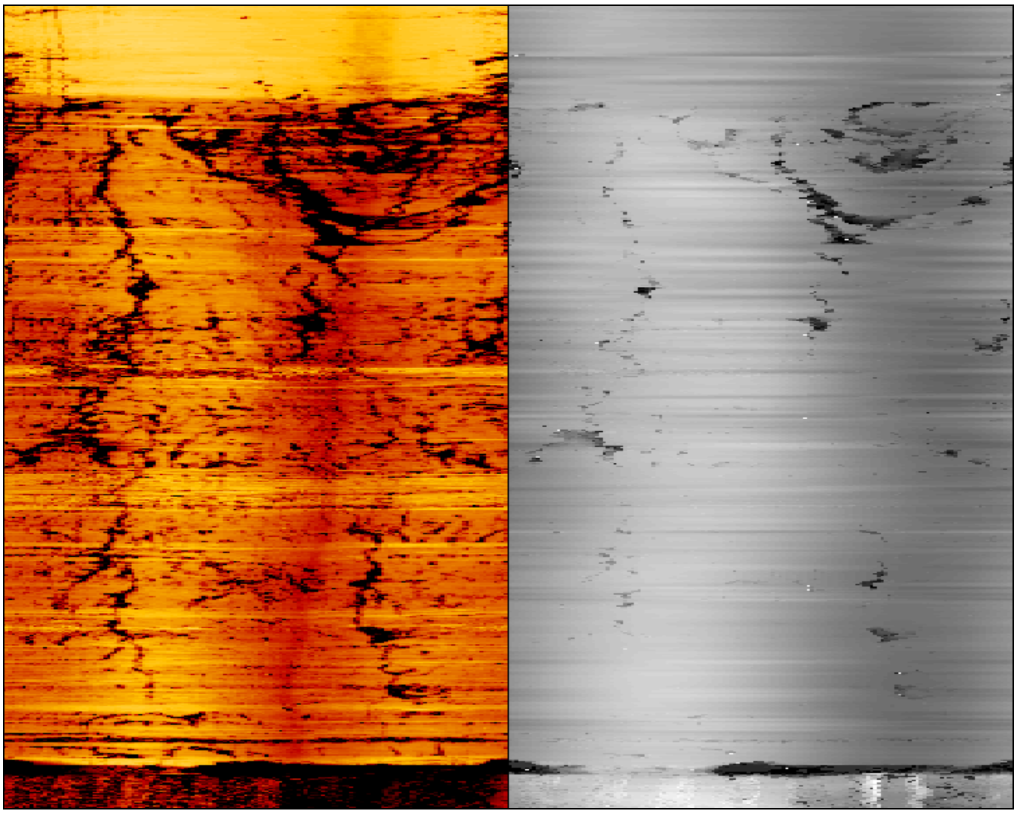
Regular calibration of the caliper response will provide accurate, high quality hole diameter information. Be sure to use calibration standards which are rigid and whose dimensions can be traced to a high degree of precision. The caliper mechanism will normally have some "play" due to mechanical tolerances, but the spring tension will provide for accurate measurements with a minimum of maintenance. Cleaning and greasing the mechanical section on a routine basis will insure repeatable results.

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument, involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris acquisition software provides records of calibration constants. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.



User Guide

QL40 ABI (2G) Acoustical Borehole Imager

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v13.09.02

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Table of Contents

1 General Information

The QL40 ABI is the latest generation of acoustic televiewer. Based on 20 years of experience and market leadership with BHTV technology, the new system consists of a completely redesigned acoustic sensor and new electronics. The electronic architecture uses a 96 dB-10Msps A/D converter directly coupled to a 150 Mflops DSP digital signal processor. The DSP is performing complex data processing operations in real time on each individual ultrasonic wave train and that allows a wider dynamic range of signal detection and easy field operation in a wide variety of logging applications.
The QL40 ABI tool is supplied as a bottom sub of the Quick Link (QL) product line and can be combined with other QL40 tools to form a tool string or it can be run as a stand alone tool. The ABI40 is the standalone - non stackable - version.

1.1 Overview

Acoustic borehole scanner tools generate an image of the borehole wall by transmitting ultrasound pulses from a fixed transducer with rotating mirror and recording the amplitude - travel time of the signals reflected at the interface between borehole fluid and the formation (borehole wall). The QL40 ABI has multi-echo capability. This is achieved by digitally recording the reflected acoustic wave train. On line analysis of the acoustic data is made by the DSP. Sophisticated algorithms allow the system to detect the reflection from the acoustic window and to separate and classify all subsequent echoes. Minimum input from the operator is needed to enable:

- Automatic or manual adaptation to variable borehole conditions.
- Improved dynamic range of signal detection.
- Very high travel time resolution.
- The implementation of different operating modes. For example, when run inside PVC casing, the tool can record both the echo of the PVC casing and that of the borehole wall. With multi-echoes processing, application of the tool may be extended to steel casing thickness and corrosion evaluation.
  Tool upgrades can be done by simply downloading new firmware to the tool from the surface computer.

1.2 Dimensions

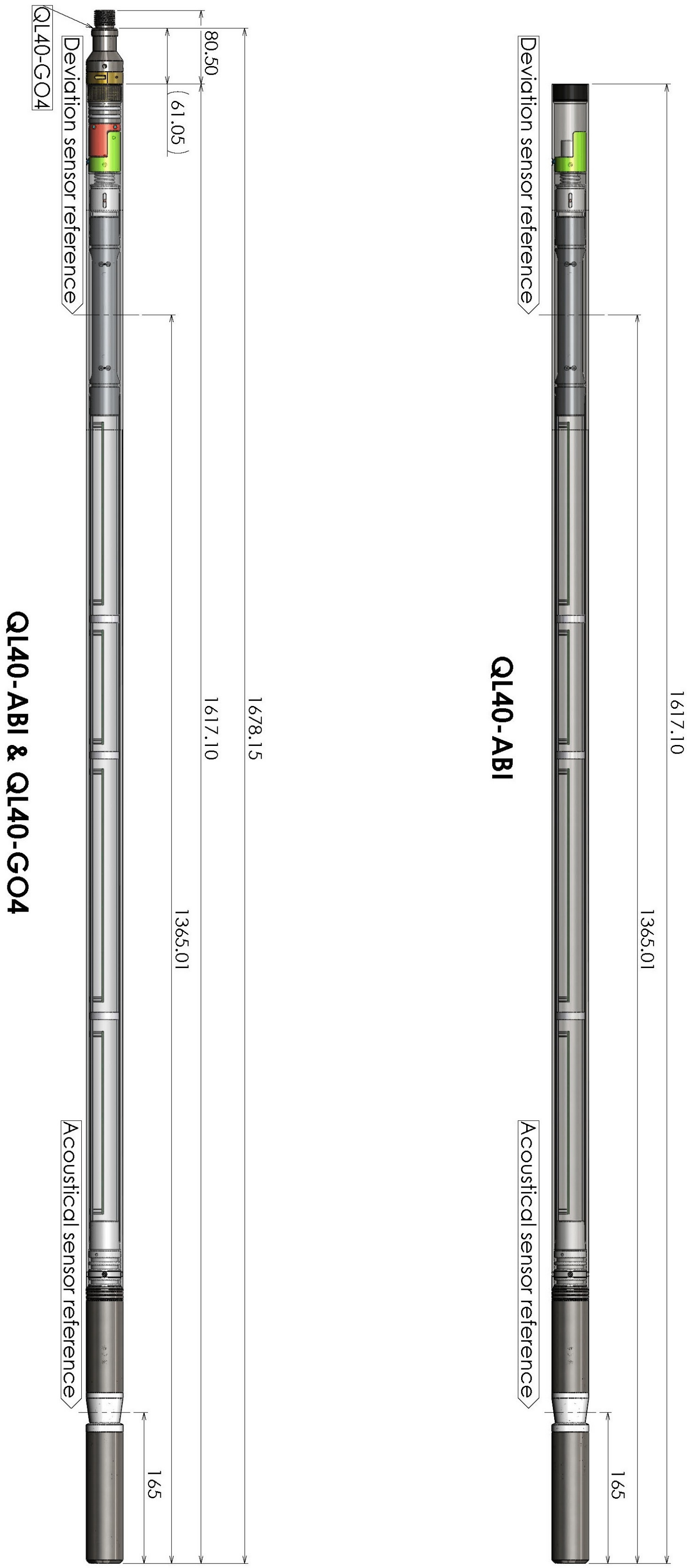


Figure 1-1 *QL40-ABI-2G dimensions*

1.3 Technical Specification

Tool

Diameter:	40mm
Length:	1.61m (63”)
Measurement point:	0.165m (from probe bottom)
Weight:	6.7 kg (14 .7 lbs)
Max. Temp:	70°C
Max.Pressure:	200bar

Cable:

Cable type:	Mono, Coaxial, 4 or 7 conductor
Digital data transmission:	Up to 500 Kbits per second depending on wireline
Compatibility:	ALTlogger – BBOX – Matrix

Acoustic sensor:

Figure 1-2 *Acoustic head*

Acoustic sensor:	Fixed transducer and rotating focusing mirror
Measurement range[1]:	2.5” – 20” (64mm-500mm)
Focusing diameter[2]:	6” (152mm)
Frequency:	1.2 Mhz
Acoustic beam width:	1.5 mm (at focal point)
Rotation speed:	Up to 35 revolutions per second - automatic
Azimuthal resolution:	72, 144, 216, 288, 360 operator defined
Caliper resolution:	0.08mm

Orientation sensor:

Sensor:	APS544
Location:	Middle point of sensor located at 1.365 m from tool bottom
Orientation:	3 axis fluxgate magnetometer, 3 accelerometers
Inclination accuracy:	0.5 degree
Azimuth accuracy:	1.2 degree

[1] Diameter range of the hole in which the measurement is possible (depends on borehole conditions).
[2] Diameter of the hole where the focusing of the acoustical beam is optimum.

Software requirements:

LoggerSuite:	11.1.1224 or higher
WellCAD	4.4.3303/13303 or higher

Logger Firmware requirements:

Matrix:	113 – 117 - 100
Jazz - BBOX	108

2 Measurement Principle

An understanding of the basic principles of operation of the televiewer is essential for successful use of the tool. The ABI produces images of the borehole wall which are based on the amplitude and time of travel of an ultrasonic beam reflected from the formation wall. The ultrasonic energy wave is generated by a specially designed piezoelectric ceramic crystal and has a frequency of around 1.2MHz. On triggering, an acoustic energy wave is emitted by the transducer and travels through the acoustic head and borehole fluid until it reaches the interface between the borehole fluid and the borehole wall. Here a part of the beam energy is reflected back to the sensor, the remainder continuing on into the formation medium at a changed velocity (Figure 2-1). By careful time sequencing the piezoelectric transducer acts as both transmitter of the ultrasonic pulse and receiver of the reflected wave. The travel time for the energy wave is the period between transmission of the source energy pulse and the return of the reflected wave measured at the point of maximum wave amplitude. The magnitude of the wave energy is measured in dB, a unit less ratio of the detected echo wave amplitude divided by the amplitude of the transmitted wave.

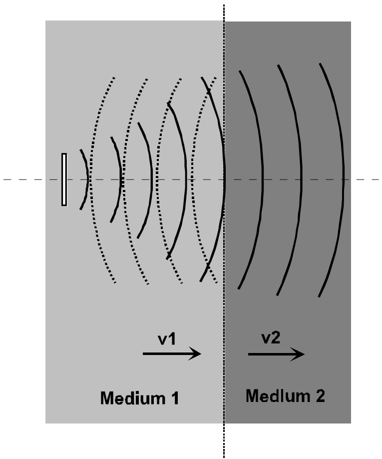


Figure 2-1 *Wave propagation*

2.1 Reflection coefficient

The strength of the reflected signal depends principally on the impedance contrast between the borehole fluid and the formation (Figure 2-1).
The reflection coefficient *r* is given by the following equation:
$r = (\rho_b v_b - \rho_m v_m) / (\rho_b v_b + \rho_m v_m)$

where ρ_b = density of formation
ρ_m = density of borehole fluid
v_b = velocity of sound of formation
v_m = velocity of sound of borehole fluid

The larger the reflection coefficient is the greater is the signal reflection and thus the ability to detect the signal. From the equation above it may be seen that when the properties of the borehole fluid and borehole wall are similar, i.e. $\rho_b v_b \approx \rho_m v_m$, the reflection coefficient *r* approaches zero and there is negligible reflection. In this situation determination of the true reflected wave is made more difficult.

2.2 Acoustic head operation

The acoustic wave is generated by applying a high voltage pulse across the two faces of a piezo ceramic disc. The applied voltage causes deformation within the crystal structure, either an expansion or contraction depending on the polarity of the applied voltage, with a resultant energy wave emitted normal to the free surface. It has been shown that the beam generated by this process has a maximum energy at a distance of twice the diameter of the disc and that after this point the beam tends to diverge. In order to optimize the beam energy at the point of investigation the ALT televiewer head has been designed as illustrated below (Figure 2-2).

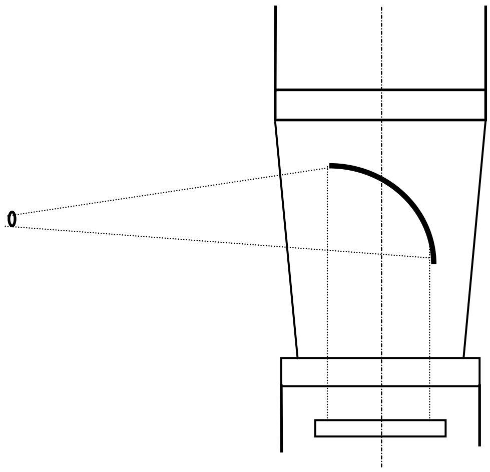


Figure 2-2 *Focussing arrangement*

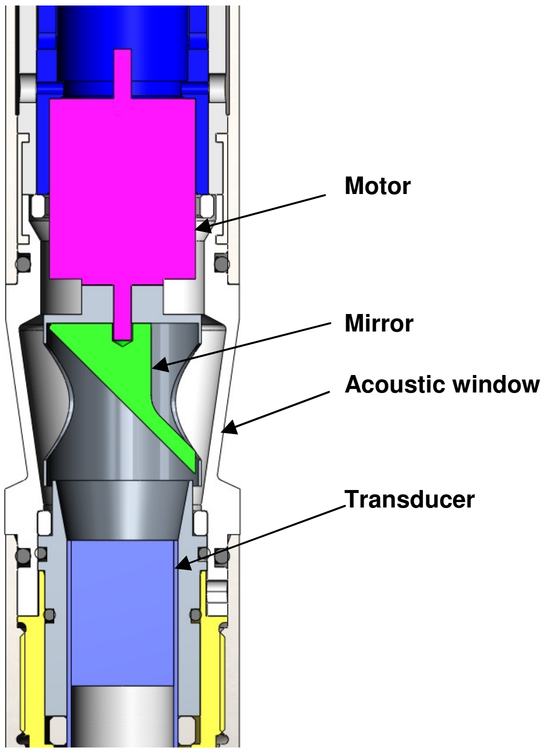


Figure 2-3 *QL40 ABI acoustic head architecture*

The acoustic wave propagates along the axis of the tool body and is then reflected perpendicular to this axis by a special reflector that focuses the beam to a high-energy point of +/- 1.5 mm diameter. The radial distance of the focal point from the axis of the tool is determined by the focal length of the mirror, +/- 75mm (for an acoustic head with a 6" focusing mirror).
The frequency of the transmitted wave is determined amongst other factors such as ceramic composition by the diameter of the piezo transducer, a smaller diameter giving a higher frequency. The ALT televiewer operates around 1.2MHz.

The reflector is mounted on the drive shaft of a stepper motor. This enables the position of measurement to be rotated through 360°. Sampling rates of 72, 144, 216, 288 and 360 measured points per revolution are available, thus at maximum resolution a near continuous image of the borehole wall is made. The higher sampling rate can be used for better resolution in larger diameter boreholes but is less useful in small diameters due to overlap of the sampling points.

3 Notes on QL tool assembly

The following explanations are only valid for the QL40 ABI tool versions. ABI40 “standalone” users can skip this chapter.

QL stands for **Q**uick **L**ink and describes an innovative connection between logging tools (subs) allowing to build custom tool stacks. QL40 describes a specific family of logging tools. Each sub is equipped with its own Telemetry board, Power supply element and A/D converter allowing an operation as stand-alone tool or as a stack in combination with other subs of the QL product family.
The QL40 probe line deals with two types of subs - Bottom Subs and Mid Subs.

Bottom Sub
A bottom sub is a tool that must have one or more sensors located at the bottom. It can be operated in combination with other QL subs connected to the top but it is not possible to connect another sub below. When used in stand-alone mode the bottom sub only needs a QL40 tool top adaptor, which fits the cable head.

Mid Sub
A mid sub is a tool that can be integrated anywhere within a stack of tools. When used at the bottom of a tool string a QL40 bottom plug must be used to terminate the string. If the mid sub is used as a stand-alone tool it needs a QL40 bottom plug at the lower end and a QL40 tool top adaptor at the top.

3.1 QL40 stack assembly

QL40 tool stacks are terminated by either a QL40 bottom sub or a QL40 bottom plug. At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available, special ones can be made on request.

To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.

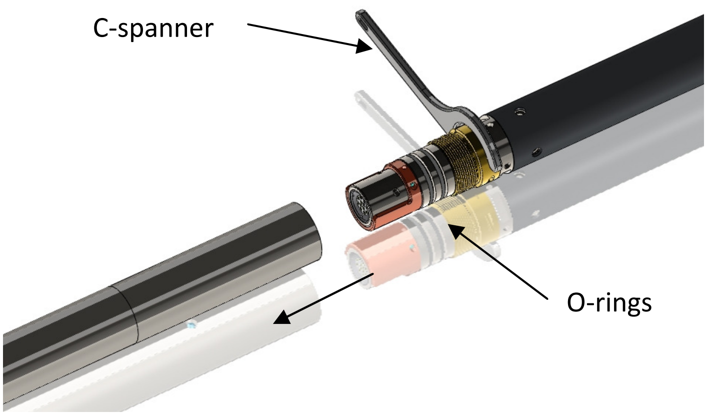


Figure 3-1 *C-spanner and O-rings of QL connection*

The following example of a QL40-ABI, QL40-GAM and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GAM sub stand-alone.

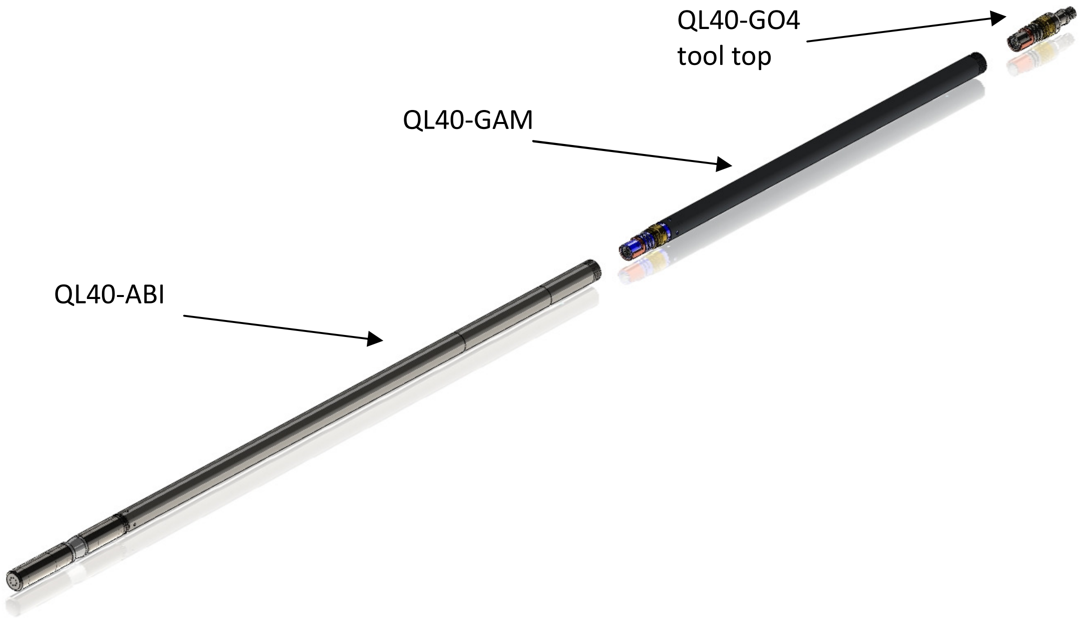


Figure 3-2 *Tool stack example*

To remove the QL40-ABI bottom sub attach the C-spanner to the thread ring as shown in Figure 3-3, unscrew the thread ring and remove the QL40-ABI bottom sub.

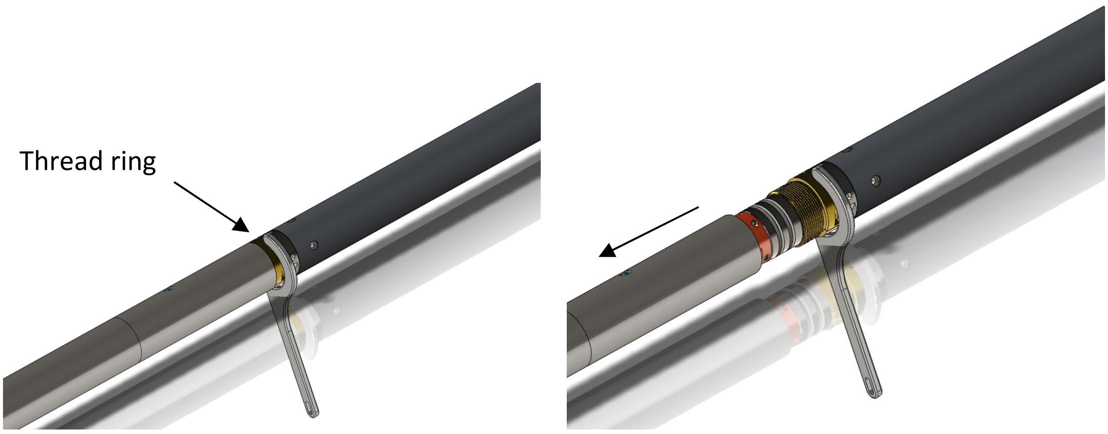


Figure 3-3 *Unscrewing the thread ring and removing the bottom sub*

After checking the O-ring integrity slip the QL40-Plug over the exposed QL connector (Figure 3-4) attach the C-spanner and screw the thread ring until the plug fits tight.

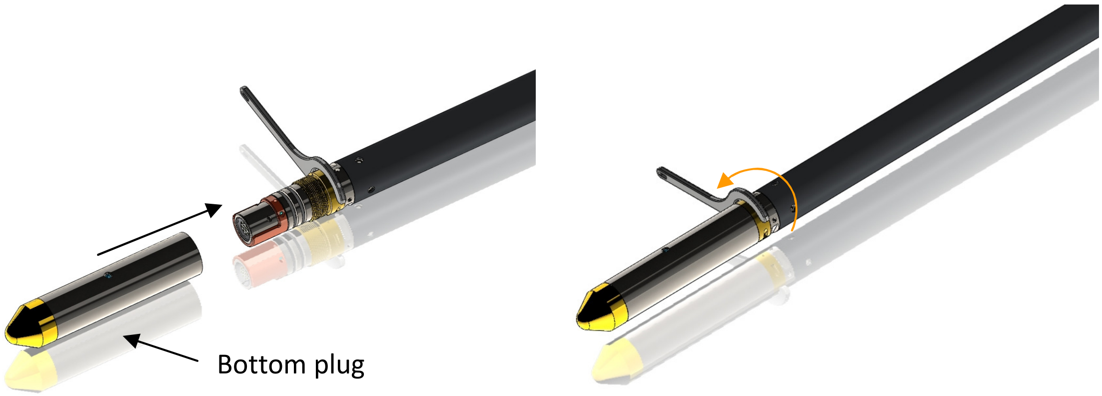


Figure 3-4 *Attaching the QL40-Plug*

The QL40-GAM can now be run stand-alone (Figure 3-5).

Figure 3-5 *QL40-GAM mid sub with tool top and bottom plug*

4 Operating Procedure

4.1 Preliminary note

Acoustic televiewer image quality is highly dependent upon tool centralisation.

One set of centralisers is supplied with the QL40 ABI and is suitable for all tools with an external diameter of 40mm. The standard assembly comprises upper and lower mounting rings with sets of 3”, 5” and 6” bowsprings. Two C spanners are provided for tightening the locking ring. Bowsprings for other borehole diameters are available on request.

The following points relating to the use of centralisers should be considered:

The centralisers should be fitted before mating the tool with the wireline cable head and should always be fitted from the cable head end to avoid damaging the acoustic window.

The compression ring of the centraliser, i.e. the one that is screwed tight, should always be fixed toward the **top** end of the sonde. This is to avoid catching on a downhole obstruction when winching up.

Use the C spanner to fasten the fixing rings but take care not to cross thread or over tighten them as this could damage the pressure housing

(The weak point of the bowsprings is the welded bearing pin. Take care during assembly as the weld can be broken by reverse bending.)

The QL40 ABI enables inspection behind PVC casing. In this situation, the PVC casing must be properly centred in the borehole and the tool correctly centralised in the casing to obtain satisfactory results.

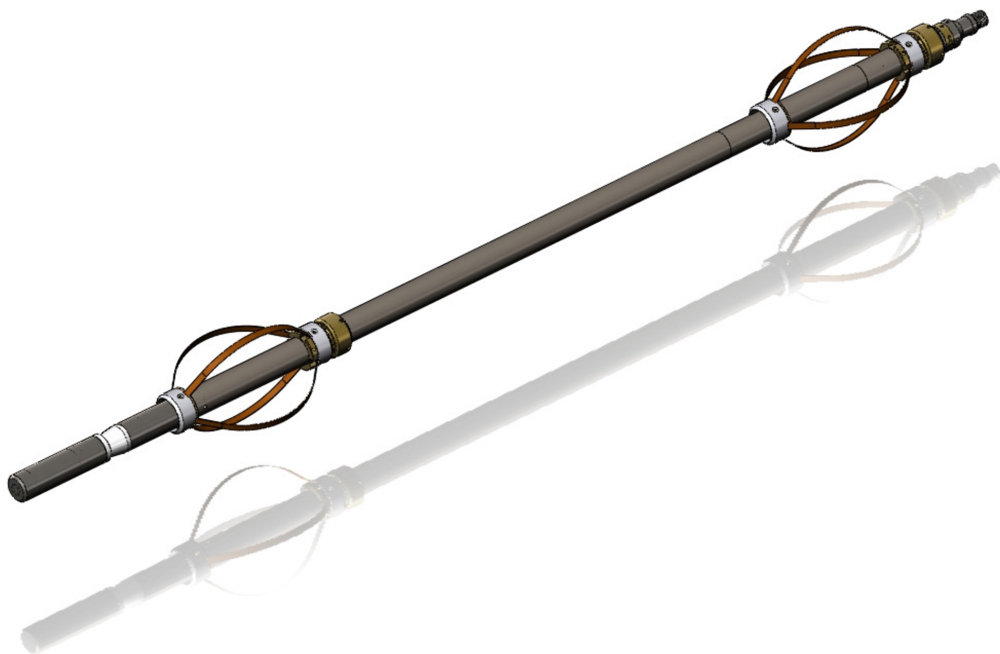


Figure 4-1 *QL40 ABI with mounted centralizers.*

4.2 Quick Start

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the data acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

1. Connect the tool to your wireline and start the data acquisition software.

2. Select the relevant QL40 ABI tool from the drop down list (Figure 4-2) in the software's **Tool** panel (if your tool is not listed check that your tool configurations file is stored in the designated folder on your computer).

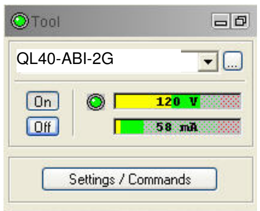


***Figure 4-2** Tool panel*

3. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure. (Setup tool communication as explained in chapter **4.5** if error message is displayed.)

4. On the **Tool** panel (Figure 4-2) click the **Settings / Commands** button to configure your tool for open hole/cased hole logging (see chapter **4.3** and **4.4** for details).

5. In the **Acquisition** panel (Figure 4-3) select the sampling mode ("depth" recommended). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button).

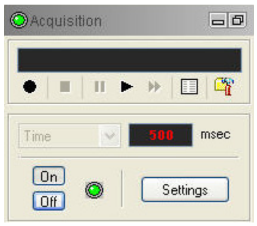


***Figure 4-3** Acquisition panel*

6. Press the **Record** button in the **Acquisition** panel (Figure 4-3), specify a file name and start the logging.

7. During logging observe the controls in the **Telemetry** panel:
   - Status must be valid (green light);
   - Bandwidth usage in green range;
   - Memory buffer should be 0%;
   - Number of **Data** increases and number of **Errors** negligible.
   - Verify motor status (synchronization) in MChNum browser is valid.
   - Do not log too fast! The **Data/sec** parameter must not exceed the speed of the motor rotating the mirror. Check against the **MotSpeed** displayed in the MChNum window.

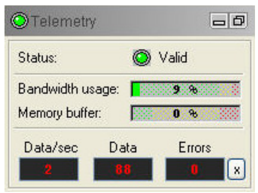


***Figure 4-4** Telemetry panel*

8. To end the logging procedure press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

9. In the **Tool** panel power off the tool.

4.3 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on **Settings** to display the **Configure Tool Telemetry** dialog box (Figure 4-5). A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate**, check the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialisation sequence the next time it is turned on.

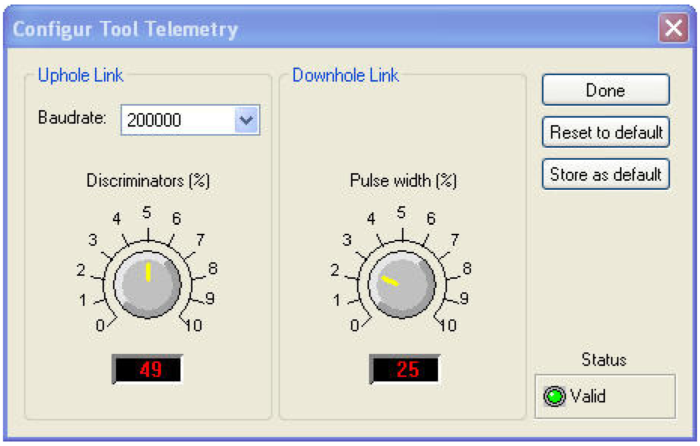


Figure 4-5 *Tool communication settings*

4.4 Tool Communication with MATRIX

The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (Figure 4-6) providing various controls to adjust the telemetry settings and monitor its current status.

The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.

The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.

The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.
For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see Figure 4-6) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.

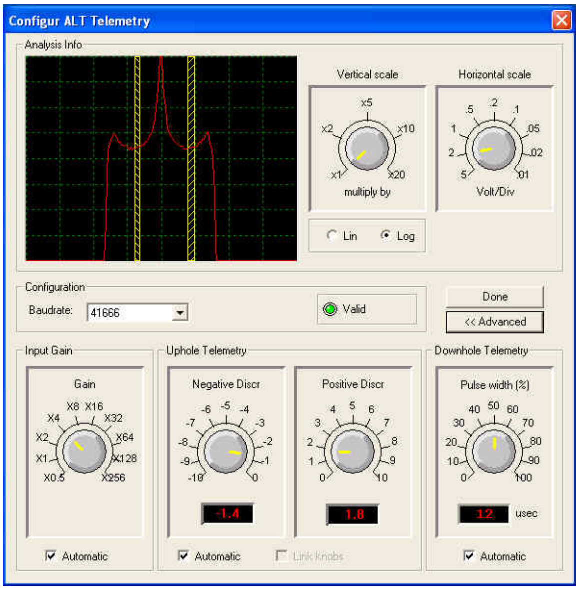


Figure 4-6 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in "Valid" status the next time the power is turned on.

4.5 Configuring Tool Parameters

The **Configure ABI Tool Parameters** dialog box (Figure 4-7) can be accessed by clicking on the **Settings / Command** button on the dashboard's **Tool** panel or by clicking on the tool's bitmap located in the **Tool Stack Manager** window.

4.5.1 Operating Modes

Three operating modes are possible for recording acoustic images with the QL40 ABI:

- Open hole mode
- Behind PVC mode
- Cased hole mode

4.5.1.1.1 Open hole mode

This record mode is used in open-hole conditions or to record the inner face of a casing.

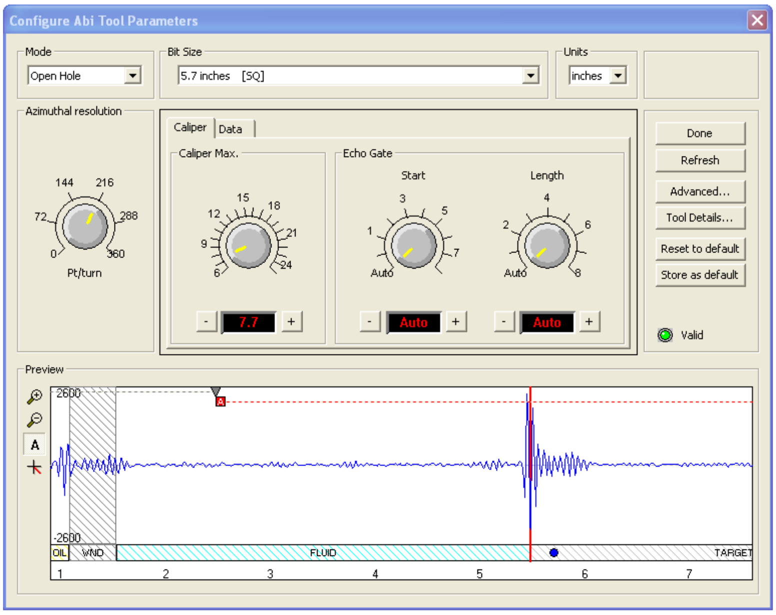


Figure 4-7 *Example of tool settings – Open hole mode*

When selecting a predefined bit size from the **"Bit Size"** dropdown list, the system configures in an automatic way the most adequate tool settings – *azimuthal resolution, caliper max, echo gates* - for the selected bit size or borehole nominal diameter. Note that User has always the choice to modify the tool settings as per his own requirements.

Imperial or **metric units** can be used for displaying the wave form preview and for configuring the caliper/echo gate settings.

The **“Open Hole”** mode gives access to two main tabs – **Caliper** and **Data** - for configuring the record:

Caliper tab:

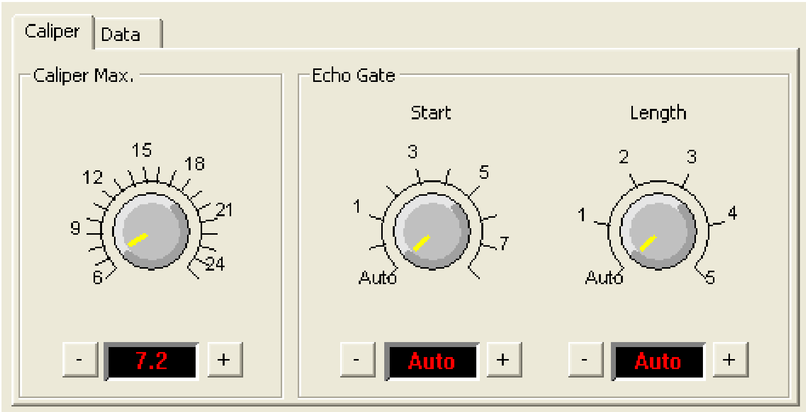


Figure 4-8 *Caliper and Echo Gate settings*

In the **Caliper** page, the **Caliper Max.** knob (Figure 4-8) controls the extension of the real time preview of the ultrasonic waveform. It must be adjusted for the borehole diameter to investigate to allow detection and recording of the main echo.

Echo Gate settings are set in the “Auto” mode by default. If required, User can define a **“Start”** gate and specify the **“Length”** interval for recording the reflected echo. The tool firmware will pick up the strongest amplitude in the signal train within the Echo Gate and records amplitude and tavel time of the borehole echo.

<u>Note that the **Echo Gate** settings can also be adjusted interactively in the waveform preview.</u>

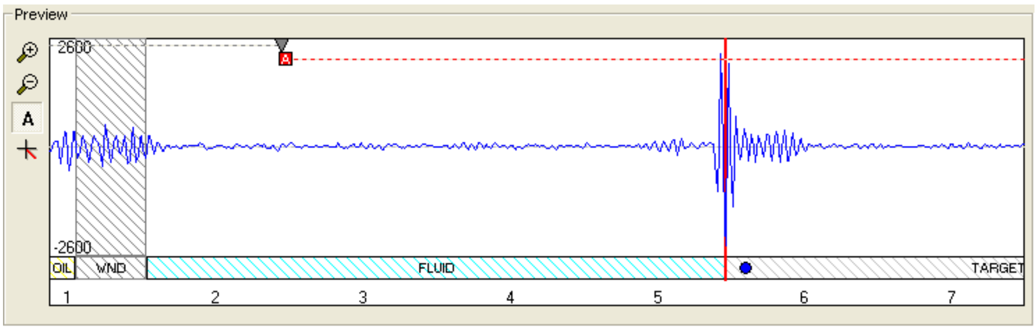


Figure 4-9 *Waveform preview - Echo gate Automatic setting*

For the open hole mode, the waveform preview allows the user to adjust the limits of two gates – the **Acoustic Window gate** and the **Echo Gate**. <u>The Acoustic Window is represented by a grey dashed line while the Echo Gate is shown as red dashed line.</u>

The Acoustic Gate allows determination of the tool’s acoustic window reflection time.

The **Echo Gate “Start”** limit can be determined automatically or adjusted interactively in the preview. Square and triangle symbols indicate whether the limit of the **“Start”** gate is automatically set (square symbol -) or if the user can adjust the limit with the mouse cursor (triangle -).

Three modes are supported to set the **Start** time of the Echo Gate - To toggle from one mode to another **right click** on the square or triangle symbol.

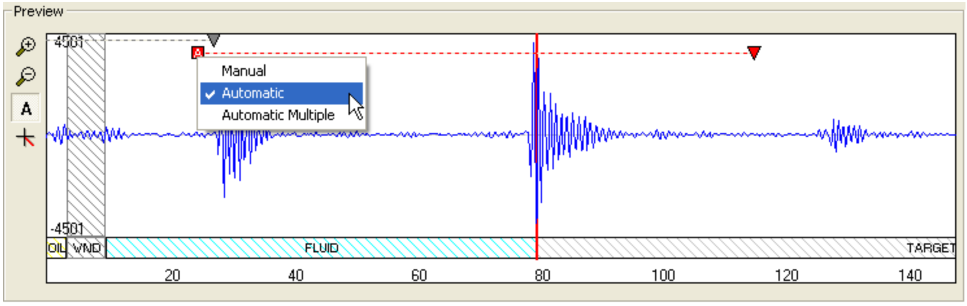


Figure 4-10 *Toggling between Echo Gate detection modes*

- *Automatic*: the system will automatically detect and record the highest amplitude occurring after the Acoustic Window Gate and the upper limit of the Echo Gate (Figure 4-11). Automatic is the recommended setting.

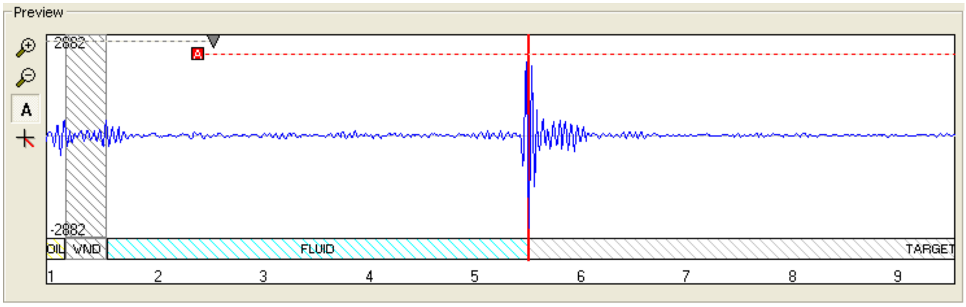


Figure 4-11 *Start gate set in automatic mode*

- *Automatic Multiple*: the system will automatically adjust the start time of the Echo Gate so that the first multiple of the Acoustic Window reflection is skipped. This setting is useful for large diameter boreholes when the amplitude of the first multiple of the Acoustic Window reflection is higher and arrives earlier than the echo from the borehole wall (Figure 4-12).

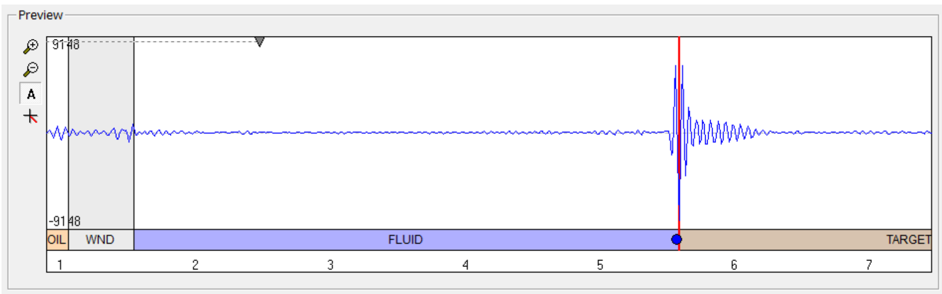


Figure 4-12 *Start gate set in automatic multiple mode*

- *Manual*: Manual adjustment of the Echo Gate start time is useful to exclude noise with amplitudes higher than the formation signal (e.g. exclude the reflection from the inside of a PVC casing) – (Figure 4-13).

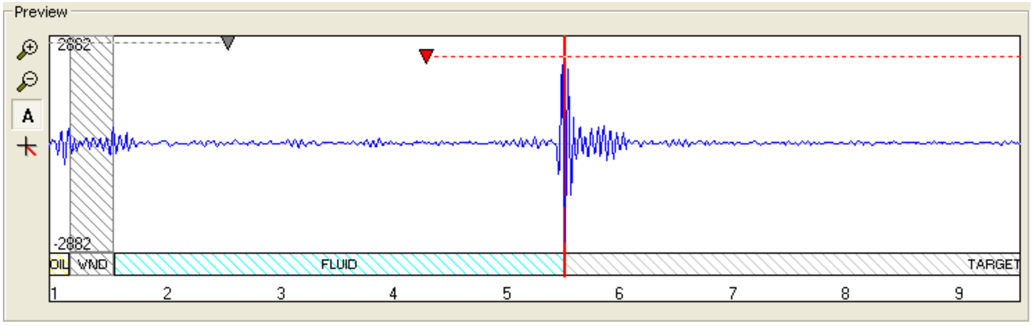


Figure 4-13 *Start gate set in manual mode*

Interactive adjustment in the waveform preview of the Echo Gate **Length** is also possible. It could be useful when multiple reflections with large amplitudes arrives towards the end of the gate period (e.g. exclude Acoustic Window reflection multiples when logging in soft formations).

To toggle the Echo Gate **Length** from the automatic to the manual mode, place your cursor at the right end of the red dashed line to display the double arrows symbol. Drag then the length limit to the desired position on the wave form preview.

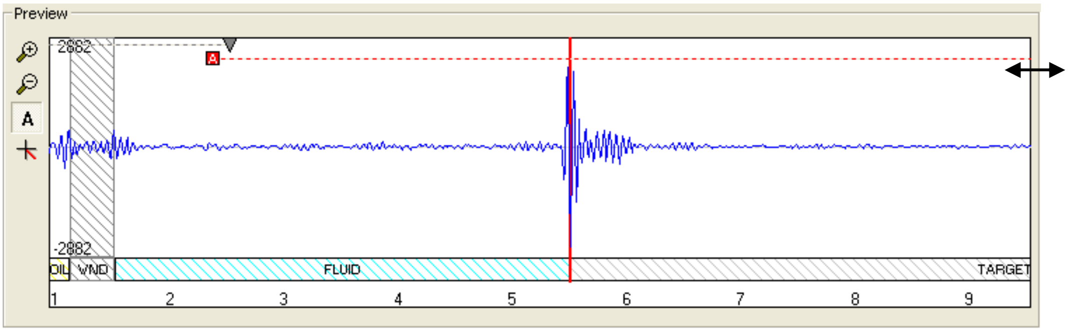


Figure 4-14 *Toggling the Echo Gate Length between automatic and manual mode*

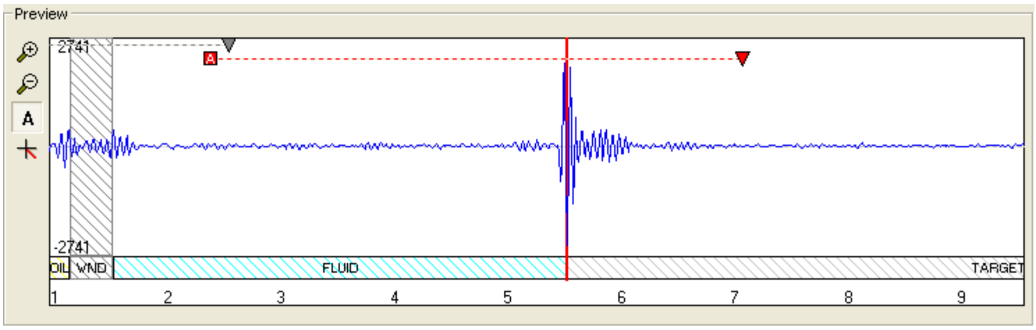


Figure 4-15 *Echo Gate Length set in manual mode*

To toggle the Echo Gate **Length** from manual to automatic mode, right click on the corresponding triangle symbol.

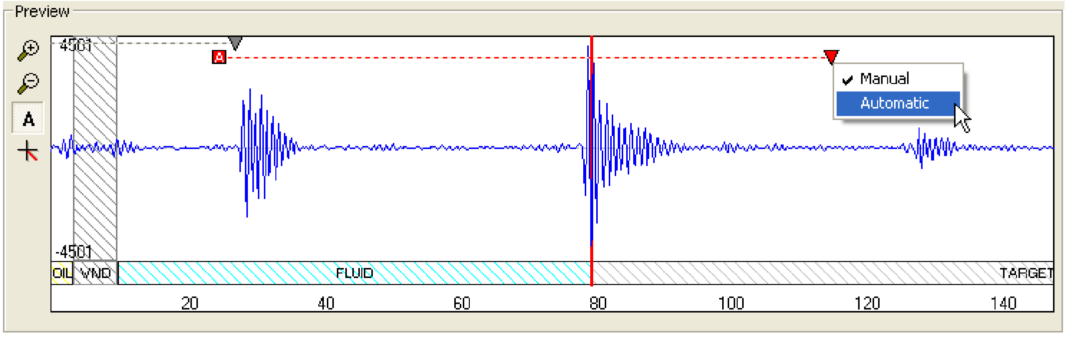


Figure 4-16 *Toggling the Echo Length setting from manual to automatic*

Data tab:

Figure 4-17 *Data record options for the Open hole mode*

The **"Target/Formation"** record option must always be checked. If unchecked, no acoustic image will be recorded and the warning message below will be displayed.

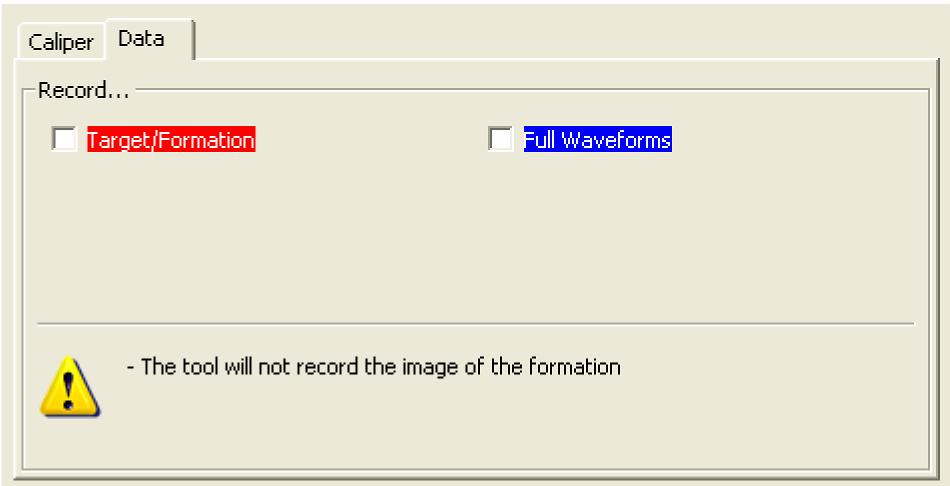


Figure 4-18 *Warning message when Target/Formation record is not checked*

For diagnostic purposes or advanced processing, the **“Full Waveforms”** record option can be activated. The system will record the complete ultrasonic waveform shown in the preview window.
Note that recording the ultrasonic waveform will affect the telemetry performance and will slow down the logging speed.

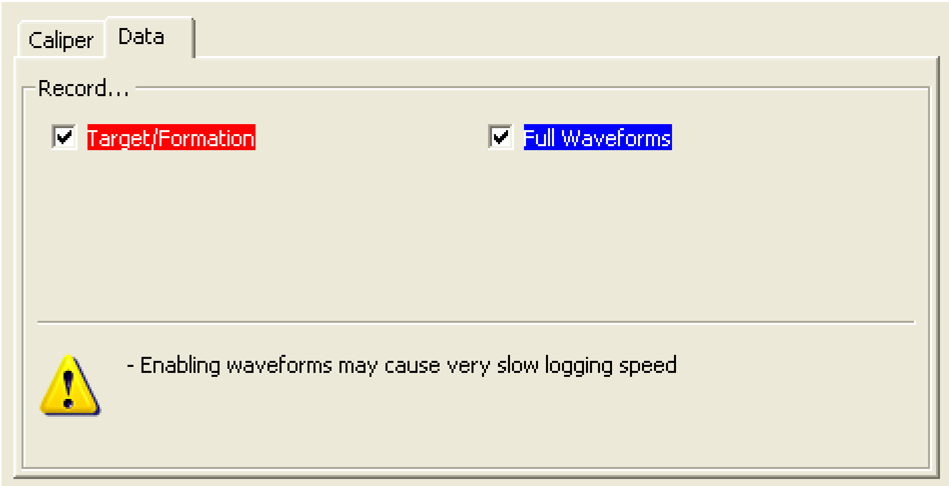


Figure 4-19 *Full Waveforms record option selected*

4.5.1.1.2 Behind PVC Mode

The **“Behind PVC”** mode is used in PVC cased boreholes. The main purpose is to log the borehole wall image located behind a PVC casing.
The algorithms implemented in the tool firmware detect and record all existing echoes on the ultrasonic waveforms. The detected echoes are then sorted and interpreted as a reflection from the casing or from the borehole wall (Figure 4-20).

Remind that for such application, the PVC casing must be properly centred in the borehole and the tool correctly centralised in the casing to obtain satisfactory results.

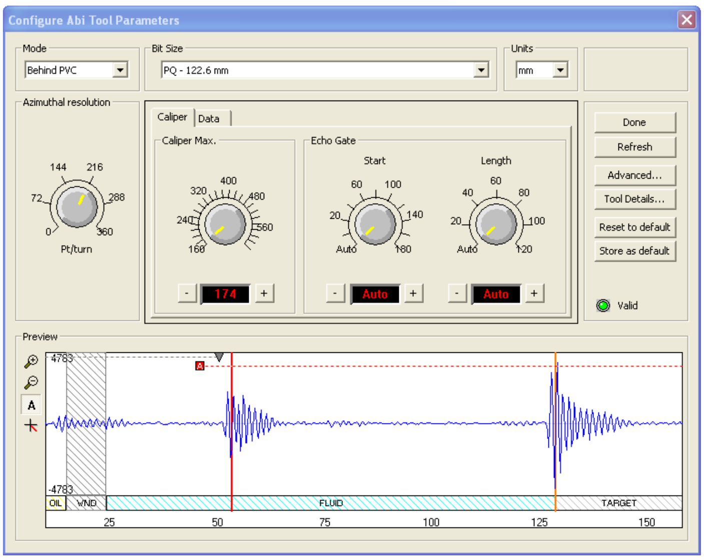


Figure 4-20 *Behind PVC settings – automatic settings*

The **"Behind PVC"** mode gives access to two main tabs – **Caliper** and **Data** - for configuring the record:

Caliper tab:

The caliper settings described in section 4.5.1.1 are applicable for the "Behind PVC" mode.

Mainly two major echoes are detected on the waveform preview. The first one is the reflected echo from the inner side of the casing. It is highlighted by the red vertical line. The second reflected echo, corresponding to the borehole wall, is highlighted by the orange vertical line.

Data tab:

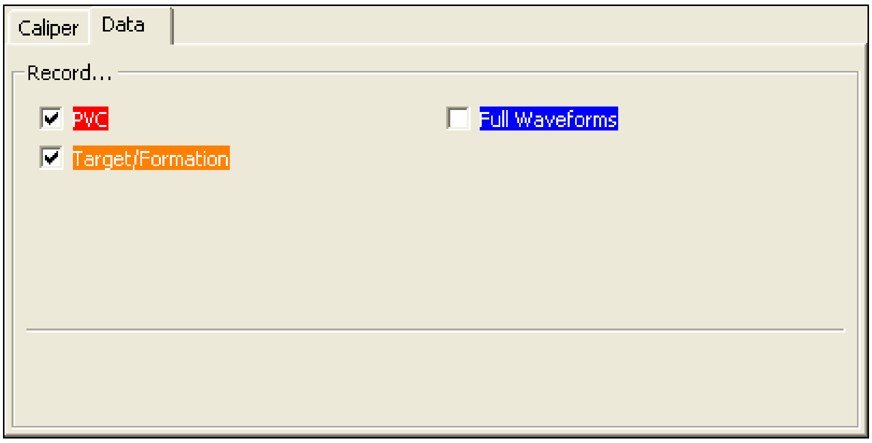


Figure 4-21 *Data record options for the Behind PVC mode*

By default, the system records both the PVC and the Target/Formation images.

The **"Target/Formation"** record option must always be checked. If unchecked, no acoustic image from the borehole wall will be recorded.

Option is given to the user to record or not the image of the inner face of the PVC casing. Recording the PVC image might be interesting to check the casing integrity or for looking at eventual encrustations.

For diagnostic purposes or advanced processing, the **"Full Waveforms"** record option can be activated. The system will record the complete ultrasonic waveform shown in the preview window.
Note that recording the ultrasonic waveform will affect the telemetry performance and will slow down the logging speed.

4.5.1.1.3 Cased hole mode

This acquisition mode is used to perform casing thickness measurements and corrosion evaluation in steel casings.

The operator will need to select from the dropdown casing list the nominal specifications of the casing under investigation (Figure 4-22).
When selecting a predefined **"Casing size"**, the system configures in an automatic way the most adequate tool settings – *azimuthal resolution, caliper max, echo gate, thickness, echo gate length* - for the casing external diameter and weight chosen.

User has also the choice to customize its own settings manually by adjusting the different knobs or interactively in the waveform preview window as described in a previous chapter.

Imperial or **metric units** can be used for displaying the wave form preview and for configuring the caliper - thickness settings.

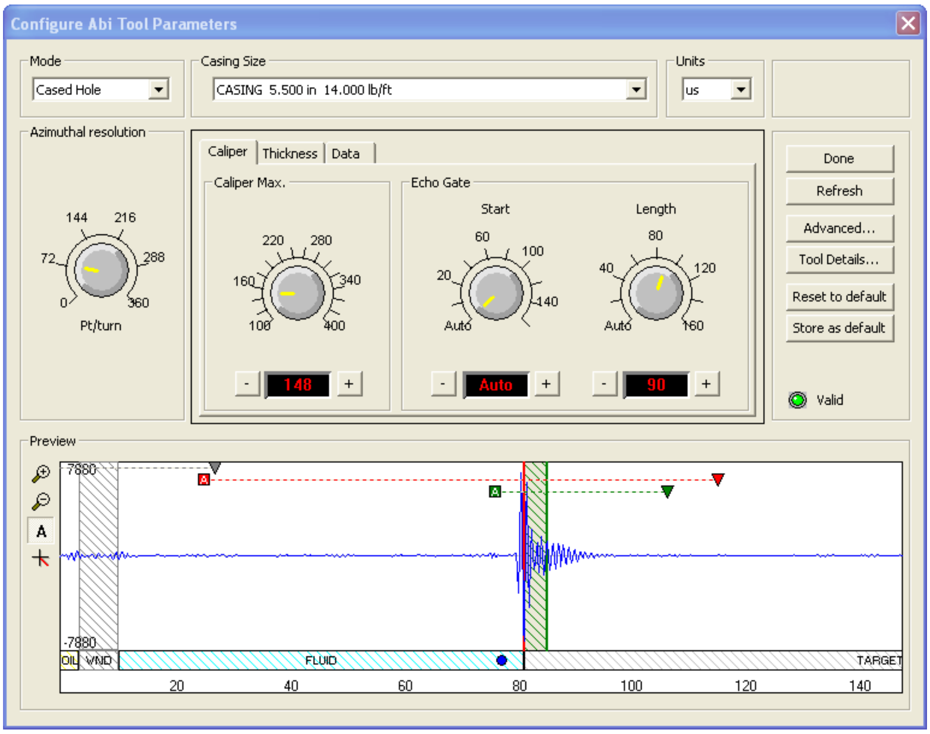


Figure 4-22 *Example of Cased hole settings*

Caliper tab:

The caliper settings described in section 4.5.1.1 are applicable for the "Cased hole" mode. Caliper settings must be adjusted for recording the echo reflected on the inner face of the steel casing.

Thickness tab:

From the thickness tab, the operator has the option to edit the internal (Low) and external (High) casing thickness dimensions manually for the record.
The Echo gate Length can be adjusted from this window or interactively from the wave form preview.

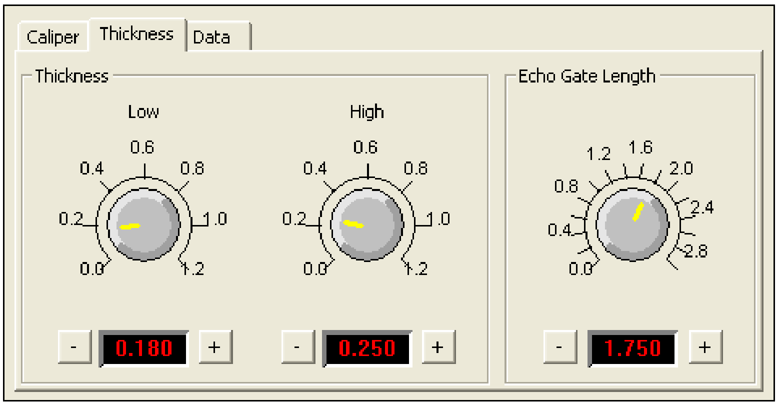


Figure 4-23 *Thickness and Echo Gate Length settings*

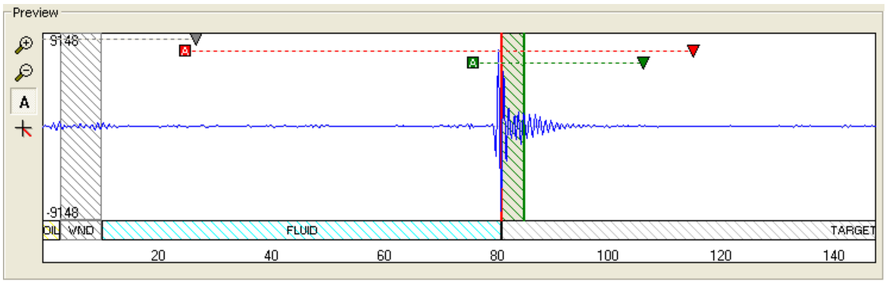


Figure 4-24 *Waveform preview – Thickness Echo Gate*

For cased hole application, in addition to the Acoustic Window and Echo Gates, a third gate - the **Thickness Echo Gate** (green dashed line – Figure 4-24) - is available for which only the end limit is user adjustable. Reduction of the gate length may be necessary if the ringing signal from the casing is superimposed by noise (e.g. multiples of the inner reflection) towards the end of the gate period.

The greyed - green hatched interval overlapping the recorded echo on the wave form preview is representing the casing thickness measured by the system for this specific ultrasonic trace and orientation.

Data tab:

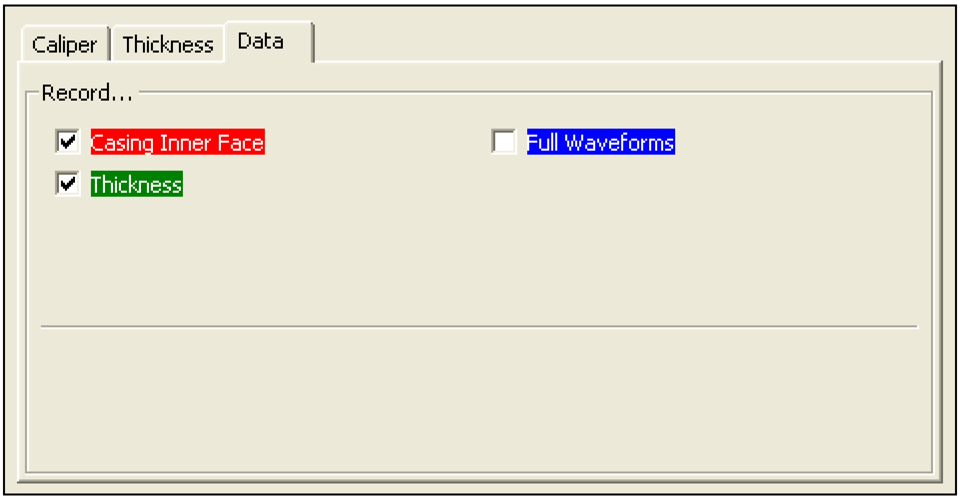


Figure 4-25 *Data record options for the Cased hole mode*

Option is given to the user to record or not the image of the inner face of the steel casing. Recording the casing inner face image is required for further internal caliper processing and for casing thickness/corrosion evaluation.

For diagnostic purposes or advanced processing, the **"Full Waveforms"** record option can be activated. The system will record the complete ultrasonic waveform shown in the preview window.
Note that recording the ultrasonic waveform will affect the telemetry performance and will slow down the logging speed.

4.5.2 Azimuthal resolution

The azimuthal resolution allows the operator to choose the number of points sampled per revolution of the focusing mirror. Sampling rates of 72, 144, 216, 288 and 360 measured points per revolution are available.

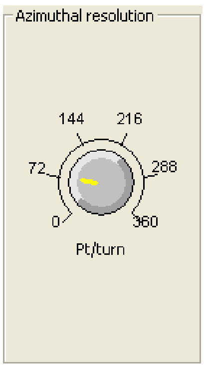


Figure 4-26 *choice of azimuthal resolutions*

The higher sampling rate can be used for better resolution in larger diameter boreholes but it might be less useful in small diameter hole as it would cause an overlap of sample points. The speed of rotation of the focusing mirror is directly linked to the azimuthal resolution and echo mode chosen.

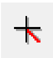
4.5.3 Additional notes on the waveform preview

Beside the interactive settings of the echo gates, the waveform preview is offering other tools to enhance the display of the ultrasonic trace:

 Zoom in the vertical scale of the echo amplitude

 Zoom out the vertical scale of the echo amplitude

Set the vertical scale automatically with the best fit for the echo display

 Display the wave azimuth control knob and scan option

 Theoretical position of the main reflector for the corresponding bit or casing size selected

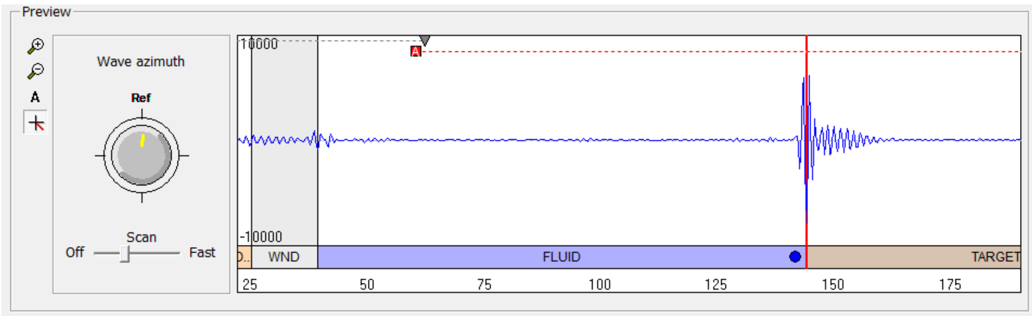


Figure 4-27 *Display of the wave azimuth control knob and scan option*

The **Wave Azimuth** knob in the full waveform preview box (Figure 4-27) gives the possibility to display the ultrasonic wave train in a preferential direction other than the reference position of the mirror.
The preview of the full waveform of the received signal is generated at the position indicated by the **Wave Azimuth** control knob. By turning the control knob, a different position relative to the tool internal reference side can be chosen.

To turn on an **automatic scan** move the slider bar handle from the **Off** position towards **Fast**. In that case the azimuthal scan position will continuously change with the azimuthal step increasing if the slider position is set towards **Fast.**

4.5.4 Advanced Settings

By clicking on **Advanced** in the “Tool Parameters” dialog box (Figure 4-28) the operator can edit the “Fluid and Casing velocity” constants to convert the acoustic travel time from µsec to metric or imperial units. The default values are 1480 m/s for the fluid velocity and 5850 m/s for the steel velocity.

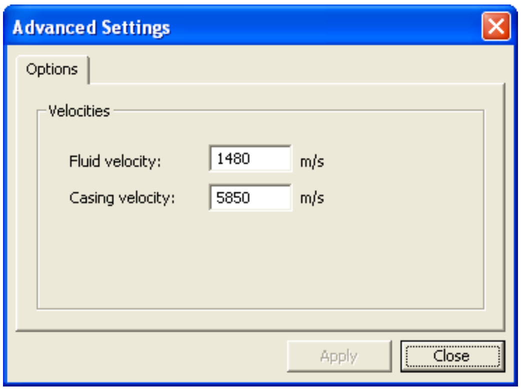


Figure 4-28 *Advanced settings*

4.5.5 Tool details

By clicking on the **Tool Details** button in the **Configure ABI Tool Parameters** dialog box four tabs (Figures 4-29 to 4-32) become available summarizing tool serial number, acoustic head details, deviation sensor model and analog front end. If necessary, newer tool firmware versions can be uploaded. The upgrade procedure will be explained in a later chapter.

Note: All the information displayed in the following dialog boxes can’t be edited

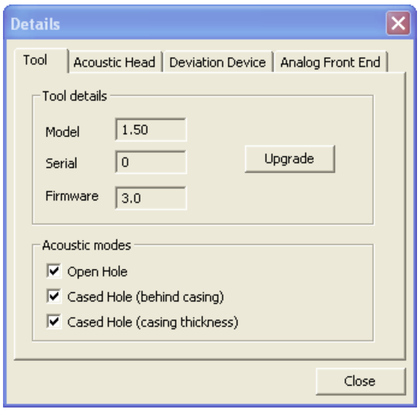


Figure 4-29 *Tool details*

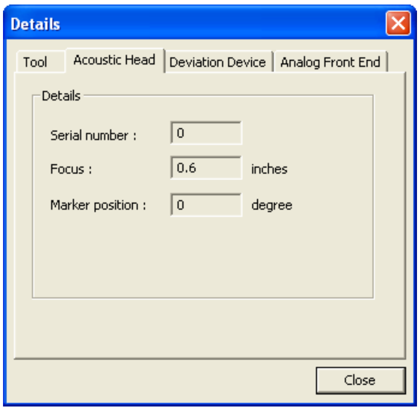


Figure 4-30 *Acoustic head details*

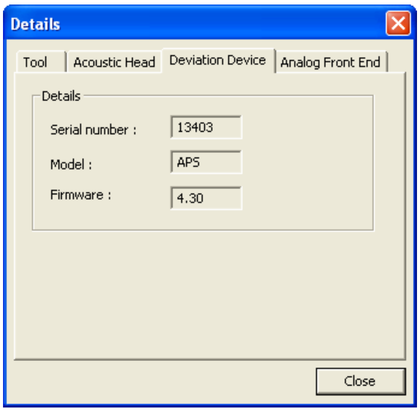


Figure 4-31 *Deviation sensor details*

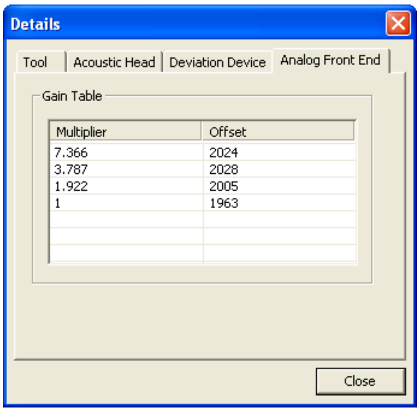


Figure 4-32 *Analog Front End*

4.6 Recorded Parameters and Browsers

4.6.1 Recorded parameters

The following data channels are recorded by the tool:

TravelTime (1st echo):	Two Way Traveltime 1st echo - µsec
Amplitude (1st echo):	Amplitude 1st echo (NM = North Magnetic, HS = High Side)
TravelTime2 (2nd echo):	Two Way Traveltime 2nd echo - µsec
Amplitude2 (2nd echo):	Amplitude 2nd echo (NM = North Magnetic, HS = High Side)
ThicknessTTime:	Two Way Traveltime within casing - µsec
Score:	Quality Index for thickness signal detection
Azimuth:	Azimuth from Magnetic North – deg
Tilt:	Inclination from verticality – deg
Roll:	Tool relative bearing calculated from accelerometers - deg
Mroll:	Tool relative bearing calculated from magnetometers – deg
Magn.Field:	Magnetic field surrounding the borehole - µT
Gravity:	Absolute value of the Earth gravity – g
Orientation:	Orientation diagnostic code
WndTime:	Two way traveltime of acoustic window reflection – µsec
WndAmpl:	Amplitude of acoustic window reflection
System Status	General system diagnostic code
VTool:	Tool head voltage - V
V12:	Internal tool voltage - V
RTHead :	Temperature sensor resistance - ohms
TCPU :	CPU temperature - °C
T APS:	Temperature inside the deviation sensor - °C
T Head :	Acoustic head internal temperature - °C
MotSpeed:	Motor - Speed of rotation – rps
Motor:	Diagnostic code
Motor Period:	Time for a single revolution – sec

4.6.2 MChNum Browser Window

Figure 4-33 and 4-34 show typical examples of the numerical values displayed in the MChNum browser window during logging.

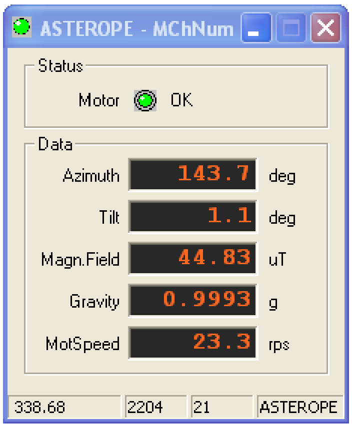


Figure 4-33 *MChNum browser display – example 1*

Motor:	Motor synchronisation status
Azimuth:	Azimuth from Magnetic North - deg
Tilt:	Inclination from verticality - deg
Magn.Field:	Magnetic field surrounding the borehole - µT
Gravity:	Absolute value of the earth gravity - G
MotSpeed:	Motor - Speed of rotation – rps

To display additional parameters in the MChNum browser right click on the MChNum browser title and select **Display Options** to add/remove channels and Led status.

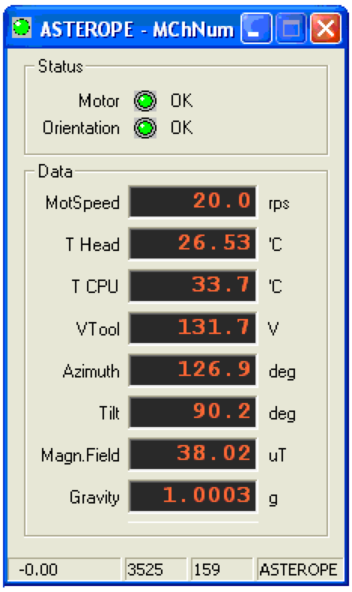


Figure 4-34 *Multi Channel Browser for Numerical Data (MChNum) displaying additional channels*

4.6.3 Surface Image Browser Window (AbiSurfaceImg)

The system returns an unwrapped image of the borehole wall based on the caliper and amplitude values of the recorded acoustic signal (Figure 4-35). The left column shows the caliper image and the right column the amplitude image.
These images consist of a succession of variable density colors. By double clicking on the log titles Minimum and Maximum scale values may be adjusted to enhance the log appearance.

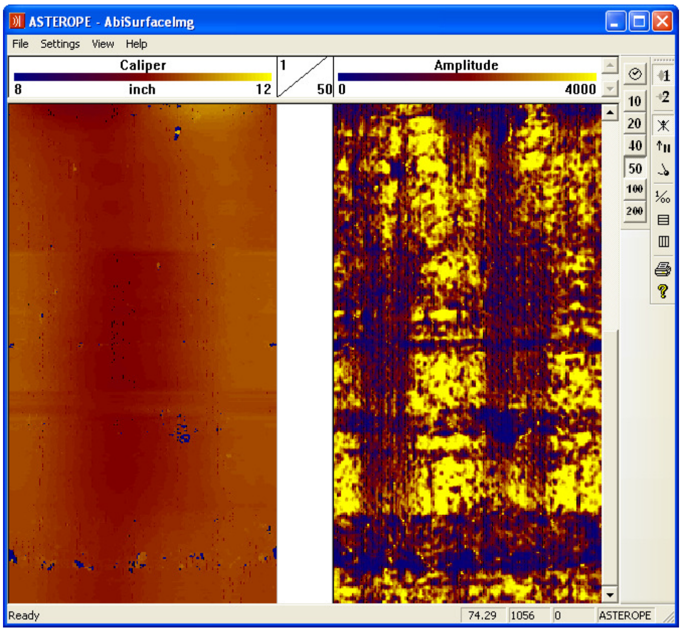


Figure 4-35 *ABI Surface Image browser window*

Note that the displayed units for the caliper log can be converted to either metric or imperial units via the menu bar's **Settings** option or by double clicking on the log title.

Echo selection :

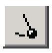
 Echo1 is displayed (borehole wall or inner side of the casing)

 Display Echo2 (borehole wall behind a PVC casing)

Image orientation:

 Image is non-oriented

 Orient image to magnetic North

 Orient image to High Side of the tool

There are two modes of tool data orientation: orientation to High Side and orientation to North. Orientation to High Side is used in inclined boreholes when magnetometers data are unavailable (for example in a cased hole).

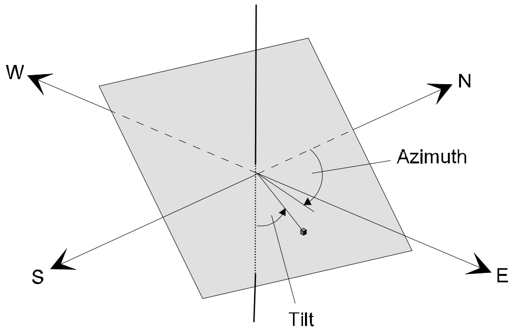
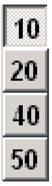


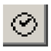
Figure 4-36 *Orientation to Magnetic North*

Vertical scales and grids:



Depth mode display and pre-defined depth scales


Operator defined depth scales, interval spacings and settings


Time mode display

4.6.4 Thickness Image Browser Window (AbiThicknessImg)

In Cased Hole Mode, the ABI Thickness browser displays on the left column an unwrapped color coded image of the **casing *thickness*** processed by the system (Figure 4-37). The right column is a color-coded image of the ***score****.* The ***score*** is a ***quality index*** on the thickness measurement. In a general way, high score values mean high reliability of the thickness measurement and the reverse.

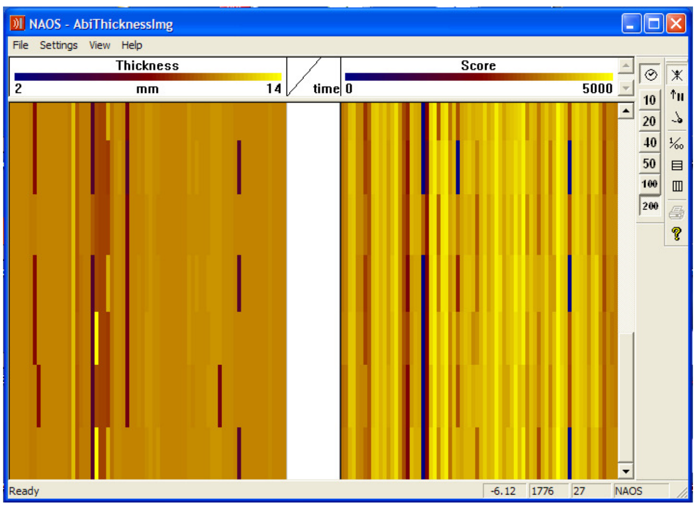


Figure 4-37 *ABI Thickness Image*

As for the Surface image browser, scales and units of the displayed parameters can be adjusted by double clicking on the log title or from the **Settings** option of the menu bar.

4.6.5 Caliper Browser Window (AbiCaliper)

Caliper browser - Open Hole Mode

The open hole caliper view (Figure 4-38) shows in real-time a cross-section of the acoustic caliper. Scaling, concentric gridding and displayed units are adjustable from the tool bar **“Settings”** option.

The black circle shows the external limit of the acoustic window.
The red circle is the cross section of the acoustic caliper corresponding to the main reflector detected by the system (borehole wall or inner surface of a casing).

As for the image browsers, the caliper view can be oriented to Magnetic North, High side or displayed without orientation.

During the acquisition, it is possible to centralize the caliper cross section to remove the effect of decentralization of the tool in the borehole.
Clicking the symbol  can do this.

Statistical caliper figures (Min, Max, Average) are displayed on the left side of the dialog box.

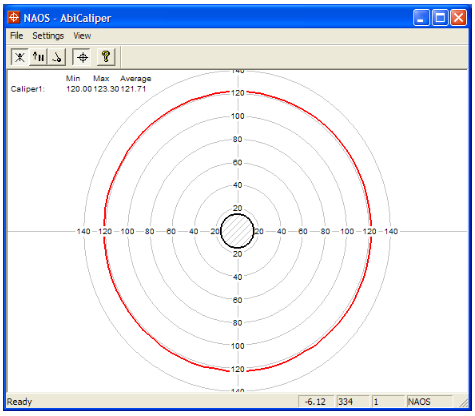


Figure 4-38 *ABI Caliper – Open Hole Mode*

Caliper browser – Behind PVC mode

The “Behind PVC” caliper view (Figure 4-39) shows in real-time a cross-section of the acoustic caliper of the PVC casing and borehole wall. Scaling, concentric gridding and displayed units are adjustable from the tool bar **“Settings”** option.

The red circle is the cross section of the acoustic caliper corresponding to the inner side of the PVC casing.
The orange circle is the cross section of the acoustic caliper corresponding to the borehole wall reflection.

As for the image browsers, the caliper view can be oriented to Magnetic North, High side or displayed without orientation.

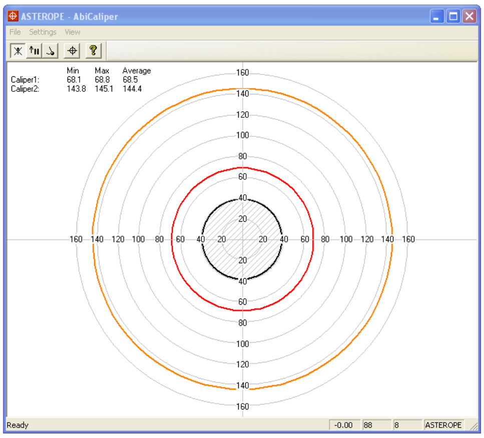


Figure 4-39 *ABI Caliper – Behind PVC Mode*

Caliper browser - Cased Hole Mode

Cross sections of both of the inner (red circle) and outer (orange circle) surface of the casing are shown in this browser (Figure 4-40), giving a good visualization of the casing thickness in real-time. The space between the 2 circles is filled with the corresponding color coded score values.
Orientation, scaling, concentric gridding and displayed units are adjustable from the menu bar's **Settings** option.

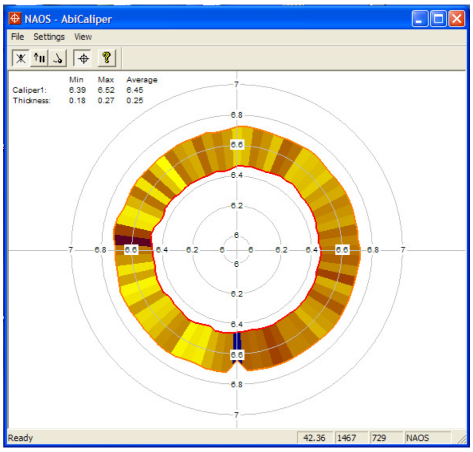


Figure 4-40 *ABI Caliper – Cased Hole Mode*

5 Performance Check & Calibration

5.1 Mirror rotation

Direction of motor rotation is **clockwise viewed from top of tool** (Figure 5-1):
Placing 2 fingers[3] on the acoustic window may check mirror rotation. In time mode, record the 2 finger traces shown[4] on the Abi surface browser. Remove your right finger from the acoustic window; the corresponding right finger trace on the Abi surface image should disappear.

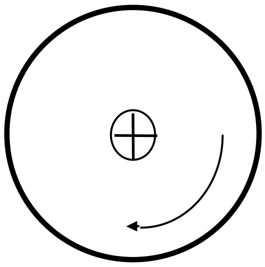


Figure 5-1 *Direction of mirror rotation*

5.2 Functionality test of the deviation system

5.2.1 Functionality test

The ABI's deviation system is factory calibrated and does not require further calibration. The functionality tests subsequently described have to be done to check that the tool is giving the correct deviation outputs:

To verify inclination at 0° and 90°, position the probe vertical (acoustic head pointing down) for 0° inclination and horizontal for 90° inclination. Note that uphole measurement is possible with the APS544 deviation system as it includes 3 accelerometers. In uphole, the inclination will be between 90° and 180° (probe vertical, acoustic head pointing up).

To verify azimuth accuracy, a good compass and an area free of magnetic materials must be used. Use a compass to orient North with the probe horizontal and verify that the azimuth reading is 0° ± 1°. Repeat the procedure for East, South and West directions.

5.2.2 Rolling test – azimuth and tilt check

Azimuth and tilt could be tested by rotating the tool about its long axis while maintaining both a constant inclination to the vertical, say 15°, and a fixed azimuth. The data imported into WellCAD should show a deviation of the azimuth less than the limit of ±1.5° and a deviation of the tilt less than the limit ±0.5°.

[3] Wet your fingers first for a better coupling
[4] Adjust the amplitude scale to enhance the finger traces

6 Maintenance

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT will void the tool warranty.

The ABI televiewer is a delicate instrument and should be treated with care at all times. Excessive shock or extreme temperatures should be avoided and the tool should always be transported in its transport case or a similarly cushioned enclosure. Never support the tool on the acoustic head. Experience shows that with attention to these points the QL40 ABI will give several years fault free operation.

The ABI televiewer separates into four basic parts

- The tool top adaptor
- The pressure housing
- The electronic chassis
- The acoustic head.

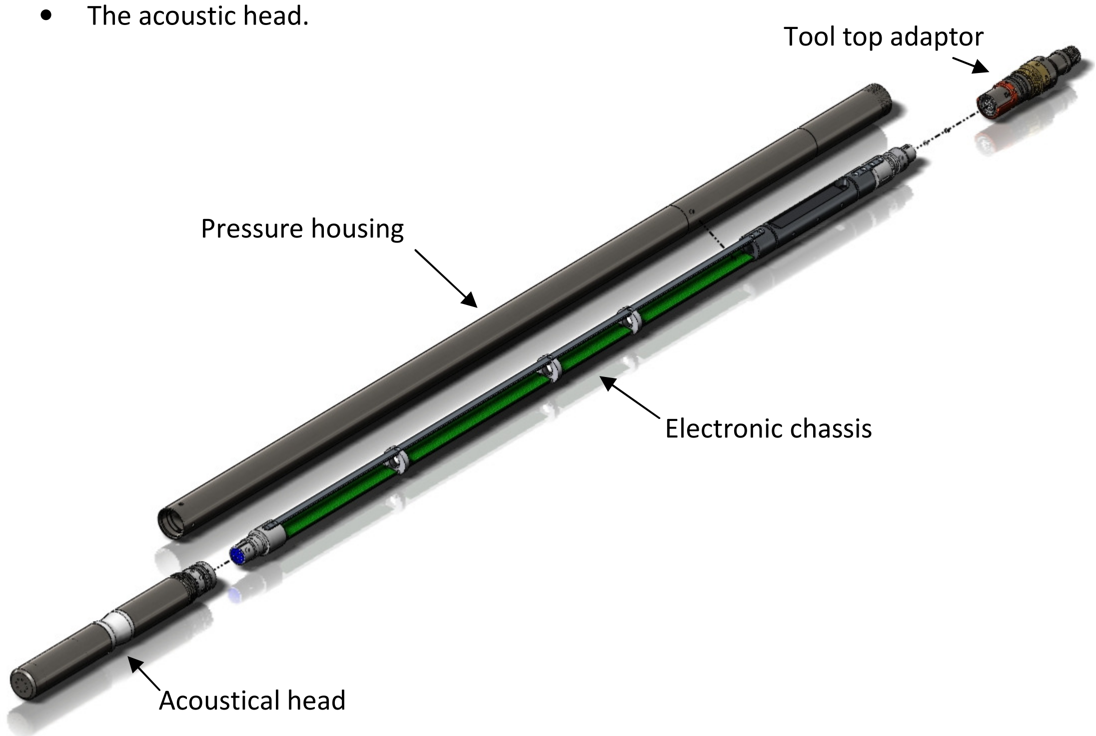


Figure 6-1 *ABI and tool top, exploded view*

Should it become necessary to open the tool, the tool parts must be separated in the following sequence:

1. Remove the tool top adapter
2. Remove the acoustic head
3. Remove the pressure housing

Disassembly of the electronic chassis from the pressure housing should never be attempted in the field.

6.1 Tool Top Adapter

The tool top adapter provides the connection between wireline cable head and chassis electronics and can be provided to suit 7 conductors, 4 conductors, mono or special wireline configurations. The adapter is fixed by the means of a threaded ring screwed in the pressure housing. To remove the tool top adapter, use the correct C spanners provided with the tool - see picture below (Figure 6-2).

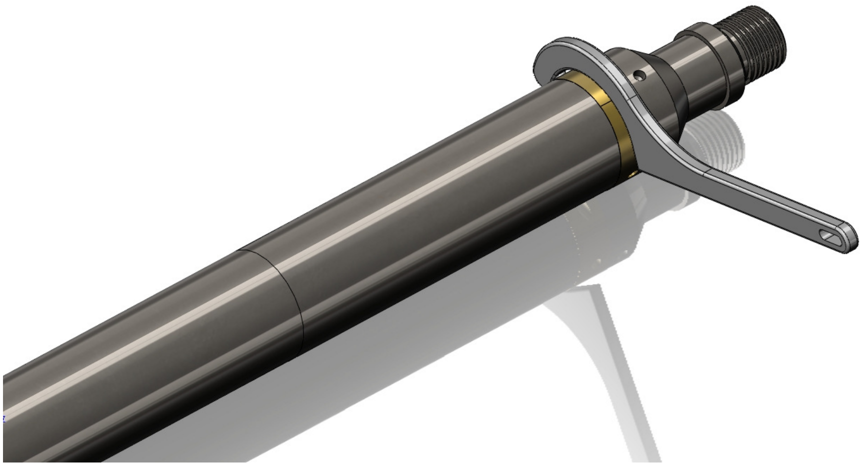


Figure 6-2 *Removing the tool top*

The wireline cable head socket and tool top adapter connector pins should be checked for cleanliness before each use of the tool. The pin inserts, whether 4 or 7 pin, have a locating mark indicating WL1 or A that should line up with the slot mating with the cable head.

Check O-Ring seals and apply silicon grease before re-assembly. Silicon grease of a similar type to RS Components Ref 494-124 is suitable for this and other O-Ring seals.
(Rem: O-Ring reference for tool top and for the quick link 40 is AS215 26,57 x 3,53 Viton Shore 75)

Figure 6-3 *QL40-GO4 Tool top adaptor*

Figure 6-4 *QL40-GO7 tool top adaptor*

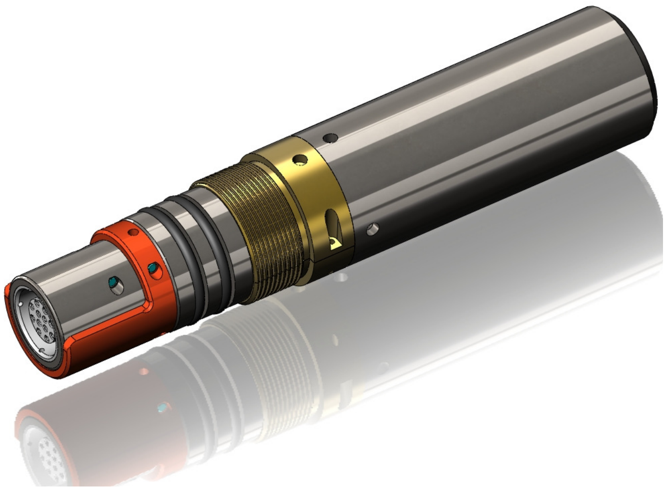


Figure 6-5 *QL40-GO1 tool top adaptor*

6.2 Acoustic head

Warning: The televiewer acoustic head is extremely delicate and must be treated gently at all times. Any laterally applied force on the end of the head is liable to cause damage!

The acoustic head is attached to the electronic chassis of the sonde by three 2.5mm hex set screws. To remove the entire televiewer head the tool top and pressure housing must first be removed as described below. Slacken off the fixing screws and slide the televiewer head off the connector. The connector has a keyway to locate the head with the correct orientation.

Figure 6-6 *Acoustical head*

Re-assembly is the same procedure in reverse order, but taking care not to force the head on to the connector. This will result in bent or broken connector pins! Check all “O” ring seals (Orings AS215, 26.57x3.53, viton, shore 75) and apply silicon grease to them.

The acoustic head needs to be properly maintained to give the best image results.
Note the following points:

- Check that there are no air bubbles visible in the acoustic window. Air can separate out of the oil filling the head, notably after airfreight at low pressure, and can also work its way out of the inner parts of the motor. The presence of air in the head is indicated by a spotty image or streaking. These effects may come and go as the orientation of the tool is changed.
- Check that there is not excessive lateral movement on the end of the head. The bellows cap must be screwed up against the acoustic window but not excessively tight.
- If the acoustic signal is lost, check for isolation between pins A&B in the acoustic head. The most common reason for loss of signal is the cutting of the signal coax to the transducer in the head. This happens when the window is rotated relative to the head body. Check with a gentle twisting motion that the window does not rotate more than a degree or two relative to the tool body.

- At very low temperatures the oil in the acoustic head becomes viscous and this may prevent the mirror from rotating. In this case keep the tool and head warm before use.

6.2.1 Cleaning the acoustic head bottom section

The bottom section of the televiewer assembly houses a pressure compensating bellows that must be free to move. For this reason the bellows cover is removable to allow cleaning of the exterior of the bellows. The interior of the bellows and main body of the televiewer head is oil filled. Both, the end of the bellows cover and its side wall, have holes to allow pressure equalization, and these holes must be kept clear. The bellows cover is threaded at the top end and held by a screw thread on the main body below the nylon window. The cover should only be **hand tightened**.

Keep the bellows section clean. This will prevent the deterioration of glue seals and the bellows itself. Grit lodged in the folds of the bellows can cause perforation if left over a period of time.

When removing the cover, it is important to **hold the nylon mirror section only,** which is locked integrally with the main tool, while unscrewing the cover. Wrenches must **NOT** be used (Figure 6-7 and Figure 6-8).

Warning: Any Rotation of the nylon section relative to the main tool pressure housing will result in damage to the head and probable tool failure.

The necessity for cleaning will depend on the borehole fluid and borehole conditions. The bellows should only be cleaned when the sonde was used in heavily contaminated fluids, i.e. heavy muds or sediments, or when the fluid is known to be corrosive. In this case it is important to clean deposits off the bellows where it is glued to the flanges at either end. The bellows wall is thin and can become perforated if allowed to corrode.

Figure 6-7 *Unscrewing the bellows cover*

Figure 6-8 *Bellows cover removed*

6.3 Pressure Housing

The main pressure housing is locked on to the televiewer head by four 2.5mm hex cap screws. After removal of the tool top, the pressure housing can be removed after undoing these screws. When separating the two parts, place the tool on suitable stands, grip the pressure housing with one hand and the acoustic head close to the joint with the other and apply a straight pull. During re-assembly extreme care should be taken not to over tighten the fixing screws which may shear off if overloaded!

The outside of the pressure housing is marked with a Y symbol to indicate the position of the Y axis vertical and upward. The purpose of this is to simplify tool checking.

When re-assembling the pressure housing make sure that the reference mark is correctly aligned with the upper side of the deviation sensor.

6.4 Upgrading ABI firmware

In accordance with the ALT policy of continuous development the ABI has been designed to allow firmware upgrades. The current version of firmware installed in a tool may be verified in the Tool Details window opened from the Tool Settings dialogue box.

Firmware upgrade procedure is as follows:
1. Checking the communication is valid.
2. Upgrading firmware

6.4.1 Checking the communication

1. Connect the ABI tool to your acquisition system.
2. Start ALTLog/Matrix software.
3. In the **Tool** panel select the appropriate tool and turn on the power.
4. In the **Communication** panel, select **Settings**. Check **baud rate** is set to **41666** and **communication status** is **valid** (Figure 6-9 or Figure 6-10).

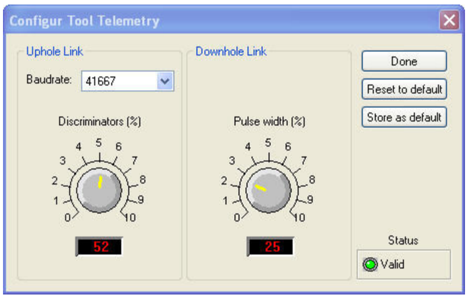


Figure 6-9 *Tool communication settings - ALTLog*

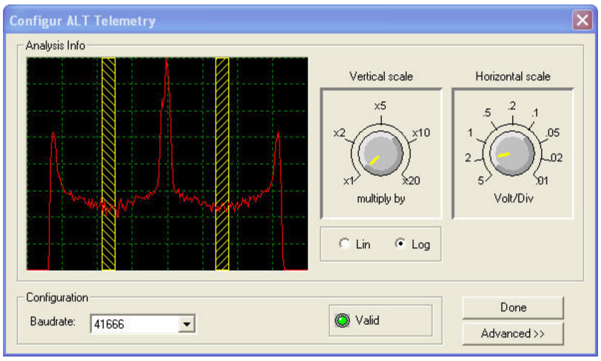


Figure 6-10 *Tool communication settings - Matrix*

Warning: Telemetry must be tuned properly. Bad communication may abort the upgrade of the firmware!

6.4.2 Upgrading the firmware

In the **Tool** panel, select **Tool settings/commands**. Check that the communication status is valid (Figure 6-11).

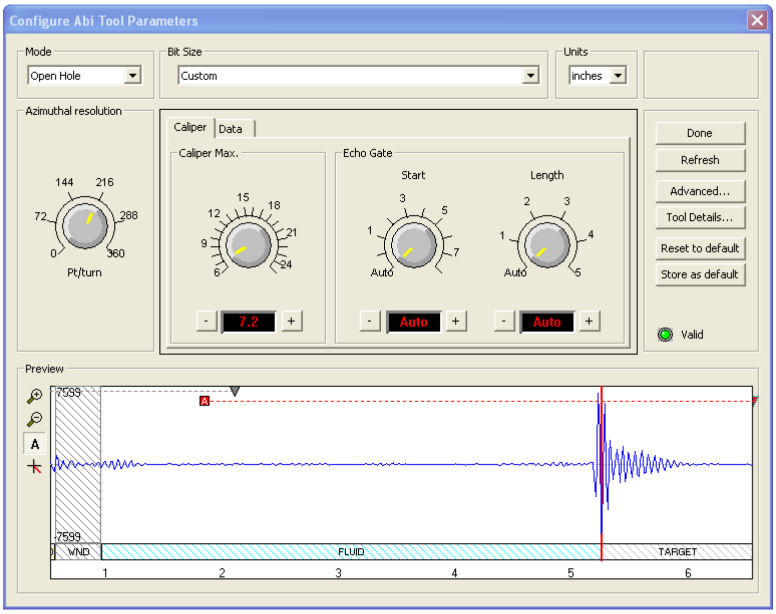


Figure 6-11 *Tool settings dialog box*

1. Click on **Tool Details**. Note that the firmware version currently in use is displayed in the firmware box. Click on the **Upgrade** button (Figure 6-12).

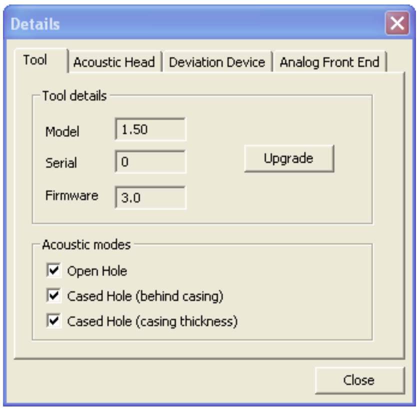


Figure 6-12 *Tool Details dialog box*

2. The following message will appear (Figure 6-13). Click **Yes** to validate your choice.

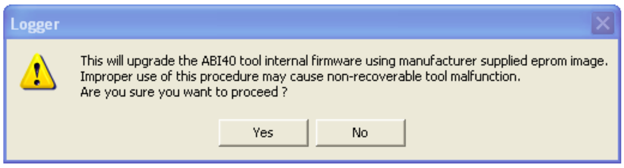


Figure 6-13 *Warning Message during firmware upload*

3. Select and open the appropriate **.hex** file provided (Figure 6-14). The upgrade will start.

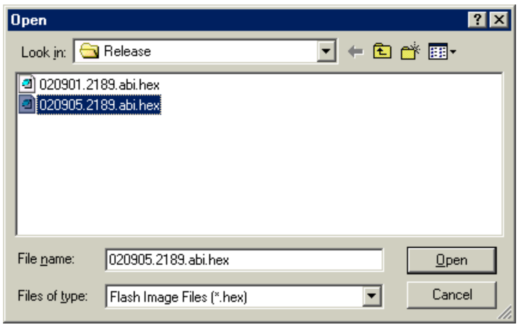


Figure 6-14 *Select firmware upgrade*

4. During the upgrade procedure, the following message is displayed:

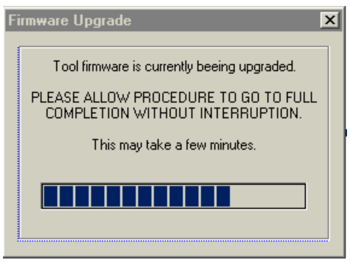


Figure 6-15 *Firmware upgrade progress window*

5. Once the upgrade has been successfully completed (Figure 6-16), click on **OK** to turn off the tool.

Figure 6-16 *Successful upgrade*

6. Power on the tool to start the upgraded firmware. Check in **Tool settings/commands** and **Tool details** that the firmware version has been changed with the new one.

Note that this error message (Figure 6-17) will appear at end of the procedure when the tool firmware upgrade has failed or has been aborted. Check tool communication settings.

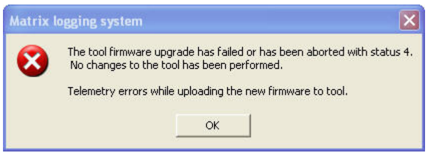


Figure 6-17 *Error message*

7 Troubleshooting

Observation	To Do
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been copied into the …/Tools folder (refer to MATRIX or ALTLog manual about details of the directory structure)?
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 4.5).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** **-**Possible short-circuit (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of a short-circuit. - If the above shows no issues, use test cable provided by ALT to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4). - If problem cannot be resolved contact support@alt.lu .
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can't receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed, decrease azimuthal resolution and/or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4). - Check bandwidth usage and telemetry error status.

Observation	To Do
Permanent No Sync message and red led status in MChNum browser. *Motor stalled and increase of current drawn by the tool.*	**! Immediately switch off the tool !** - Stepper motor and mirror synchronization issue. Contact ALT for Acoustic Head service.
WellCADimport : acoustic images not imported	- Check your WellCAD version (please refer to 1.3 Technical Specifications chapter).
WellCAD import : Magnetic North and High Side orientation options not available	- Check your WellCAD version (please refer to 1.3 Technical Specifications chapter).

8 Notes on Data Processing

The processing of data acquired with the QL40 ABI and the ABI 40 tools is usually performed using the WellCAD software. We would like to refer the user to the WellCAD user guides for a detailed description of the software's functionality. In particular *Book 3 - Image & Structure Module* should be of help when processing image data.
The following paragraphs will focus on three processes to process traveltime data for which the input of correct units and parameters is crucial in order to obtain accurate results.

8.1 Estimation of Fluid Velocity

The procedure described below outlines the estimation of the borehole fluid velocity which can be used as input for the computation of caliper data described hereafter.

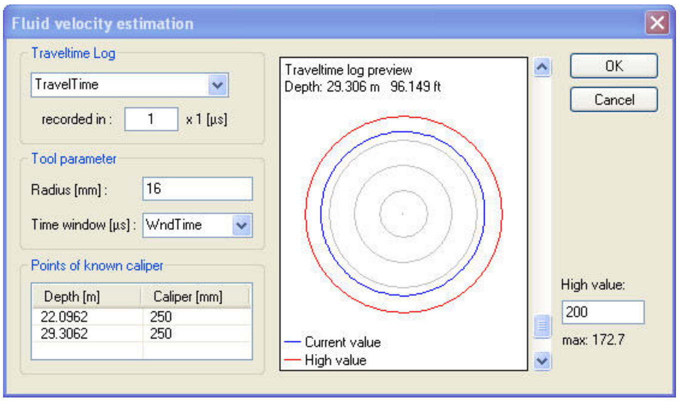
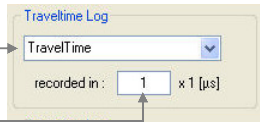


Figure 8-1 *Fluid velocity estimation dialog box*

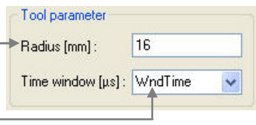
1. From the **Process > Image Module > Image Logs** menu in WellCAD select the **Estimate Fluid Velocity** entry. The corresponding options dialog box will open (Figure 8-1).

2. Select the TravelTime log from the corresponding drop down list in the dialog box.



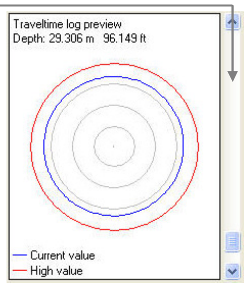
3. Set the unit the traveltime has been recorded in. For the QL40 ABI or ABI40 tool this manual refers to the unit is 1 µs. (Older tools measured in 0.1 µs. You can find out by double left clicking on the log title of the TravelTime log. The unit should show *µs*. If no unit is shown the measurement was made on *0.1 µs*.)

4. Enter the radius of the acoustic head at the measurement point into the corresponding edit box. For the ABI tools described here a value of 16 mm is appropriate.

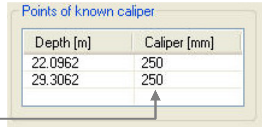


5. Select the Time window channel *WndTime* which contains the traveltimes from transducer to the acoustic head window and back (has been recorded by your tool along with the other measurements).

6. Use the scroll bar next to the preview of the cross sections generated from the traveltime data and find a depth at which the caliper of the pipe or borehole is known and best reflected by the measurement (for example the nominal internal diameter of casing or the bit size).



7. Right click into **Points of known caliper** list and add a new row for a reference point. The depth value will automatically set to the depth of the preview. Enter the known caliper value in [mm].



8. Try to set a least a reference point at or near the top and base of the well. Click **OK** when finished. A new log containing the estimated velocity profile will be created.

8.2 Computation of Caliper Data

The following steps summarize the steps to compute radius and caliper data from the acoustic traveltime recorded with your ABI tool:

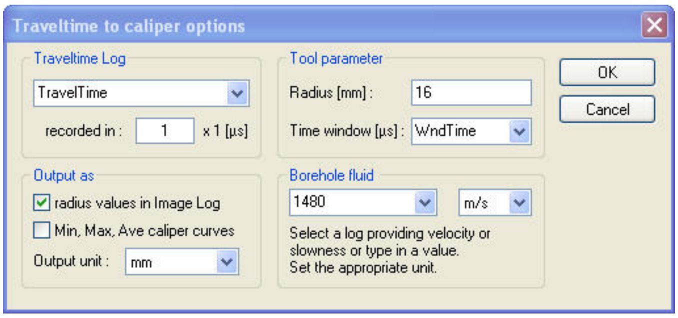
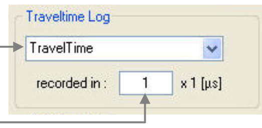


Figure 8-2 *Traveltime to caliper conversion dialog box*

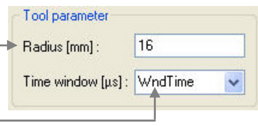
1. Select the **Calculate Caliper** process from the **Process > Image Module > Image Logs** menu. The options dialog box (Figure 8-2) will open.

2. Select the TravelTime log from the corresponding drop down list in the dialog box.



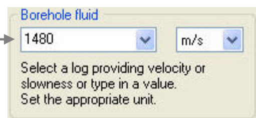
3. Set the unit the traveltime has been recorded in. For the QL40 ABI or ABI40 tool this manual refers to the unit must be set to 1 µs. (Older tools measured in 0.1 µs. You can find out by double left clicking on the log title of the TravelTime log. The unit should show *µs*. If no unit is shown the measurement was made on *0.1 µs.*)

4. Enter the radius of the acoustic head at the measurement point into the corresponding edit box. For the ABI tools described here a value of 16 mm is appropriate.

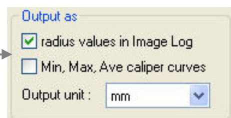


5. Select the Time window channel *WndTime* which contains the traveltimes from transducer to the acoustic head window and back (has been recorded by your tool along with the other measurements).

6. If you estimated a fluid velocity as described in the paragraph above or have measured values extend the drop down list and select the corresponding log. You can also enter a textbook value manually. Ensure the correct unit has been selected.



7. Select the output options and unit. You can create a new Image Log containing a radius value for each traveltime measurement. In addition you can create Min, Max and Average caliper curves.



8. Click on **OK** to close the dialog box ad start the computation.

8.3 Calculation of Casing Thickness

If you made measurements in cased hole mode you will get a log containing the traveltime within the steel casing (thickness travel time). The procedure described below summarizes the conversion of the thickness traveltime into a true thickness value.

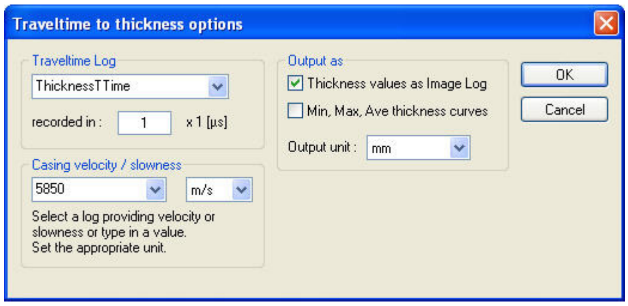
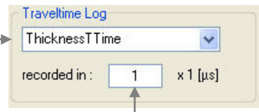


Figure 8-3 *Traveltime to casing thickness conversion dialog box*

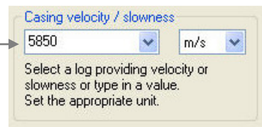
1. From the **Process > Image Module > Image Logs** menu in WellCAD select the Calculate Thickness… entry. The corresponding options dialog box will open (Figure 8-3).

2. Select the ThicknessTTime log from the corresponding drop down list in the dialog box.



3. Set the unit the thickness traveltime has been recorded in. For the QL40 ABI or ABI40 tool this manual refers to the unit must be set to 1 µs. (Older tools measured in 0.01 µs. You can find out by double left clicking on the log title of the ThicknessTTime log. The unit should show *µs*. If no unit is shown the measurement was made on *0.01 µs*.)

4. Enter the velocity of sound in steel into the corresponding edit box. A typical value for steel is 5850 m/s. If you have a velocity profile available in a log extend the drop down list and select the corresponding channel.



5. Choose the output option and unit. The thickness values can be given as a Image Log with on thickness value for each traveltime thickness measurement and as curve of the minimum, maximum and average thickness determined.

6. Click on **OK** to close the dialog box ad start the computation.

9 Appendix

9.1 Parts list

Detailed part numbers and descriptions are available for tool delivery and spare part kits. Please contact support@alt.lu for further details.

9.2 Technical drawings

The following technical drawings are available on request:

- 19” Rack connection diagram.
- Wiring Diagram.

Index

QL40-GAM
QL40 - GAMMA PROBE

(Preliminary)

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May 6, 2010

Table of Contents

General Information

QL40 Stackable Logging Tool Overview

QL stands for Quick Link and describes the latest line of stackable logging tools. This development is a joint venture of Mount Sopris Instruments (MSI) and Advanced Logic Technology (ALT). Innovative connections between tool elements (subs) allow users to build their own tool strings in the field.
The Tool Stack Factory – a sophisticated extension of the acquisition software – provides a convenient way to configure tool strings for operation.
Each sub has a Telemetry and Power supply element, the TelePSU, allowing them to operate individually without a separate telemetry sub. As a result all QL subs can be operated as standalone probes or in combination with other subs. The GenCPU card in each measurement handles Analog to Digital conversion and/or counting of the measurement signal and formatting of the data for transmission up hole.
When used as a standalone or stack of active subs the tool is completed by adding a Tool Top sub and where applicable a Tool Bottom sub. At present two Top subs are available, a MSI single conductor and GOI 4 conductor. Consult the factory for additional options.
The number 40 indicates a nominal OD of 40mm. Over coating and special measurements may make some subs larger in diameter than this. See their particular specifications.

Minimum requirements:

Matrix v10.3 software with appropriate Matrix Logger firmware
See the installation instructions for Matrix software for more information.

Controls, Connectors, and Layout

Connectors for the tool are as follows. The probe top described below is a Mount Sopris standard single conductor probe top. Other variations of probe tops and wiring can be accommodated at the factory such as the GO-4 probe top listed below.

Probe Top sub connections:

MSI-1 conductor

Pin	Signal	Origin
Probe top housing	Tool power ground	Armor
Center pin in probe top	Tool power positive	Center conductor

GOI-4 conductor

Pin	Signal	Origin
Probe top housing	Tool power ground	Armor
1	Tool power positive	Com A&B
2, 4	No Connection	No Connection
3	Tool power positive	Com C&D

QL40-GAM
The QL40-GAM sub provides natural gamma measurement. The QL40-GAM can be operated as a stand-alone probe or can be stacked above or below another sub on a MATRIX logging system.

GAMMA

The natural gamma measurement is made by the use of a sodium Iodide crystal, which when struck by a gamma ray emits a pulse of light. This pulse of light is then amplified by a photo multiplier tube, which outputs a current pulse. These pulses are then detected, digitized and combined with data from other subs (if present in the stack). The data is then transmitted up the wireline using a pulse coded digital data protocol.

QL40 GAM Specifications:

Power Requirements
DC voltage at probe top. MIN. 80 VDC MAX. 160 VDC Nominal 120VDC
Current 38 mA nominal

Gamma Detector
NaI (tl) 0.875" dia X 3.0" long 22.22mm dia. x 76.2mm long

Gamma Detector measuring location
162 cm up from bottom of locking ring

Operating temperature range
32 to 158 degrees F 0 to 70 degrees C

Pressure rating
2900 psi	200 bars

Dimensions
Length	42.13 inches	107 cm
Diameter	1.66 inches	42.3 mm with neoprene heat shrink and PVC electrical tape
Weight	10.3 lbs	4.67 kg

Installation

Installing the QL40-GAM and support equipment

Before operating the QL40-Gam, Gamma sub, determine if the sub will be used in a stand-alone configuration, or if it will be used in conjunction with another QL Series sub.
The subs are connected by threading the male end of the top sub into the next lower one. Note the key way.
Remove the bottom protector from the Top sub. The GOI-4 Top sub is shown below:

Locate the spanner wrenches as shown below:

Align the top sub with the key way inside the female housing of the next section. Inspect all O-rings for defects and make sure threads are clean. Threads and O-rings should be lightly greased. Do not use silicone grease intended for O-rings on threads. When connecting subs, it is best to balance each sub section on a tool stand so that the ends join with no load. See photo below.

Slide the top sub in until the threads meet the mating ones inside the housing. Start turning the brass nut by hand until the threads engage. Slightly raise or lower the joint so the pieces mate evenly and the threads turn easily.
Warning: Do not force the threads! When properly aligned they should turn smoothly.
Use the spanner wrenches to tighten the threads until the brass nut is fully engaged. **Do not use cheater bars on the spanner wrenches.**
The threads should go on smoothly. If they are binding adjust the supported location top or bottom section so they are level and evenly aligned.

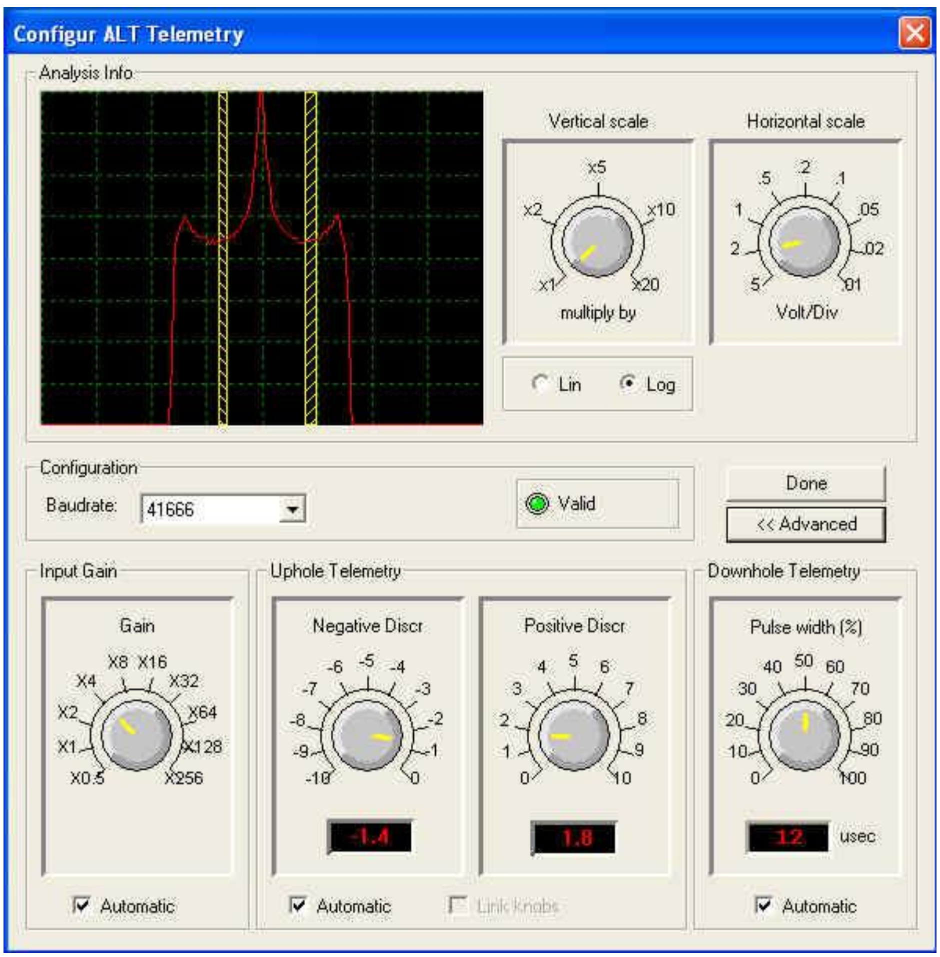
Gamma stand alone mode

In order to operate the sub as a stand-alone probe, a top and bottom sub must be connected to the sub. Remove the probe-top thread protector from the top sub then thread the top sub onto the cablehead of the winch assembly. Inspect the o-ring on the cablehead for cuts or abrasions before each use to ensure an adequate seal. See the logging software operating instructions to configure it to log this tool.

Operating Procedure

Operation

To use the QL40-Gam, Gamma with the MATRIX logging system, make sure the correct sub files are installed in the C:\Logger\Tools\QL40-12 directory. The files are most easily installed using **LoggerSettings.exe** utility program supplied with the software installation. QL40 sub files may be found on the installation or separate CD.
In the case of the Matrix logger, the power settings are set to default values used for all probes equipped with the QL TelePSU downhole power supply. Different wirelines may require some adjustment to the telemetry. These settings are accessed by pressing the Settings button in the Telemetry section of the Matrix dashboard. The user may also view the pulse stream on the cable line by pressing on the Scope button. To change telemetry settings, press the properties button after the Modem Settings window appears. The user can observe the discriminator settings and make changes as necessary using the “Advanced Settings” button in the Telemetry window on the dashboard. The two discriminator bars should be placed in the middle of the displayed troughs, as shown in the following figure. When correct discriminator settings are made, SAVE the configuration, naming it as to describe the wireline configuration and the settings will be recorded for future use. In general the “factory” settings will not need adjustment.



Performance Checks and Calibrations

Calibrations are performed at the factory and require a basic knowledge and understanding of the tool. In the event the user feels the tool needs to be calibrated it is advisable to speak with a representative of Mount Sopris. Performance checks for the gamma measurement can be made on the surface before logging. With the tool powered on and viewing data on the computer screen a small source of natural gamma radiation can be placed in close proximity to the detector area about 6 inches above the bottom of the probe. An increase in gamma counts will then be observed on the computer screen if the tool is working properly. API and uranium K factor calibrations are available for this sub. Contact the factory for details.

Preventative Maintenance

The QL40 series tools require some maintenance. Make sure the threads on the brass nut on the sub bottom are free of sand mud or other dirt. A thin layer of anti-seize is recommended. When disassembling the sub string dry the joint as it is separated to prevent fluid from entering the sub top and getting into the Lemo electrical connector inside.
After replacing top and bottom protectors it is good to wash the probe off after each use. ***Never take the probe apart. This probe is very difficult to disassemble and requires special steps to be taken in order to gain access to the inside of the probe without damaging the electronics. If you have read this after attempting to disassemble the probe chances are the probe has experienced damage and will need to be sent to the factory to be repaired.*** Inspect O-rings occasionally and keep the threads on both ends of the probe clean, to minimize problems in the future.
The heart of the gamma section is the photo multiplier tube and the sodium iodide crystal. Both units are very fragile and can be damaged if the probe is dropped or experiences a very abrupt temperature or mechanical shock. Take great care while handling or packing the probe for transportation.

Locking Ring assembly Maintenance

Tools required:

1.5mm Allen wrench
2 ea 40-42mm spanner wrench
Paper towels or clean rags

Replacement Parts:

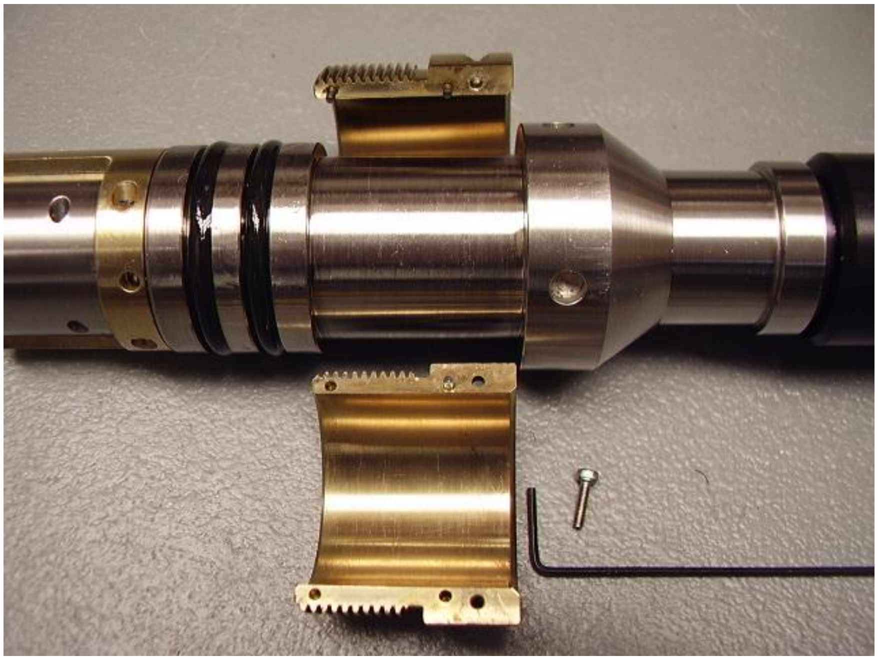
ALT26005, Large Threaded Ring, Qty 2
28-174-995 M2x8 SHCS, Qty 2

Disassembly:

Unscrew and remove the two M2x8 socket head cap screws and separate the two halves.
Four guide pins align the two ring halves and tend to hold them together after the screws are removed. To pry the halves apart you can use a pair of spanner wrenches inserted into the wrench holes on opposite sides of the ring mating surfaces to pull them apart slightly.

Do this carefully to prevent bending the guide pins.

Place something small in the opening and move the spanners to the other side and pry it open slightly. This should be enough to release the two rings as below.



Clean inside surfaces thoroughly and reassemble, coating the inside with a very light film of anti-seize compound. Nickel based compounds are best, to prevent any sticking between the brass and steel surfaces

Troubleshooting

Problems with the Tool

NEVER DIS-ASSEMBLE THE PROBE WITHOUT CONSULTING THE FACTORY FIRST

Disassembly Instructions

The QL40-GAM Gamma Probe should **never be disassembled** unless service is necessary. This is a very difficult probe to disassemble, and is highly recommended that any service be performed by Mount Sopris, ALT or a qualified technician.

Appendix

Suggested QA Procedure

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris family of acquisition programs records the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

Casing and Water Factors for QL40-GAM (to be developed in the near future)
Similar factors exist for the Mount Sopris 2PGA probe, which may be used as close approximations. See the 2PGA manual for details

2PGA-1000
POLY- GAMMA PROBE

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
October 10 2002

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General Information

Overview

The 2PGA-1000 Poly-Gamma is a combination probe providing natural gamma, spontaneous potential (SP), and single point resistance (SPR), measurements. The operator must make these measurements in two separate runs. i.e. the gamma is made in one run and the S.P. , and SPR are made together on the second run. The Poly-Gamma probe is also the base foundation for the Poly series of probes. The Poly-Gamma when connected to a Poly-Resistivity probe is capable of making multiple Normal resistance measurements along with the, above-mentioned, Poly Gamma measurements, all in one run. The Poly-Gamma probe can be operated as a stand-alone probe on an MGX, MGX II or any other system capable of supplying the correct power. The Poly-Gamma connected to the Poly-Resistivity section can only be operated with the MGX II system.

The SP and SPR measurements must be run in open (uncased), fluid filled, boreholes. The natural gamma may be run in any borehole conditions within specifications.

Controls, Connectors, and Layout

Connectors for the tool are as follows. The probe top described below is a Mount Sopris standard single conductor probe top. Other variations of probe tops and wiring can be accommodated at the factory but will not be discussed in this document.

PROBE TOP CONNECTOR:

Pin	Signal	Origin
Probe top housing	Tool power ground	Armor
Center pin in probe top	Tool power positive	Center conductor

BOTTOM CONNECTOR:

This connector is made of rings and the numbering of the rings begins from the inner most ring.

Ring	Signal	Origin
1	SP, SPR or 64" Normal	Electrode below probe top
2	Center conductor	Center pin on probe top
3	Pulse return	Returns Gamma pulse to center cond.
4	Pulse	Output from Gamma circuit
5	Armor	Armor of probe top
6	Gate	From Poly Electric tool

Layout for the tool in general is as follows starting at the bottom of the tool. The bottom connector is below the scintillation crystal and Photo multiplier. Next is the electronic section for the gamma and electric measurements, followed by the electrode and probe top.

Theory of Operation

SINGLE POINT RESISTANCE

The single point resistance measurement is made by passing an AC current between a surface electrode or (mud plug), and the probe electrode. The probe electrode is located just below the probe top and should be the only piece of metal exposed during the logging process. The surface electronics rectifies the AC voltage between these two electrodes and by using Ohms law the system calculates the resistance between them.

Ohms law: $r = E / I$

r = resistance in ohms;
E = potential in volts;
I = current in amperes.

The SPR measurement is the sum of cable resistance, and the resistance based on the composition of the medium, the cross sectional area and length of the path through the medium. Therefore the single point resistance log is not quantitative.

SPONTANEOUS POTENTIAL

The spontaneous potential, also known as self-potential or SP uses the same electrodes as the SPR measurement. This natural potential, which originates from electrochemical differences between borehole and formation fluid, or electro-kinetic "streaming" is measured by the surface electronics. The circuit measures a DC voltage between the surface electrode and the probe electrode. This potential may be positive and /or negative with respect to the surface electrode.

GAMMA

The natural gamma measurement is made by the use of a Sodium Iodide crystal, which when struck by a gamma ray emits a pulse of light. This pulse of light is then amplified by a Photo multiplier tube, which outputs a current pulse. These pulses are then detected, shaped and transmitted up the cable line. The center of the Sodium Iodide crystal is approximately 20 inches, or 508 mm below the center of the R & SP electrode. The approximate location of the gamma detector is referenced by a band of colored tape on the housing of the probe. The user must maintain this band of tape, or marker, as it may tend to degrade with use of the tool. When a Poly Gamma tool is used in conjunction with the Poly Electric tool, the pulses are sent down to the circuitry in the Poly resistivity and sent up the cable in a digital format.

The Poly Gamma tool is capable of using a power source that is positive or negative with respect to the armor. This gives the tool more flexibility and reduces the risk of damage to the tool due to a wrong switch position or the choice of a wrong probe file. Worthy of note is the crystal detector and the Photo multiplier tube. Both of these devices are fragile at best and are quit costly to replace. Sopris has taken steps to afford these items as much protection as possible. These items are subject to be damaged by sudden shock so when shipping or transporting the tool ensure it has proper protection from vibration and shock to reduce the chances of damage.

2PGA-1000: Specifications:

Power Requirements
DC. voltage + or - at probe top. MIN. 52 VDC MAX. 88 VDC@ 35mA nominal, 100mA start up.

Tool Output
Positive pulse, 1.25uS wide, adjustable if required.

Gamma Detector
NaI (tl) .875" dia X 3.0" long 22.22mm dia. X 76.2mm long

Gamma Detector location
Using the center of the R & SP electrode measure towards the bottom of the tool 20”, or 508 mm.

Operating temperature range
14 to 120 degrees F -10 to 50 degrees C

Pressure rating
2000 PSI 13789 k PASCAL

Dimensions

Length	31.3 inches	79.5 cm	
Diameter	1.63 inches	4.1 cm	with neoprene heat shrink and PVC electrical tape
Weight	7 lbs	3.2 kg	

Installation

Installing the Poly - Gamma and support equipment

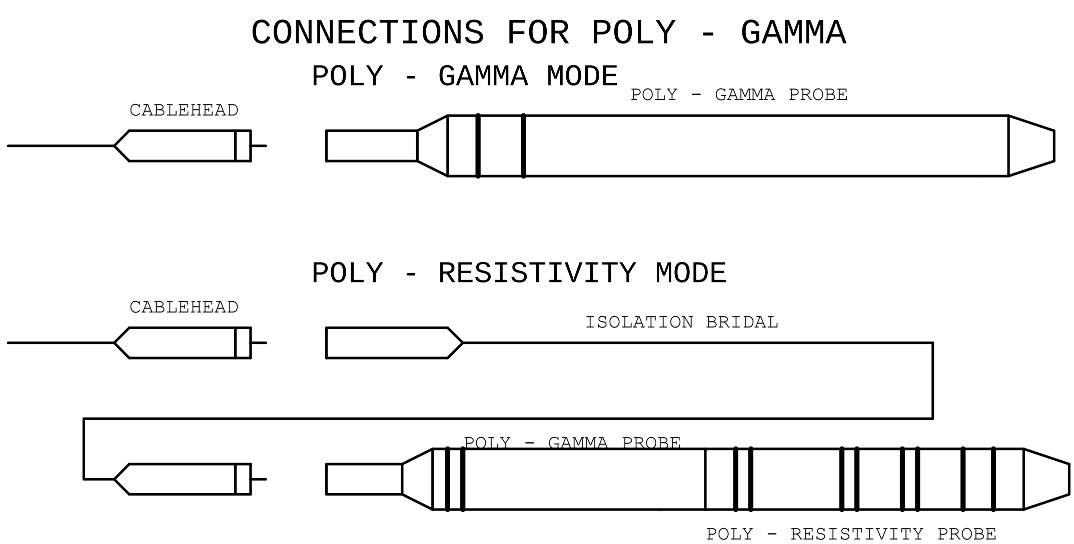
Before operating the Poly - Gamma probe, determine if the probe will be used as a stand-alone probe, or if it will be used in conjunction with a Poly Series probe.

Poly - Gamma stand alone mode

In order to operate the probe in the borehole the lower thread protector must be installed in the bottom of the probe. This thread protector seals out any borehole fluid and shorts two of the rings on the bottom connector of the probe, to send the pulses from the gamma circuitry up the cable line. Remove the thread protector from the probe top then thread the probe top onto the cablehead of the winch assembly. Inspect the o-ring on the cablehead for cuts or abrasions before each use to ensure an adequate seal. If you are going to run a Spontaneous Potential log, the probe top and cablehead, including the spring, must be taped at least 2 feet above the measure electrode. Follow the operating instructions in this manual or in the logging software before logging in regards to this tool.

Poly - Resistivity mode

If the Poly - Gamma is to be used in conjunction with the Poly - Resistivity probe you will need to remove the thread protector from the bottom of the Poly - Gamma probe. Then remove the thread protector from the top of the Poly - Resistivity probe. Thread the two probes together and hand tighten this connection. With a roll of PVC electrical tape, cover all exposed metal surfaces at this connection, not the electrode located just below this connection. Next you will need to install the isolation bridal. This bridal comes as an accessory to the Poly - Resistivity probe and must be used in order to achieve a valid measurement. Install the bridal on the cablehead first by only rotating the bridal and not the cablehead. This is easily done by extending the bridal to its full length. Damage to the cablehead may occur if any other methods are used. Next remove the thread protector from the probe top of the Poly - Gamma and thread the probe onto the bridal assembly, rotating only the probe assemblies. Cover all exposed metal surfaces at this connection, but not the electrode, with PVC electrical tape. Follow the operating instructions in the Poly - Resistivity manual or in the logging software before logging.



Operating Procedure

Operation

SP & SPR MEASUREMENTS

Operation of the Poly - Gamma probe is as follows. These operation instructions discuss running the SP & SPR measurements first, while logging down the borehole. When the desired logging depth has been reached, the system will then be set up to log the gamma measurement out of the borehole. These instructions are only for discussion and the user can determine for themselves which measurement will be taken in what order. After the user has determined from the **Installation** section what mode the tool will be used in, they will also need to set up the surface equipment properly. If the tool is to be used with an MGX version of surface logger, the surface electrode or mud plug must have a good, consistent electrical contact with the earth and the other end plugged into the banana jack located on the logger. Place the tool selection switch on the logger to the ELECTRIC position. Following the instructions for the logger and choosing the correct probe file, turn the PROBE POWER switch to the ON position. At this time the user may want to calibrate the system, which is discussed in detail in the MGX manual. If the system has been prepared for logging, lower the probe into the borehole and zero the tool for proper depth correlation. Follow the logging instructions for the MGX logger to begin the logging process. When the desired logging depth has been reached, turn the TOOL POWER switch to the OFF or center position.

GAMMA MEASUREMENTS

The gamma measurement will now be logged out of the borehole. Following the instructions for the logger, and choosing the correct probe file, place the tool selection switch to the PULSE 2 position and turn the TOOL POWER to the ON position. Follow the logging instructions for the MGX logger to begin the logging process. When the logging process has ended, ensure that the TOOL POWER switch is in the OFF or center position before removing the probe from the cablehead.

USE WITH AN MGX II SYSTEM

To use the Poly - Gamma with the MGX II logging system, obtaining both logs are much the same as described above with the MGX logger. The main difference is the MGX II system has no switches for tool selection or PROBE POWER switches. These functions are achieved on the MGX II logger internally, by the use of electronics and the MSLog software. Complete logging instructions for the MGX II are discussed in detail in the MGX II and MSLog manual and should be referred to if any question arise.

Performance Checks and Calibrations

Calibrations are performed at the factory and require a basic knowledge and understanding of the tool. In the event the user feels the tool needs to be calibrated it is advisable to speak with a representative of Mount Sopris. Performance checks for the gamma measurement can be made on the surface before logging. With the tool powered on and viewing data on the computer screen a small source of natural gamma radiation can be placed in close proximity to the detector area about 6 inches above the bottom of the probe. An increase in gamma counts will then be observed on the computer screen if the tool is working properly. To verify the electric measurements are working the user may use a calibration box, available from Mount Sopris, which when connected properly to the system, provides different resistance and voltage values for calibration. To check the Electrode of the tool for connection place an Ohmmeter set to read ohms on the center conductor of the probe top. Place the other meter lead on the electrode. The meter should read approximately 620 ohms.

Preventative Maintenance

The 2PGA-1000 Poly - Gamma requires little maintenance other than washing the probe off after each use. ***Never take the probe apart. This probe is very difficult to disassemble and requires special steps to be taken in order to gain access to the inside of the probe without damaging the electronics. If you have read this after attempting to disassemble the probe chances are the probe has experienced damage and will need repaired.*** Inspecting o-rings occasionally and keeping the threads on both ends of the probe clean, will minimize problems in the future. The heart of the gamma section is the Photo multiplier tube and the Sodium Iodide crystal. Both units are very fragile and can be damaged if the probe is dropped or sees very abrupt shock. Take great care while handling or packing the probe for transportation.

Troubleshooting

Problems with the Tool

In the event the tool develops a problem, follow the troubleshooting procedure listed below.
NEVER DIS-ASSEMBLE THE PROBE WITHOUT KNOWLEDGE OF PROCEDURE

GAMMA Problems

No counts from the probe.

1. Are the MGX switches set correctly? **PULSE 2** and **ON** positions.
2. Are the PROBE CURRENT and PROBE POWER LED's on?
3. Is the correct probe file being used? MGX and MGX II versions.
4. Check cable for conductive leakage across the center conductor to ARMOR. (20 Meg MIN.)
5. Is the thread protector installed in the bottom of the probe in the stand-alone mode?
6. Is the logger supplying the correct voltage as specified in this document?
7. If no result from the above , consult Mount Sopris.

SP & SPR Problems

Troubles with electric logs.

1. Check that the MGX or MGX II is connected properly.
2. Ensure surface electrode is placed in the ground and add some water to this area if possible.
3. Check switch setting on the logger, **ELECTRIC** and **ON** positions, and ensure the correct probe file is in use.
4. If no response from the above, remove the probe from the cablehead and with a DVM set to read ohms check the resistance from the center pin in the probe top to the electrode located below the probe top. The meter should read 620 Ohms.
5. While cablehead is disconnected from step 4 check the cable line for leakage from the center conductor to the ARMOR. (20 Meg MIN.)
6. If no result from the above consult Mount Sopris.

Disassembly Instructions

The 2PGA-1000 Poly -Gamma Probe should **never be disassembled** unless service is necessary. This is a very difficult probe to disassemble, and is highly recommended that any service be performed by Mount Sopris or a qualified technician. An M3 socket head cap screw has been placed near the top of the probe to prevent the housing from being accidentally turned off the probe top. If probe must be entered first remove the bull-nose from the bottom of the probe. Use a long M3 screw and anchor it into the center of the slip-ring connector in the bottom of the probe. Pull the slip-ring connector straight out and remove the connector from the rear. Now remove the M3 socket head screw from joint of the housing and probe top. Unscrew the housing from the probe top and slide housing off. Use care with the fragile PMT and crystal inside. Reverse steps to re-assemble.

Schematics

Available upon request

2PGA-1000

Drawing #	500S-2094	50002094A.S01	Title: Power Supply, Disc, Pulse Driver
Drawing #	500S-2094	50002094A.S02	Title: High Voltage Osc. And Dynode Multiplier
Drawing #	500S-2067	50002067A.S01	Title: High Voltage Interface
Drawing #	500K-2074	50002074A.S01	Title: Signal Cable Poly Gamma

Appendix

Suggested QA Procedure

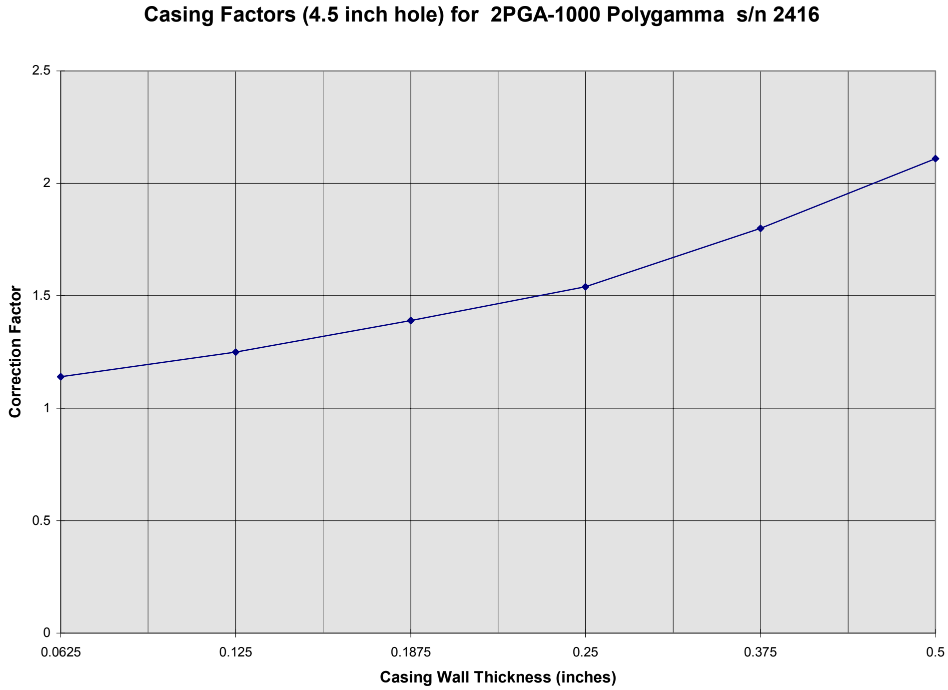
General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

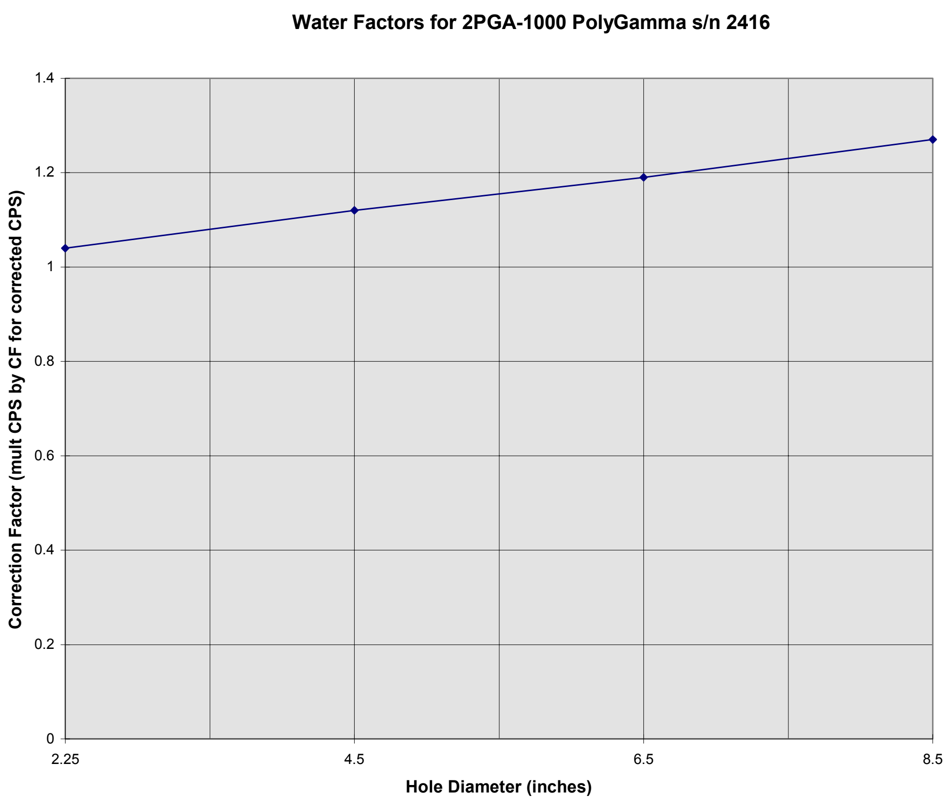
When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris family of Acquire programs records the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

Casing and Water Factors for 2PGA-1000





2PIA-1000
POLY INDUCTION PROBE,
2EMA-1000 Conductivity Probe
(2EMB-1000 and 2EMC-1000)
EMP-2493 and EMP-4493

Mount Sopris Instrument Co., Inc.
Golden CO U.S.A.
September 5, 2002

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Tables and Figures

The majority of information in this manual is from:

Geonics Limited, 1992, “Geonics EM39 Borehole Conductivity Logger Operating Manual”, Geonics Limited, Mississauga, Ontario, Canada.
Geonics Limited, 1986 Technical Note TN-20, “Geonics EM39 Borehole Conductivity Meter Theory of Operation”, Geonics Limited, Mississauge, Ontario, Canada.

General Information

Overview

The 2PIA-1000, 2EMA-1000 and EMP-2493 probes measure the conductivity and magnetic susceptibility of the material around the probe. The 2PIA-1000, probe is provided with the standard Poly probe top, which will enable the user to run the induction tool beneath the 2PGA-1000, Poly - Gamma. It can be run stand alone when used with the 2ADP-1000 probe top adapter.

The 2EMA-1000, probe indicates a tool with the Mount Sopris Instruments single conductor probe top attached while the 2EMB-1000, version has the Mount Sopris 4 conductor probe top. The 2EMC-1000, version has the GOI 4 conductor probe top.

The EMP-2493 is the original designation for the 2EMA-1000 and the EMP-4493 is the four-conductor probe top version. The very first versions of these probes had a different pulse driver circuit than is now used in the 2EMA-1000. The original pulse driver put out a smaller pulse height. Many EMP-2493 have been updated with a pulse drive circuit with characteristics similar to the 2EMA-1000. If you have the original pulse drive electronics you should select the appropriate tool driver in MSLog otherwise the tool driver for the 2EMA-1000 is correct. In all other respects the EMP-2493 is the same as the 2EMA-1000 and comments concerning the 2EMB-1000 and 2EMC-1000 apply to the EMP-4493.

These probes are based on the Geonics EM-39 slimline induction tool. Conductivity is measured in millisiemens per meter (mS/m) and the Magnetic Susceptibility is measured in percent of primary magnetic field. The tool has been optimized for conductivity readings therefore Magnetic Susceptibility measurements may be qualitative rather than quantitative.

In the following document the probes will be referred to generically as the induction probe. Features specific to individual models will be referred to by model number as above. References to the 2EMA-1000 are applicable to the 2EMC-1000 and 2EMB-1000 other than the cable head type they are used with. Earlier versions of the probe such as the EMP-2493 are essentially the same except a few that have the original pulse drive circuitry.

Some models, except for the 2PIA-1000, have Magnetic Susceptibility outputs connected as the negative pulse output. Some tool, driver files have this channel enabled some do not. Consult Mount Sopris Instruments with questions.

Controls, Connectors, and Layout

Controls for the induction probe consist of a rotary switch located inside the probe. To manually set this range switch you will need to open the probe by unscrewing the housing at the joint just above where the black heat shrink ends at the probe top. Remove housing and locate the range select switch using Figure 1. Set the switch as per Table 2. To have the tool select two ranges automatically refer to Table 3. Note that when the automatic selection is desired the switch must be set to position 5, for the surface equipment to be able to switch ranges in the tool. The factory setting is position 5, for the range switch.

Connectors for the 2PIA-1000 consist of the slip ring connector on top of the probe top. This connector mates with an identical connector when the tool is attached to a 2PGA-1000 Poly - Gamma or a 2ADP-1000 Poly top adapter. The slip ring connector has 6 conductors, with 1 being the inner most ring and continuing to the outer ring which is number 6. The ring functions and labels are listed below

Ring	Signal	Origin
1	Not used	Not used
2	Power	CL, center cond.
3	Not used	Not used
4	External Pulse input	Poly Gamma tool, 2ADP
5	Power	Armor
6	Mag Sucep Pulse output	From the EM-39 tool

Table 1 2PIA-1000 Poly Probe Top Connector

Layout for the tool in general is as follows, starting at the bottom of the tool. On the bottom of the housing is a black Delrin thread protector that can be removed and replaced with the weight section provided with the probe. The top of the housing is about 16cm below the probe top. At the top of the probe is the thread protector and Poly or other style probe top. Internal electronics from the bottom of the tool consist of a series of coils and In-phase and Quadrature phase support electronics. Next would be the amplifier board connected to the anticoincidence board. These two boards perform the range switching and pulse driving capabilities of the tool.

Theory of Operation

The conductivity measurements are made by using a magnetic field to induce an electric field, which in turn produces electric currents in the material being surveyed. Because the magnitude of these currents is proportional to the conductivity of the material being measured, the magnetic field generated by the induced electric currents is measured. At high conductivities the accuracy of the induction tool diminishes due to skin effect.

The magnetic field at a given point is composed of the primary magnetic field and the magnetic field produced by the material as a result of being immersed in the magnetic field. The ratio between these fields is the magnetic susceptibility. The magnetic susceptibility measurement works best when the conductivity is low. A different probe model is available that has a modified coil array, which is optimized for the magnetic susceptibility measurements. Consult factory for more information about this type of tool.

The coil array in the induction probe has been designed so that it is not sensitive to material at a radial distance smaller than about 10 cm from the probe axis. The reason for this is to reduce sensitivity to the borehole fluid. The vertical resolution of the tool is 65 cm. This is measured as the vertical distance where the response is more than half the maximum response to an infinitely thin bed. The volume of investigation is similar to that of the 40 cm normal resistivity probe, therefore the induction tool and the normal resistivity tool give similar responses. The shape of the volume of the investigation is radically different between the two tools. See Geonics technical note TN-20 for more details on the theory of the induction logging and the response of the EM-39 conductivity probe.

The receiver circuit rectifies the received signal using a synchronous rectifier and generates two DC voltages, one proportional to the average value of the quadrature phase component of the received signal (with respect to the primary magnetic field), and another proportional to the in phase component of the received signal. The quadrature phase component is proportional to the conductivity and the in phase component is related to the magnetic susceptibility.

These DC voltages are then converted into pulse trains whose frequencies are proportional to the measurements. These pulses are sent up the logging cable for counting at the surface. The probe sends an ~ 12.5 KHz pulse train to indicate a measurement of zero, and ~ 17.5 KHz pulse train indicates a full, scale measurement. Positive pulses are sent and represent the millisiemens per meter (conductivity). Negative pulses are sent to indicate either the magnetic susceptibility if the tool is connected to a 2ADP-1000 adapter or the gamma count rate from the Poly - Gamma tool if the unit is connected to a 2PGA-1000.

The reason a zero count rate of 12.5 KHz was selected is that in the presence of metallic objects negative readings occur. These objects are commonly smaller than the volume of the investigation of the probe, thus the mechanism used to subtract the primary field and the response from borehole fluid can cause negative readings. This can be useful information.

Range of measurement is controlled, by changing the gain of the receiver circuit. The gain can be changed manually in the probe or by applying different polarities to the probe for power. These polarities set a latching relay in the tool, which controls the gain setting. Only two different ranges are achievable by this method.

Installation

WARNING Fragile

Because the tool housing is non-metallic, thin wall fiberglass it should be treated with extra care. Do not drop, bend, or otherwise stress the tool or leakage can result from fractures in the fiberglass housing or its metal joints.

Installing the 2PIA-1000

Installation of the probe only requires that you have decided to either run the tool under the Poly Gamma or as a standalone probe. In the standalone mode you should attach the 2ADP-1000 Poly to MSI single conductor cablehead adapter to the top of the probe. Next attach the probe string onto a Mount Sopris single conductor cablehead connected to the winch. The 2PIA-1000 probe is constructed of lightweight fiberglass and may need an additional weight section installed when logging in mud - filled boreholes. To do this, loosen the setscrew in the black Delrin cone on the bottom of the probe and unscrew the cone. Install the weight section in the reverse manner.

Installing the 2EMA-1000, EMP-2493

As this probe runs only stand alone you attach the probe to the appropriate cable head and winch. The 2EMA-1000 probe is constructed of lightweight fiberglass and may need an additional weight section installed when logging in mud - filled boreholes. To do this, loosen the setscrew in the black Delrin cone on the bottom of the probe and unscrew the cone. Install the weight section in the reverse manner. Select the appropriate tool driver.

Range Selection

Range selection is determined by the wiring of jumpers in the probe. If the probe has the factory setup then the polarity of the voltage to the probe selects one of two ranges. The third range can be manually selected by removing the housing of the probe and manually selecting the proper range with the range select switch as detailed below. The probe can also be set to operate in one range regardless of the polarity of the voltage applied to the probe top by setting the Range select switch to the desired position 2 through 4.

Probe Range Select Switch Position	Conductivity Range
2	0 - 10,000 milliSiemens/meter
3	0 - 1000 milliSiemens/meter
4	0 - 100 milliSiemens/meter
5*	Select Range “A” or “B” from the surface

Table 2 Range Select Switch

Range Selection	Range “A”	Range “B”
0-100 mS/m	JP12 to JP11	JP12 to JP13 *
0-1000 mS/m	JP10 to JP11 *	JP10 to JP13
0-10000 mS/M	JP11 to JP 9	JP9 to JP13

Table 3 Range Jumper Installation

Note: Only two jumpers are to be installed at any one time.
* denotes factory setting

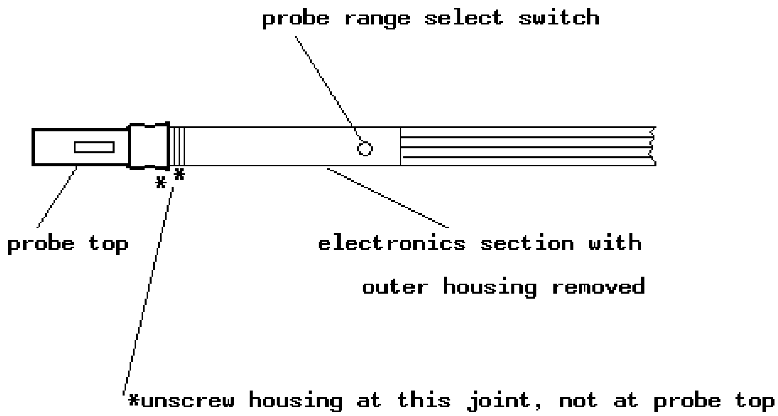


Figure 1 Probe Range Select Switch

Operating Procedure

Operation

The operating procedures described below will include MGX and MGX II versions. In most cases the range of measurement control will be done from the surface. If you choose to do this manually, refer to the Controls section of this manual.

MSLog

1. Select the correct tool driver from the Tool panel selection box. If the correct one is not available run MSLConfig to install it.
2. In the Tool panel, click the Power On button.
3. Click the Depth panel upper right corner icon. Click Zero Tool.
4. If you wish to fill out the header, in the Acquisition panel click Header button.
5. In the Acquisition panel, click Record and select a file name.
6. Turn on the desired, Depth Sampling mode.
7. If you are printing, turn on the printer in MCHCurve.
8. Log to the desired interval as normal. Refer to the MSLog manual for additional information on logging.
9. When done, in the Acquisition panel, click Stop.
10. In the Tool panel, click the Power Off button before removing the probe.

Logshell

If the probe or combination of the Poly gamma and Poly Induction are to be used with an MGX series logger, the **PULSE 2** position on the Probe Select switch must be used for logging. **Range 'A'** is selected by placing the Probe Power switch in the **ON (Close)** position, while **Range 'B'** is selected by placing the Probe Power switch in the **OFF (Open)** position.

If the probe is being operated with an UM-4591, a HLM-4180, a FLM-4180, or a GLM-4180, set the range of the probe by momentarily setting the caliper control to CLOSE to select range 'A', and OPEN to select range 'B'. Probe operation is then accomplished using the conventional settings on these modules. *This only applies to the 2EMC-1000 and 2EMB-1000 if they are properly wired for four-conductor operation.*

For use with the Series 5, Altlogger, the probe wiring may be configured in a number of ways depending on the 4pulse adapter configuration. Consult Mount Sopris Instruments.

If the probe or combination is to be operated with an MGX II logger, choose the corresponding probe driver for the proper range and combination of tools and the unit will provide proper power and polarity to the probe.

The probe can be logged at a speed of approximately 30 ft/min or 10 m/min with good results and no loss of resolution. The probe is extremely lightweight and may require the addition of an optional bottom weight when logging in heavy muds. Consult the factory for details. The zero point or depth reference of the probe is the thickened ring located 91.4 cm (36 in.) below the probe top joint.

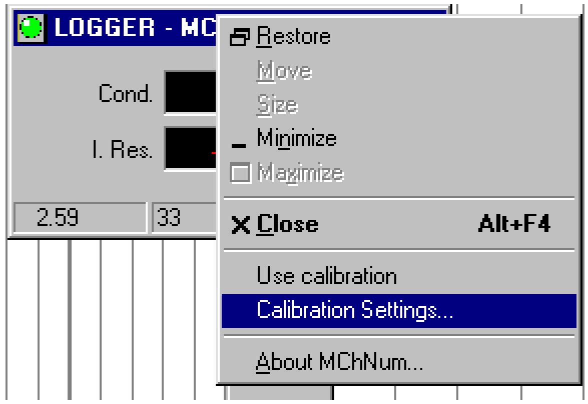
Performance Checks and Calibrations

Although the instrument is set to read correctly at the factory, it is necessary to check the instrument calibration before logging the tool. For highest accuracy, it is recommended to perform these calibrations prior to logging. Allow the probe to operate under power for at least 10 minutes, in borehole fluid, prior to making any calibrations

To calibrate the probe, connect the probe to the logging system as discussed in the Installation section of this document. Turn power to the probe on utilizing one of the various types of data acquisitions systems discussed in the Operating procedure section. Place the probe in borehole fluid and allow it to warm up. Pull the probe from the borehole and hold the probe at the cablehead/probe top joint and elevate the probe in a vertical direction so the bottom of the probe is pointing straight up in the air and is at least 3 meters above the ground. Ensure that the person and or device holding the probe in this position does not have any metal objects attached, such as a watch, screws, or duct-tape, as these items are conductive. Also ensure that the tools are at least 3 meters from any metal buildings, vehicles, even the logging unit. Set the data acquisition equipment to read zero conductivity at this point; this is the first calibration point. To obtain the second calibration point, two methods can be used. The first method discussed utilizes a calibration coil. This coil is placed over the conductivity probe. Located on the coil is a switch to choose different values for the second calibration point. Depending on the range setting of the tool certain values may over - range the tool, so it is important to know what range the tool is functioning in before making a calibration. When the probe value for the second calibration point has been chosen, set the acquisition equipment to read this value. If a calibration coil is unavailable set the acquisition system for the second calibration point to a value of the frequency of pulses from the tool at the zero point plus 5000 (i.e. if zero is 12500 counts then the second calibration number would be 17500. Also be sure that you adjust the scaling of the probe file to match the range of the tool (i.e. 100mS/m, 1000mS/m or 10000mS/m). The frequency output of the probe with respect to conductivity is quite linear and with only one point, zero, we can establish the full scale calibration point with reasonable accuracy by adding 5000 to the frequency that represents zero conductivity. <u>For this method to work properly it is essential that the scaling or output of the probe file (i.e. RgtOut or High Ref. number is set equal to the range in which the tool is operating.</u>

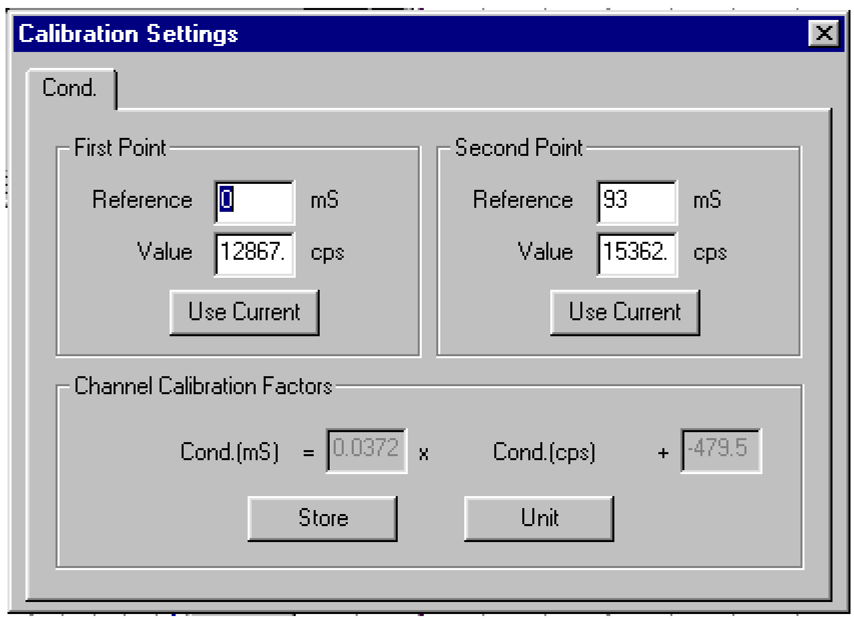
MSLog calibration

1) Turn Probe power On.
2) Turn Sampling to Time and On.
3) Lower the Probe without a weight into the borehole fluid and allow it to warm up for 10-15 minutes or until the Induction channel stops drifting.
4) Right click on MCHNum.
5) Uncheck Use calibration
6) Right click on MCHNum.



7) Click Calibration Settings..

8) Quickly pull the probe from the borehole and hold it into the air bottom end up. You should be away from any metal objects that would disturb the measurement.



9) Press the First Point Use Current button to capture the frequency of the input at the zero Reference.
10) When you have a calibration standard
    a. Slide the calibration standard over the probe. Select the proper setting for the range of operation. In this example the 0-100 range is selected and the switch setting of 93 is entered in the Reference for the Second Point.
    b. Hold the probe with the calibration standard over the end into the air.
    c. Press the Second Point Use Current button to capture the frequency of the input at the 93 ms (in this example) Reference.
11) When you don't have a calibration standard.
    a. Note the First Point Value.
    b. Add 5000 to the First Point Value and enter it in the Second Point Value box.
    c. Enter the full, scale value for the operating range you have selected into the Second Point Reference box. In the example above you would enter 100.
12) Press Store to save the values to the tool driver file.
13) Press the X in the upper right corner of the browser to close the dialog.

14) On the MSLog Browsers and Processors menu press Close all.
15) Select each Browser or Processor from the menu individually and press the Start button. Wait until the browser or processor Connects then select the next one in the list, press Start and so on until all the processors and browsers are running. This is necessary so that the browsers and processors can read the new calibration information stored in the tool driver file in step 12 above.

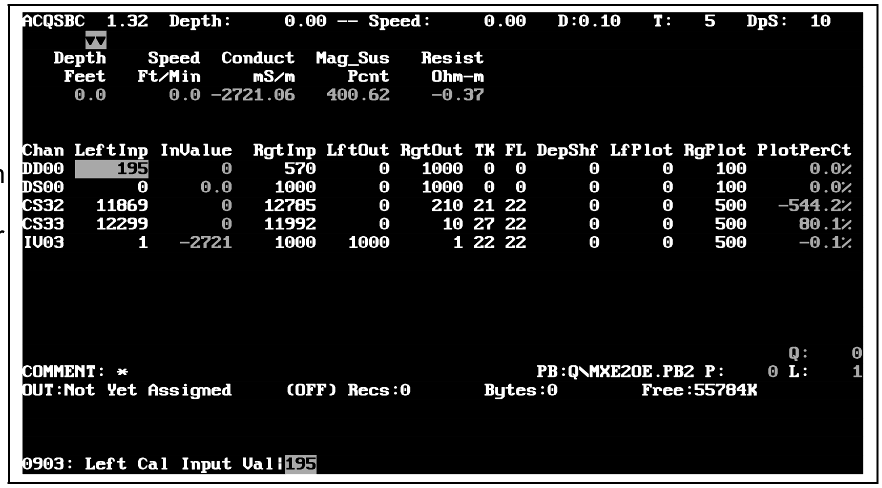
Logshell calibration

The following is a brief, step by step, procedure for Logshell users of both the MGX and MGX II loggers. Items in ( ) will be information regarding the MGX II version of Logshell.

1) Connect the probe or probes to the Logger and activate LOGSHELL.

2) Select the **LOG** option from the menu and select the probe driver from the **Probe** menu.

3) Enter the data file name at the **DataFile** menu and set the depth at the **Depth** menu.



4) When you have reached the ACQSBC or the (PolyLog) screen you are ready to check the probe calibration. For MGX users choose the proper **Probe Select Switch** position and the proper **Probe Power Switch** position for range selection.. For MGX II users, the system has already powered the probe and you must choose **Calibrate** from the menu.

5) The factory calibration factors for conductivity are seen in the **CS32** line. As seen in the figure, **LeftInp** is **11869**. This number is equivalent to 0 conductivity. This equivalence is set, by placing the number **0** in the **LftOut** column.

6) Verify the number **0** is in the **LftOut** column of the **CS32** line. If it is not, move the cursor to that position press <**0**> and then <**ENTER**>.

7) Hold the probe at the cable head/probe top joint and elevate the probe in a vertical direction so that the probe bottom is pointing straight up in the air and is at least three meters above the ground. Make sure that you do not have any metal objects such as a watch or a ring on the hand holding the probe and that no conductive objects are nearby. You may have to move a few yards away from any nearby buildings or power lines.

8) While the probe is held in the air, verify that the number in the **InValue** column of the **CS32** line matches the **LeftInp** number **11869**. If the number does not match, move the cursor to the **CS32** line, and while the probe is held in the air as described above, press **F3**. This copies the **InValue** number into the **LeftInp** column of the **current** line.

9) Set the MGX Probe Power switch so that it selects the 0-1000mS/m range. The default factory setting will be to operate with the switch in the **ON(Close)** position.

10) Place the calibration ring on the probe as shown in Figure 2.

11) As seen in the figure above, **RgtInp** is **12785**. This number is equivalent to 210mS/m conductivity. This equivalence is set, by placing the number **210** in the **RgtOut** column. Verify the number **210** is in the **RgtOut** column of the **CS32** line. If it is not, move the cursor to that position press <**210**> and then <**ENTER**>. With the calibration coil in

position **b**, note the number in the **InValue** column. Press <**F4**>. This copies the **InValue** number into the **RgtInp** column of the **current** line.

Note: In calibration coil position **a,** the coil can be used to calibrate the equipment to 12.4 mS/m, which is better for operating the probe int the 0 - 100 mS/m range. Repeat step 11 replacing the number **210** with **12.4**.

12) Perform this step only if a second calibration point is not available (if you don't have a test coil). Note the number in the **LeftInp** column of the **CS32** line. This is the zero input frequency. Add **5000**(cps) to this number. Move the cursor to the **RgtInp** column of the **CS32** line. Type the calculated number into that column and press <**ENTER**>. Move the cursor to the **RgtOut** column, press <**1000**> and <**ENTER**>.

Note: The frequency output of the probe with respect to conductivity is quite linear and with only one point, zero, we can establish the full scale calibration point with reasonable accuracy by adding 5000 to the frequency that represents zero conductivity. This second number then represents 1000mS/m in the example above. If a different scale is used, 5000 plus the zero value from the **LeftInp** column will be equal to that range full scale value i.e. 100 or 10,000mS/m. For this method to work accurately it is essential that the **RgtOut** column number is set equal to the range in which you are operating the probe!

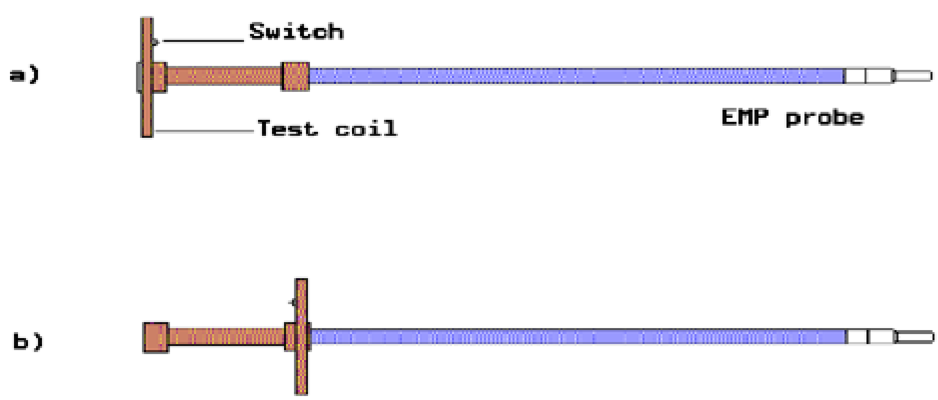


Figure 2 Calibration Set-up with Geonics Test Coil

Preventive Maintenance

The 2PIA-1000, probe, should provide long life with no maintenance. If the accuracy of the probe is suspect, proceed to align the probe as follows.

Adjusting the Anticoincidence Circuit:

1. Remove the housing from the probe top. Remove the outer shields by unsoldering the wire braid and green wire attached to the braid. Slide each shield down about 6 inches.

2. Locate R15 and R36 on the rectifier board then connect P29-2, P29-3 and P29-6 together. See Figure 4 for component placement.

3. Connect the probe to the logging cable and power up tool. Looking at the Input value on the acquisition screen adjust R3 and R7 for 12.5 KHz.

4. Turn off power to the tool. Remove the shorts on P29 and re-solder R15 and R36.

5. Reinstall the shield and **be sure to solder the green wire to the braid**. Inspect the O-ring on the probe top for cleanliness, cuts or abrasions then replace the housing.

Null Adjustment:

1. Remove the tool from its external housing. Locate and identify adjustment slots on the end of the probe. Use Figure 3 as a reference.

2. Connect the probe to the logging cable and power up tool. Get the tool at least 3 meters from any metal object and as high off the ground as reasonable.

3. Set the range switch on the probe to the 100mS/m range. See Figure 1 for switch location and Table 2 for switch position.

4. Adjust control 2 for conductivity and control 3 for magnetic susceptibility on the probe to obtain a zero of 12.5 KHz on both channels. See Figure 3 for controls. There could be interaction between controls therefore it may be necessary to repeat this process.

5. Turn off power to the tool. Reinstall the shield and be sure to solder the green wire to the braid. Inspect O-ring on the probe top for cuts or abrasions. Replace housing.

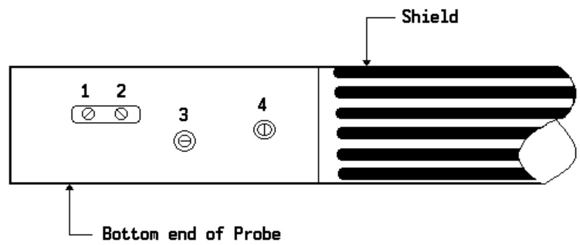


Figure 3 Linearity and Null Adjustment

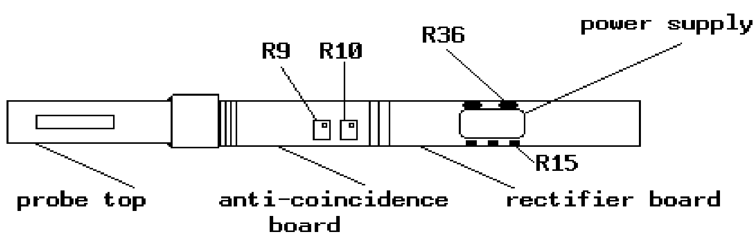


Figure 4 Location of Discrete Components

Troubleshooting

Problems with the Tool

In the event the tool develops a problem, follow the troubleshooting procedure listed below.

No data from the probe.

1. Are the MGX switches set correctly? **PULSE 2** and **ON or OFF** positions
2. Are the PROBE CURRENT and PROBE POWER LED's on? (MGX users)
3. MGX II users, is the correct probe driver chosen?
4. MGX II, is the TO PC light flashing?
5. Is the proper voltage applied to the cable line conductor wire? Approximately 68 volts D.C., for the MGX and 68 to 72 volts D.C. for the MGX II.
6. Are the cables between winch, MGX unit and the PC connected properly?
7. Check the logging cable for conductive leakage across the center conductor to ARMOR.
8. If an oscilloscope is available verify if the probe is sending pulses, if not consult Mount Sopris.
9. Is the slip ring connector on the probe top clean?

Disassembly Instructions

The 2PIA-1000, probe, should never be disassembled unless service is necessary. In the event service is necessary, it should be returned to Mount Sopris Instruments, or a qualified technician. In the event you need to get into the probe, unscrew the housing from the probe top at the junction about 2” just above where the black heat shrink ends on the housing. Before reinstalling the housing inspect the o-ring on the probe top for any damage like cuts or abrasions. This is very important. If the O-ring fails borehole fluid can fill the tool and damage the tool permanently. Flooded tools usually require complete replacement of the electronics.

WARNING: Because the tool housing is non-metallic, thin wall fiberglass it should be treated with extra care. Do not drop, bend, or otherwise stress the tool or leakage can result from fractures in the fiberglass housing.

Appendix

Suggested QA Procedure

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris family of Acquire programs records the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

Technical Addendum

Induction Probe Calibration Procedure Update

Models affected: 2PIA-1000, 2EMA-1000, EMP-2493, and EMP-4493

The temperature of the induction tool is important when it's calibrated. Whenever there is a substantial difference between the temperature of the borehole and the temperature of the probe during calibration there can be a shift in the observed log, possibly resulting in negative conductivity numbers being reported for numbers near 0.

From experience with Geonics EM-39 based Mount Sopris Induction tools, the following method of calibration is suggested for the most reliable results.

We recommend that the probe be placed in the borehole, power applied, and the probe allowed to warm up for at least 10 to 15 minutes before calibration. After the warm up, stabilization period, the probe should be quickly removed from the borehole and a zero and second calibration point determined and recorded using the EMP-N294 Induction Probe Calibrator. Do this as rapidly as possible to make sure the probe does not have a chance to change temperature. This is a greater concern on sunny days. The probe can then be returned to the borehole for logging. If you do not do this, the probe calibration will drift until the probe thermally stabilizes.

After logging, another quick calibration can be performed to determine if there was any appreciable change in the calibration numbers. If there is a large difference, then it’s likely the probe should have more time to stabilize in the borehole before calibration.

Operating in air filled versus water filled holes may require a different amount of time for the probe to stabilize. This is due to the fact that water provides a better heat sink, allowing the probe to come to thermal equilibrium sooner in water.

Specifications

Power Requirements
D.C. voltage at probe top Min. 30 VDC Max. 80 VDC @ 50mA to 90mA depending on tool configuration
Cable Armor Negative and Pos, not polarity dependant
Center conductor Pos and Negative, not polarity dependant

Tool Output
Pulse type, positive and negative going, 1.25uS wide from ~ 12.5 KHz to 17.5 KHz

Radius of Investigation
Radius of maximum sensitivity 28 cm
Minimum radius of sensitivity 10 cm

Vertical Resolution
65 cm

Ranges or Scales
100mS/m, 1000mS/m, 10000mS/m
Accuracy
5% of full scale

Resolution
0.02 % of full scale

Repeatability
+/- 2% full scale for temperature changes less than 10 degrees Centigrade

Noise level
Less than 0.5 mS/m

Measurement point
91.4 cm (36”) from the joint of the probe top
Temperature range
-30 to 50 degrees Centigrade
Operating frequency
39.2KHz

Primary field source
Self contained dipole transmitter
Sensor
Self contained dipole receiver
Coil separation
50 cm

Maximum depth
1000 m (water filled)

Length
170 cm

Diameter
3.65 cm

Weight
3.2 kg (without weight section)

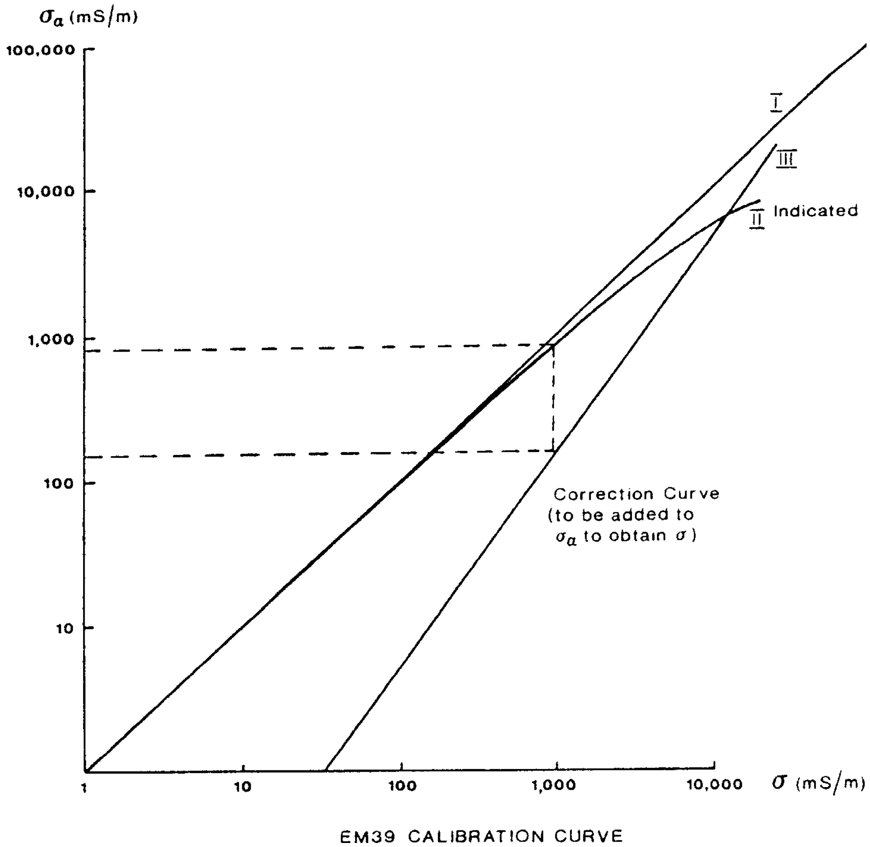


Figure 5 EMP/EM39 Calibration Curve

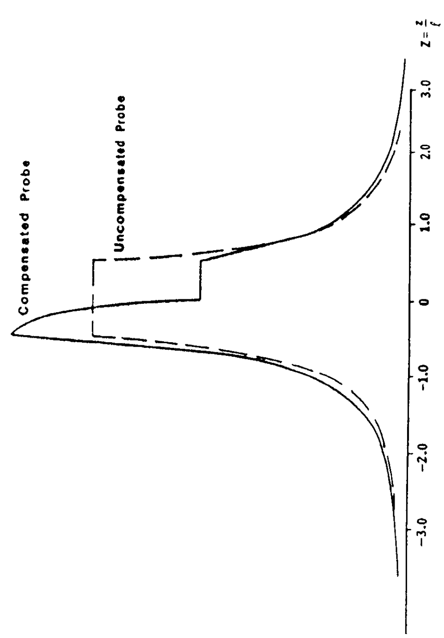
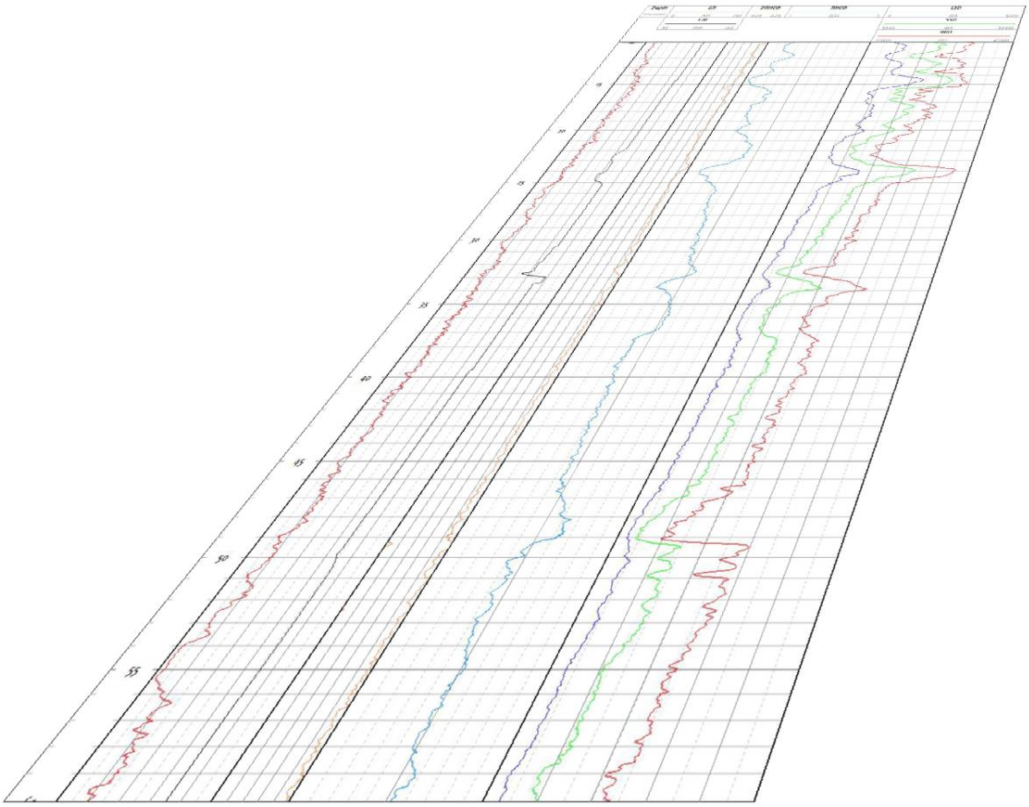


Figure 6 Vertical Response with λ = 58cm

Schematics

2PIA-1000 Poly Induction Probe

Drawing Number 500S-2078   50002078A.S01 - S03   Title: EMP/Poly EMP Anticoincidence



User Guide

QL40 HM 453, HMM 453, HM805ED, & HM 453E
Magnetic Susceptibility

MOUNT SOPRIS
INSTRUMENTS

Advanced Logic Technology

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V2020.07.17

Table of Contents

1 General Information

The QL40-HM-453 Magnetic Susceptibility bottom sub is a versatile wireline tool that can be used in a wide variety of logging applications.

It is designed for measurement of magnetic susceptibility of rocks in both liquid filled and dry boreholes. The QL40-HM-453 is capable of logging inside PVC or other non-metallic casings. It is characterized by high stability and exceptionally wide dynamic range. The magnetic susceptibility measurement uses a 2 kHz frequency.

The HM-453 probe uses a 2-coil array with 25 cm spacing between the transmitter coil and receiver coil for the magnetic susceptibility measurement.

This magnetic susceptibility probe is also available in three other models: the QL40-HM-453E extended range probe, QL40-HM-805ED hyper extended range probe, and QL40-HMM-453 dual range probe (**see Figure 2-1 and Figure 2-2**). All probes operate the same way, but the ranges and physical dimensions are different.

A combination QL40-HMI Magnetic Susceptibility and Induction probe is also available, but tool details and specifications are found in a separate manual.

QL40 Stackable Logging Tool Overview

QL stands for Quick Link and describes the latest line of stackable logging tools. This development is a joint venture of Mount Sopris Instruments (MSI) and Advanced Logic Technology (ALT). Innovative connections between tool elements (subs) allow users to build their own tool strings in the field. The Tool Stack Factory – a sophisticated extension of the acquisition software – provides a convenient way to configure tool strings for operation. For more information about the Tool Stack Factory, see the LoggerSuite Manual.

Each sub has a Telemetry and Power supply element, TelePSU, allowing stand-alone operation. A GenCPU card in each sub handles Analog to Digital conversion and/or counting of the measurement signal and formatting data for transmission up hole.

The QL40-HM-453 bottom sub can be operated as a stand-alone probe or can be stacked below inline subs. The stack is completed by adding a Tool Top sub. Varied tool top subs are available. Top subs include an MSI single conductor, GO4 conductor, GOI Single conductor and GO7 conductor. Consult the factory for additional options.

The number 40 indicates a nominal probe OD of 40mm and tool joint connection diameter, but some probes in the 40mm probe line can have larger diameters. The QL40-HM-453, HM-453E, and HMM-453 are 45mm diameter probes with the 40mm QL tool connection. The QL40-HM-805ED probe is an 80.5 mm diameter probe with the 40mm QL tool connection.

For a more detailed discussion of QL subs and their connections, please refer to **Chapter 3**.

1.1 Dimensions

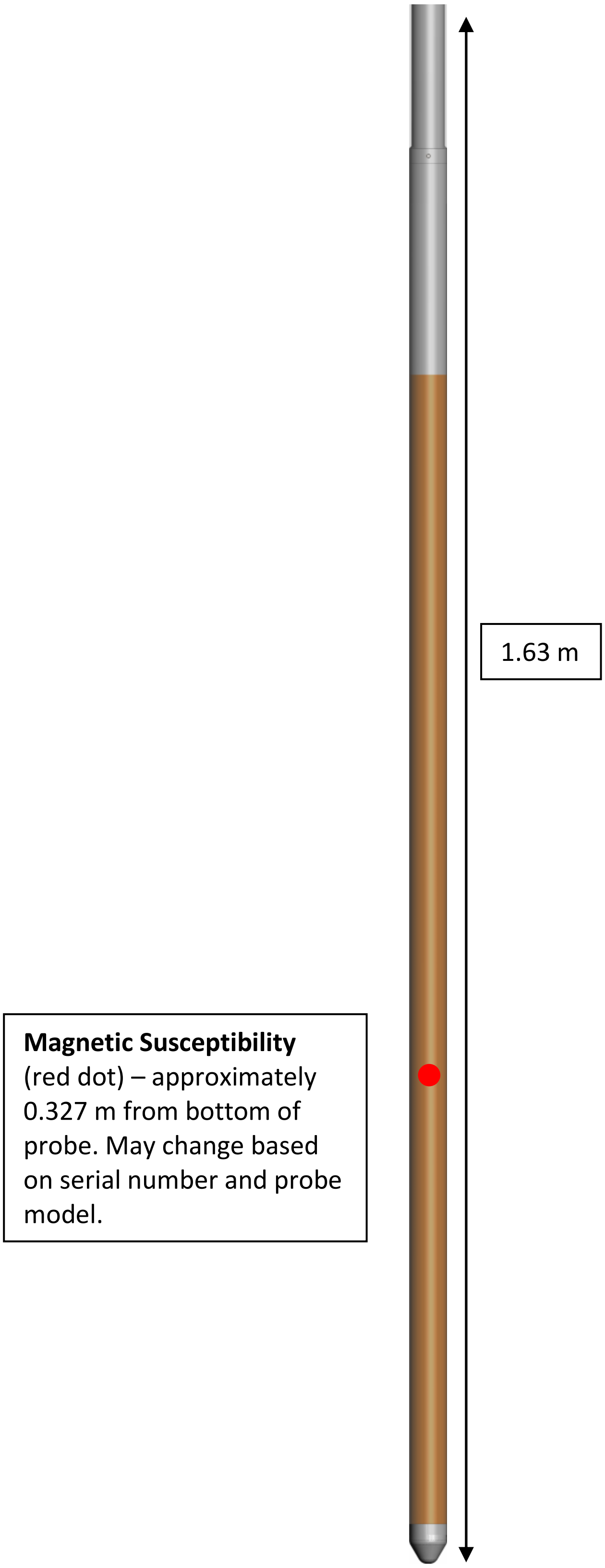


Figure 1-1 Tool general arrangement

1.2 QL40-HM-453 Technical Specifications

Tool:

Diameter:	45 mm (1.77 in.) *May vary by tool type
Length:	1.632 m (64.25 in.) *May vary by tool type
Weight:	5.7 kg (12.5 lbs)
Max. Temperature:	70 °C (158 °F)
Max. Pressure:	200 bar (2900 PSI)

Cable:

Cable type:	Mono, Coaxial, 4 or 7 conductor
Digital data transmission:	Up to 500 Kbits per second depending on wireline
Compatibility:	ScoutPro – Scout – Matrix – BBox – OPAL

Measurement:

Sensor:	HM-453, HM-453E, and HM-805ED Two coil system HMM-453, Four coil system
Intercoil Spacing:	HM-453, 25 cm HM-453E, 30 cm HMM-453, 25 cm and 30 cm
Operating Frequency:	1935 Hz
Estimated Range:	HM-453, 10^{-5} – 0.5 SI HM-453E, 10^{-4} – 2 SI HMM-453, 10^{-5} – 0.5 SI and 10^{-4} – 2 SI HM-805ED, 10^{-5} – 10 SI
Range (Real):	See W&R Technical Data Manual
Accuracy:	< 3%
Zero Temperature Stability:	< 0.5 * 10^{-5} SI/°C
Communication (Negative Pulse):	0 – 35,000 cps

Power:

DC voltage at probe top:	Min 80 VDC Max 160 VDC Nominal 120 VDC
Current:	Nominal 25mA

2 Measurement Principle

2.1 Magnetic Susceptibility

The magnetic susceptibility (MS) of a volume of rock is a function of the amount of magnetic minerals, mainly magnetite and pyrrhotite, contained within the rock. MS measurements can provide a rapid estimate of the ferromagnetism of the rock. These measurements can be interpreted to reflect lithological changes, degree of homogeneity, and/or the presence of alteration zones in the rock mass. During the process of hydrothermal alteration, primary magnetic minerals (e.g. magnetite) may be altered or oxidized to weakly- or non-magnetic minerals (e.g. hematite). Anomalously low susceptibilities within an otherwise homogeneous high susceptibility (ferromagnetic) rock unit may indicate altered zones.

Basic flows and diabase dikes containing higher concentrations of magnetic minerals can be easily outlined with magnetic susceptibility measurements when they occur within a sedimentary sequence that normally contains little or no magnetic minerals (from NRCAN.GS.CA website).

The QL40-HM-453 probe uses a pair of coils spaced 25 cm apart, and it generates a 1.9345 kHz square wave which is transmitted into the surrounding rock material. The signal measured by the receiver coil is proportional to the magnetic susceptibility of the host rock.

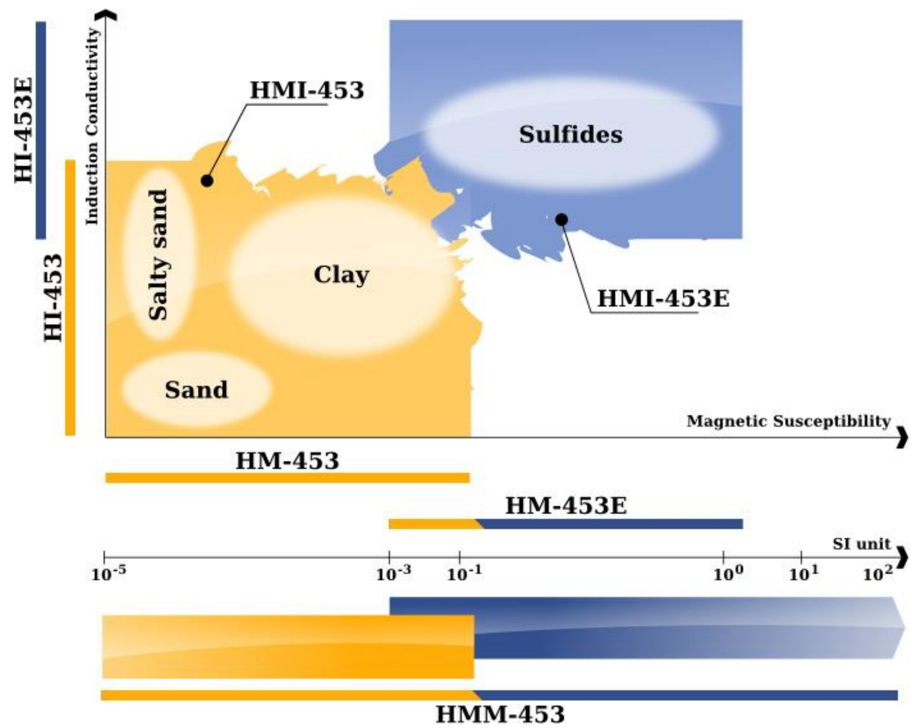


Figure 2-1 Diagram of Mag. Susc. and Induction tools with corresponding ranges of measurement.

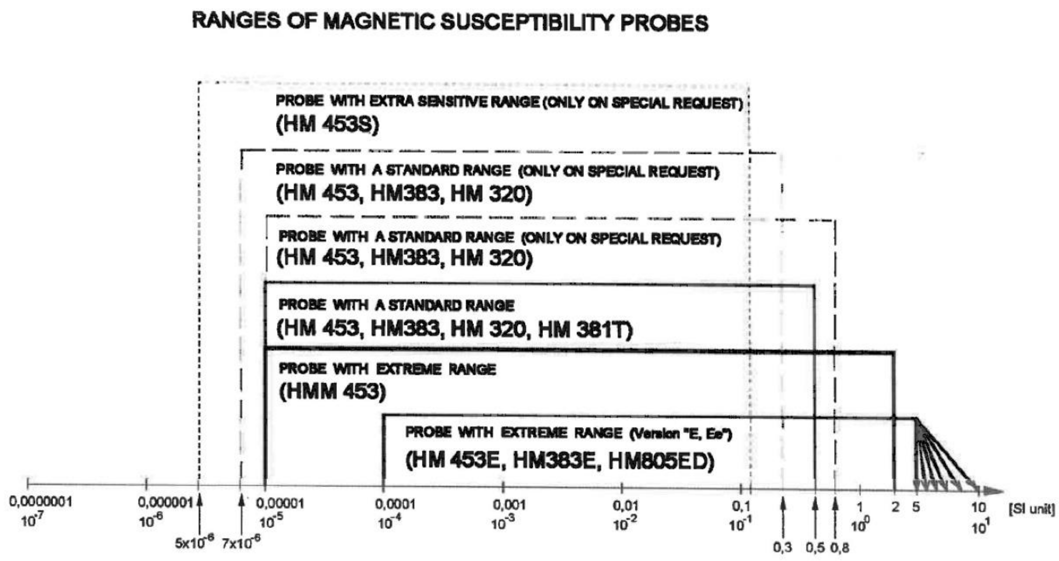


Figure 2-2 Diagram of Mag. Susc. tools with corresponding ranges of measurement.

3 QL40 HM 453 Assembly and Set up

QL stands for **Q**uick **L**ink and describes an innovative connection between logging tools (subs) allowing for custom built tool stacks. QL40 describes a specific family of logging tools. Each sub is equipped with its own Telemetry board, Power supply element and A/D converter allowing an operation as stand-alone tool or as a stack in combination with other subs of the QL product family.
The QL40 probe line deals with two types of subs - Bottom Subs and Mid/Inline Subs.

Bottom Sub
A bottom sub is a tool that must have one or more sensors located at the bottom. It can be operated in combination with other QL subs connected to the top but it is not possible to connect another sub below. When used in stand-alone mode the bottom sub only needs a QL40 tool top adaptor, which fits the cable head.

Mid/Inline Sub
A mid/inline sub is a tool that can be integrated anywhere within a stack of tools. When used at the bottom of a tool string a QL40 bottom plug must be used to terminate the string. If the mid/inline sub is used as a stand-alone tool it needs a QL40 bottom plug at the lower end and a QL40 tool top adaptor at the top.

3.1 QL40 Tool Stack Assembly

A QL40 tool stack may be terminated by either a QL40 bottom sub or a QL40 bottom plug. The QL40-HM-453 is a bottom sub, so it does not require a QL40 bottom plug.

At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available; special ones can be made on request. Common tool tops include the QL40-GO4 for Gearhart-Owen 4 conductor cableheads, the QL40-MS1 for single conductor Mount Sopris cableheads, and the QL40-GO1 for Gearhart-Owen single conductor cableheads.

To assemble and disassemble the subs or top, the C-spanner delivered with the tool must be used (**Figure 3-1**). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with a small amount of the silicon grease that was supplied with the subs.

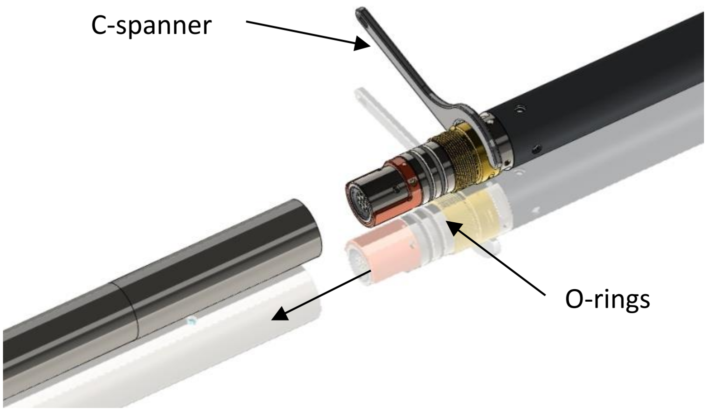


Figure 3-1 *C-spanner and O-rings of QL connection*

The following example of a QL40-ABI-2G, QL40-GR, and QL40-GO4 (**Figure 3-2**) describes how to replace the QL40-ABI-2G with a QL40-Plug to run the QL40-GR sub stand-alone.

QL40-GO4
tool top

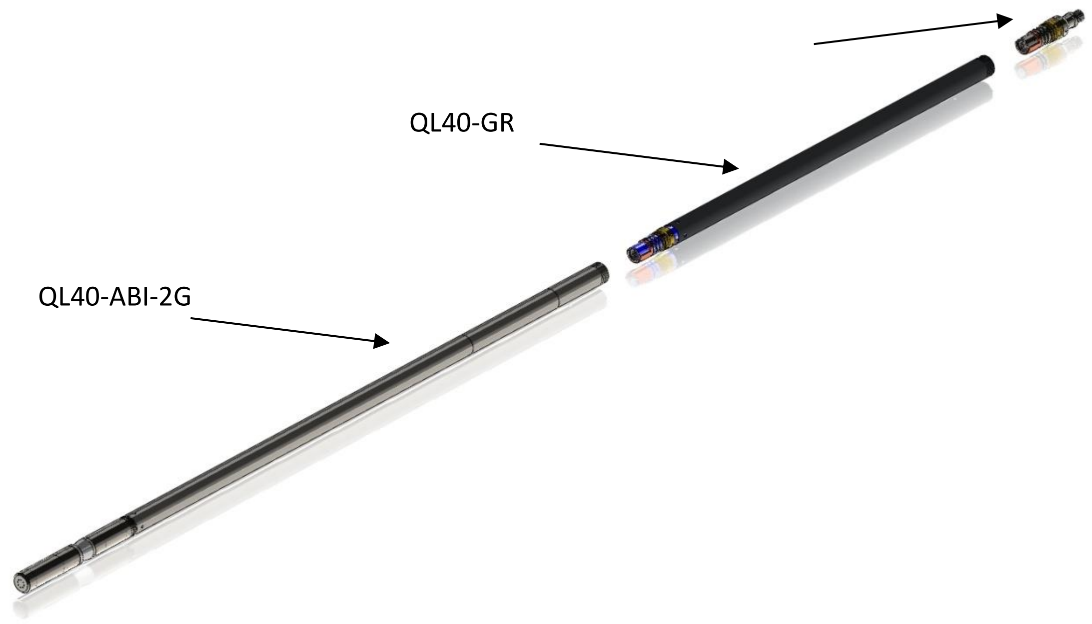


Figure 3-2 *Tool stack example*

To remove the QL40-ABI-2G televiewer sub from the QL40-GR gamma sub, attach the C-spanner to the thread ring as shown in **Figure 3-3**, unscrew the threaded ring, (counter-clockwise about the tool axis when looking towards the bottom of the tool), and remove the QL40-ABI-2G bottom sub.

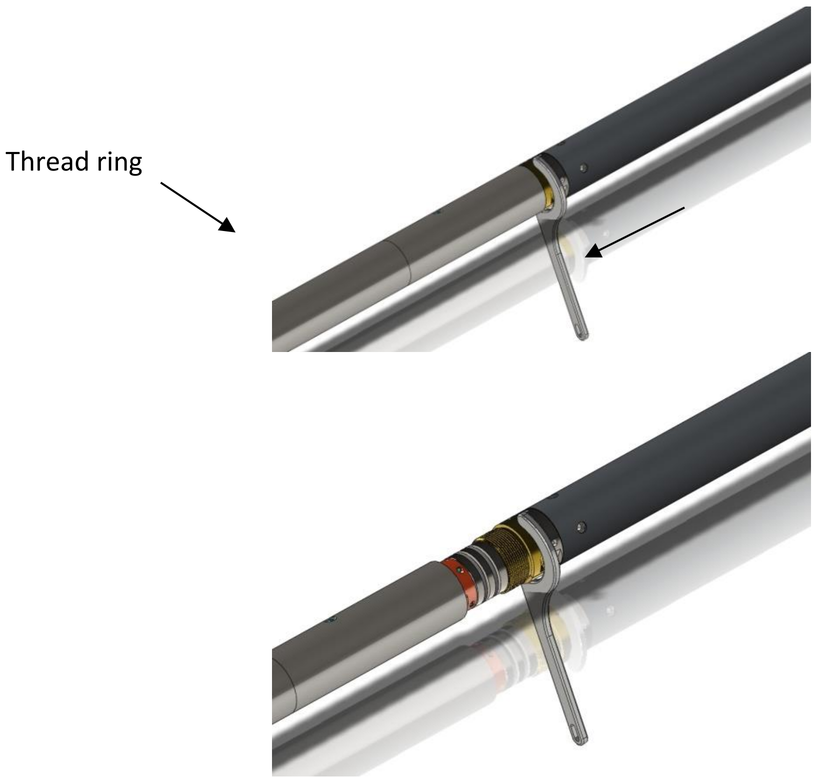


Figure 3-3 *Unscrewing the thread ring and removing the bottom sub*

After checking the O-ring integrity, align and slip the QL40-Plug, also known as the QL40-BOT, over the exposed QL connector (**Figure 3-4**). Attach the C-spanner, and screw the threaded ring until the plug draws up tight to the ring. **Do not** overtighten the threated ring.

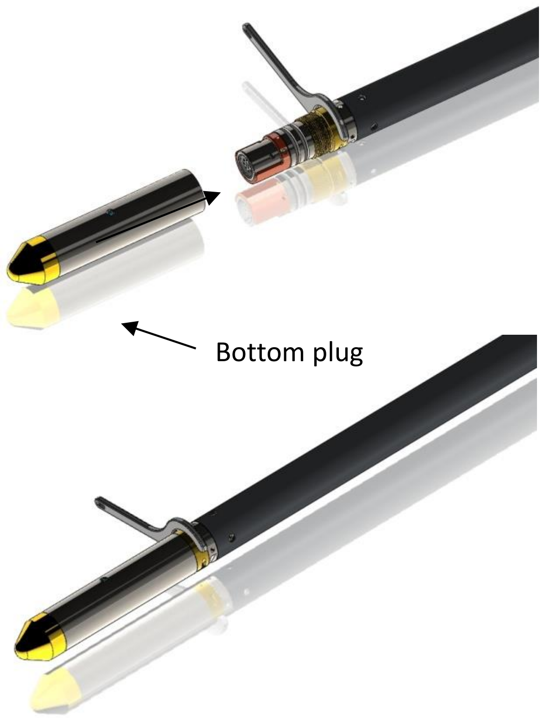


Figure 3-4 *Attaching the QL40-Plug*

The QL40-GR can now be run stand-alone (**Figure 3-5**).

Figure 3-5 *QL40-GR with top and bottom*

4 Operating Procedure

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the **LoggerSuite** acquisition software. LoggerSuite is the collection of Logger, LoggerSettings and TFD2LAS softwares. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

4.1 Quick Start

1. Connect tool to cablehead and lower into the borehole. Start Logger acquisition software.

2. Select the relevant QL40-HM-453 tool stack from the drop down list (**Error! Reference source not found.**) in the **Tool** panel (if your tool stack is not listed, check that your tool configuration file is stored in the designated folder on your computer or create a new file using the Tool Stack Factory).

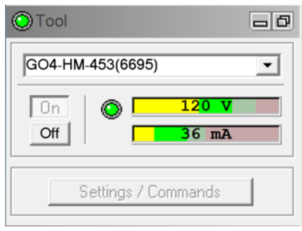


Figure 4-1 *Tool panel*

3. In the **Tool** panel switch on the tool (click **On** button). Verify that the voltage indicator shows a valid green level (shown as 120 V in **Figure 4-1**). The current indicator should also be green and greater than 10 mA (shown as 36 mA in **Figure 4-1**). The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure (Setup tool communication as explained in **Chapters 4.2 and 4.3**).

4. Click the extend icon in the **Depth** panel and press **Zero Tool** (**Figure 4-2**).

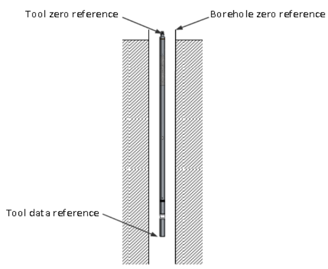


Figure 4-2 *Correct tool positioning when zeroing depth*

5. The tool should be allowed to warm-up in the borehole fluid for at least 15 minutes before calibrating, so it is at the borehole temperature. This will provide the most accurate calibrations.

6. Remove the tool from the borehole. Calibrate the QL40-HM-453 tool by following the steps outlined in **Chapter 4.5**. Place the tool into the borehole.

7. In the **Acquisition** panel (**Figure 4-3**) select the sampling mode (**Depth Down** or **Depth Up** depending on logging direction). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button). Note: The sampling button needs to be set to **OFF** before changing modes. **Time** mode is used for calibration and verifying tool operation at the surface.

8. If desired, complete a **Header** in the **Acquisition** panel (**Figure 4-3**). Press the **Record** button, specify a file name, and start the logging.

9. During logging observe the controls in the **Telemetry** panel **(Figure 4-4)**:

   - Status must be Valid (green light);
   - Bandwidth usage in green range, usually below 80%;
   - Memory buffer should be 0%;
   - Number of **Errors** negligible as **Data** increases.

10. To end the logging procedure, press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

11. In the **Tool** panel, power off the tool (click **OFF** button).

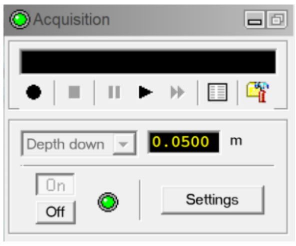


Figure 4-3 *Acquisition panel*

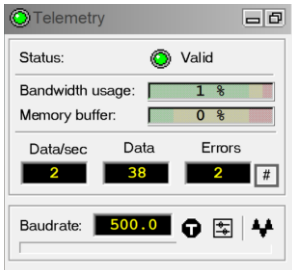
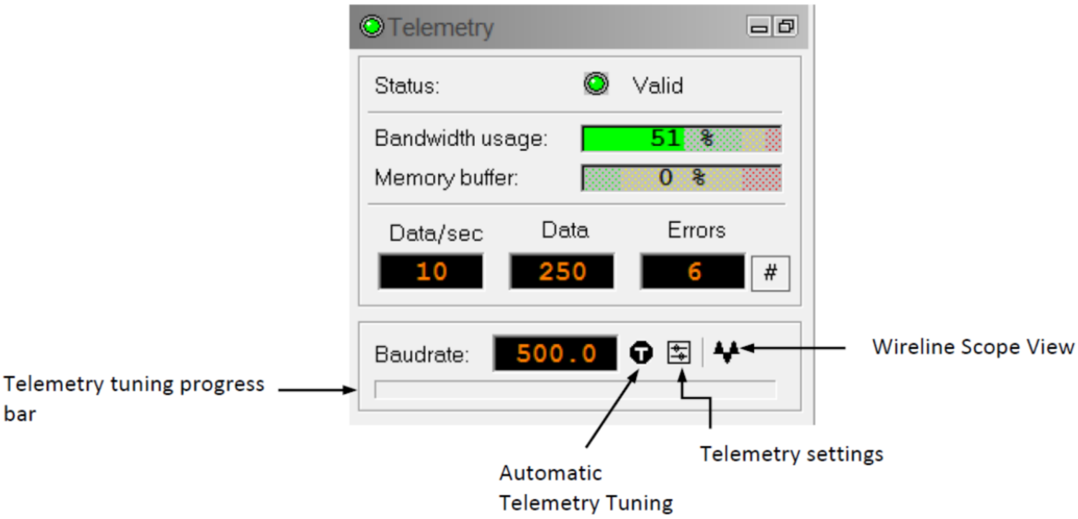


Figure 4-4 *Scout* Telemetry panel

4.2 Tool Communication with OPAL/SCOUT (ALT MODEM)

The telemetry provided through the **OPAL-SCOUT** systems implementing the **ALT MODEM** controls and configures **AUTOMATICALLY** the telemetry settings for any wireline. In case communication status is not valid the user has different options to adjust manually the telemetry settings from the telemetry panel of the dashboard:



Baud rate:
Indicates the default baud rate or optimal baud rate in kbps found by the system for the selected winch/telemetry scheme.

This tool does not require baudrates higher than 100.0 kbps. Manual adjustment might be necessary to lower the baudrate using the **Telemetry Settings** button and then the **Settings** tab.

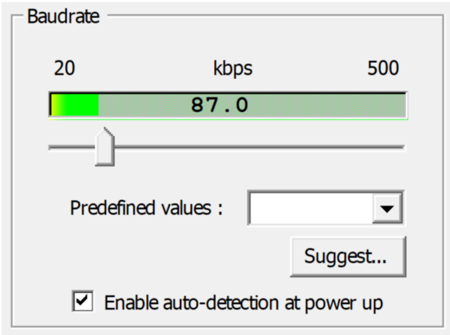


Figure 4-2 *Scout baudrate settings*

Automatic Telemetry Tuning:

The Tune button resets the telemetry tuning automatically. This process defines:

- The optimum baud rate for the winch configuration selected
- A transfer function and a filter to re-construct at the surface the shape of the pulse trains distorted by the wireline.

A **progress bar** at the bottom of the telemetry window shows the progression of the telemetry tuning. At the end of the process the baud rate display is refreshed with the optimal baud rate value.

Refer to **LoggerSuite manual** for more information on the advanced telemetry settings.

4.3 Tool Communication with MATRIX

The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on , the operator has access to the **Configure ALT Telemetry** dialog box (**Figure 4-5**) providing various controls to adjust the telemetry settings and monitor its current status.

The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.

The status of the configuration should be flagged as **Valid**. In any other case (e.g. Int. resp.) the telemetry should be adjusted (we assume a pulse signal is displayed in the analysis view). Click on the **<<Advanced** button to display additional controls to tune the telemetry.

The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.

In general, the gain setting should not be left in the automatic mode once a valid setting has been determined. Uncheck the box to disable automatic gain.

For each wireline configuration, the discriminators (vertical yellow lines) **Positive Discr** and **Negative Discr** can be adjusted to obtain a valid communication status (see *Figure 4-6* for an example of a suitable discriminator position). There is also the option to alter the **Baudrate** to optimize the logging speed. The input **Gain** can be increased (long wirelines) or decreased (short wirelines) to set up the discriminator levels correctly.

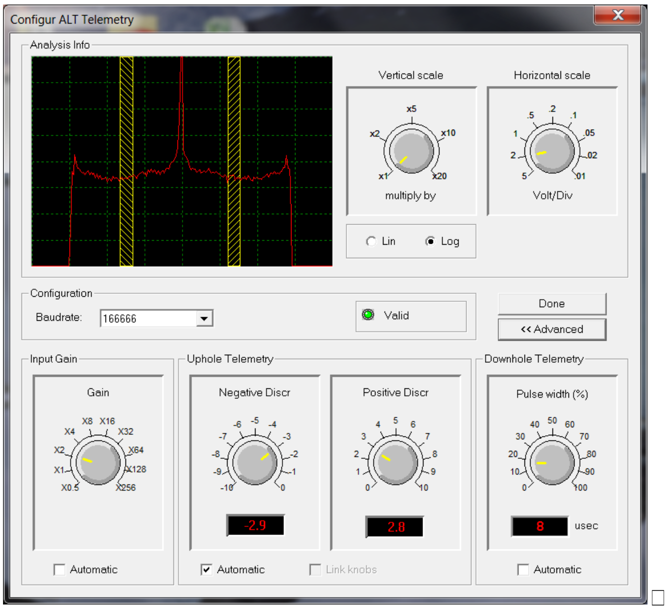


Figure 4-6 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in **Valid** status the next time the power is turned on.

4.4 Recorded Parameters, Processors and Browsers

4.4.1 Recorded parameters

The following channels are recorded by the QL40-HM-453 tool:

Time	Sampling Time [seconds]
TCPU	Temperature (recorded on CPU board) [degrees C]
COUNT	Magnetic Susceptibility Counts
MagSus	Magnetic Susceptibility [10e-3 SI Units]
Speed	Logging Speed in [meters/minute or feet/minute]
ToolPowerVoltage	DC Voltage supplied to the probe [Volts]
ToolPowerCurrent	Electrical Current supplied to the probe [mAmps]
Tension	Wireline Tension [daN]

Table 1 *QL40-HM-453 recorded channels*

4.4.2 MChNum Browser

Figure 4-7 shows a typical example of the numerical value displayed in the MChNum browser window during operation.

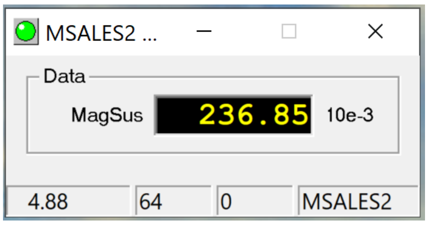


***Figure 4-7** MChNum browser window*

The other parameters listed in **Table 1** can be displayed in real time if required. To do this, click on the MChNum browser green LED and click on **Display options…** from the menu.

Select in the **Numerical Displays** tab and add the additional channels to display using the left and right arrows **(Figure 4-8)**.

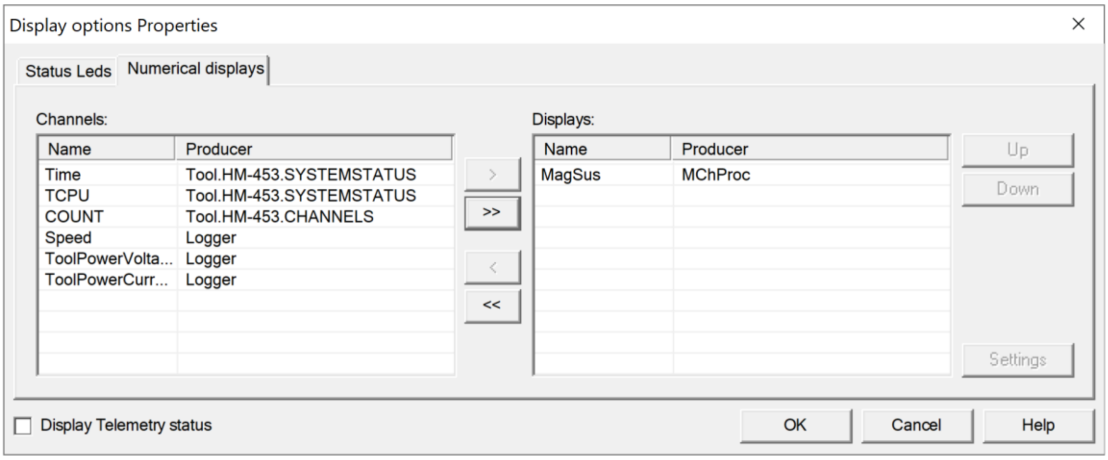


***Figure 4-8** Display Options Properties window*

It is possible to change the number of decimal digits displayed for a channel. Select the channel and click on **Settings** to configure the number of digits after the period **(Figure 4-9)**.

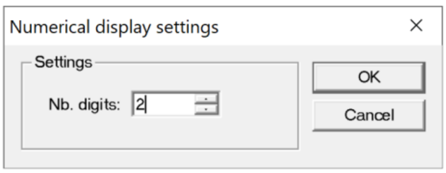


***Figure 4-9** Numerical Display Settings window*

4.4.3 MChCurve Browser

The MChCurve browser **(Figure 4-10)** displays the recorded parameters by means of curves in real time.

The user can modify the curve presentation by double clicking on the log title (colors, column position, scale, filter, grids, etc.).

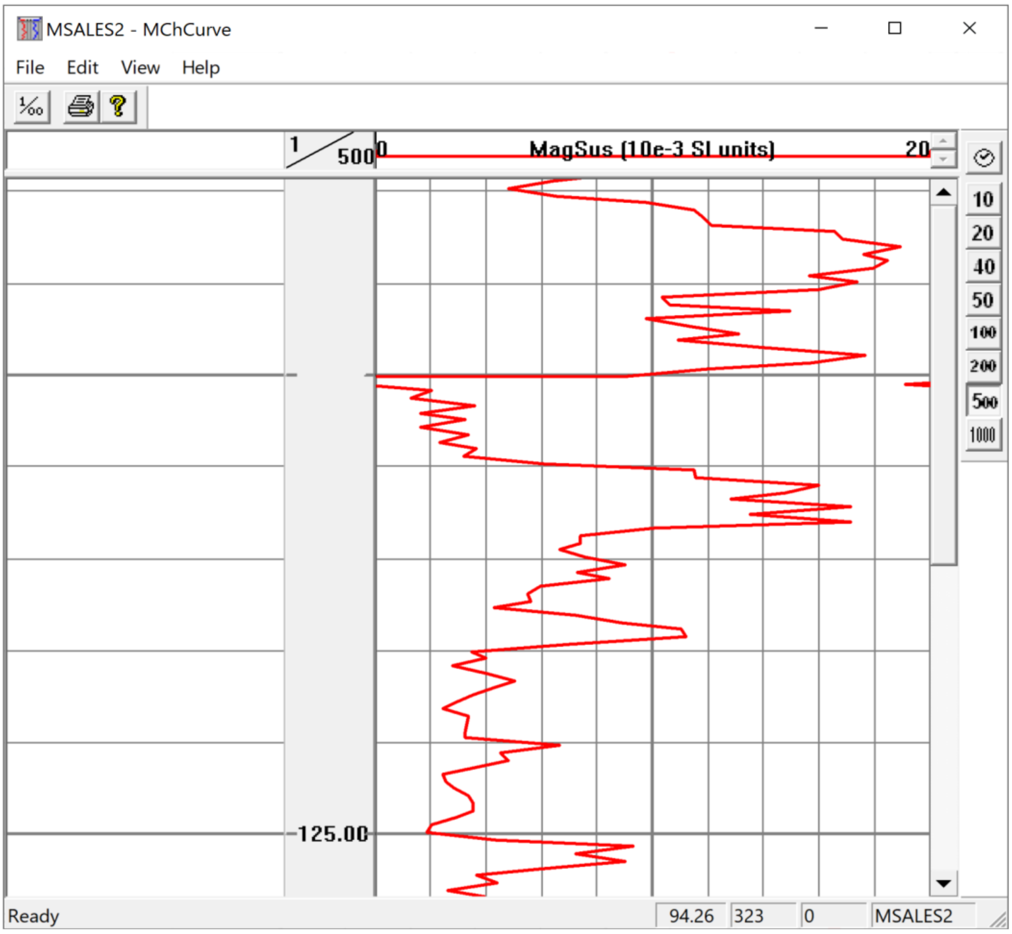


Figure 4-10 *QL40-HM-453 MChCurve browser*

The other parameters listed in **Table 1** can be displayed in real time if required. To do this, select **Edit** and click on **Show Logs…** from the menu (**Figure 4-11**). All logs with a check mark will be displayed.

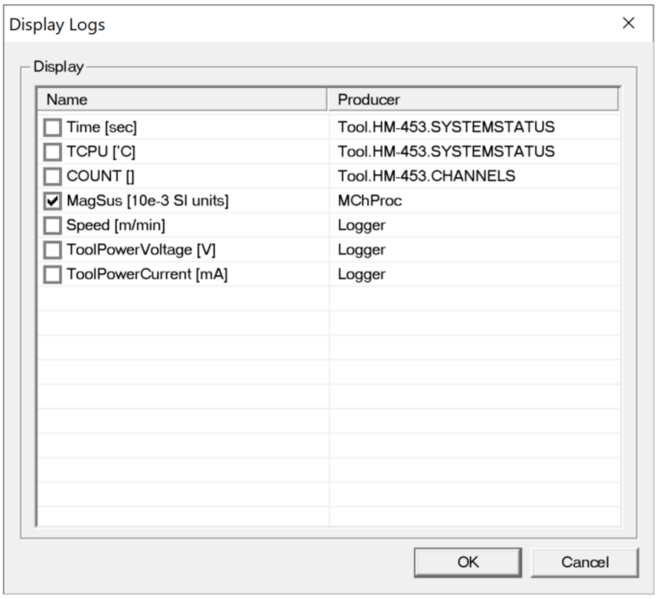


Figure 4-11 *Display Logs window*

4.5 Performance Check and Calibration

An example of a calibration/zero fixture is shown below:

Figure 4-12 *QL40-HM-453 calibration stand.*

Calibration of the magnetic susceptibility measurement is simple and only requires two calibration pucks and a calibration mount plate (**Figure 4-13**). The two calibration pucks provided with the QL40-HM-543 probe are 5.0 x 10^{-3} SI Units and 2.4 x 10^{-3} SI Units.

Figure 4-13 *QL40-HM-453 calibration mount and pucks*

If required, two other calibration pucks are available for purchase: 0.5 x 10^{-3} SI Units and 2 x 10^{-1} SI Units (see **Appendix**). The QL40-HM-805ED probe comes will a calibration ring with multiple pucks (see **Figure 4-14**). Calibration reference values discussed below should be modified based on tool model, geologic environment, and available calibration pucks.

Figure 4-14 *QL40-HM-805ED calibration mount and pucks*

The QL40-HM-453 Magnetic Susceptibility probe should be calibrated in the field before every use.

4.5.1 Calibration Steps

1. Connect the QL40-HM-453 probe to the cable head, and turn on the tool as outlined the **Section 4.1 Quickstart** Lower the tool into the borehole fluid and allow it to warm up for at least 15 minutes to allow the tool to equilibrate, so that the measurements do not drift. Remove the probe from the borehole.

2. In the **Acquisition** panel, turn **Time** sampling **On**. Left click on the Green LED in the upper left corner of the **MChNum** window and click on **Calibration Settings…** (**Figure 4-15**).

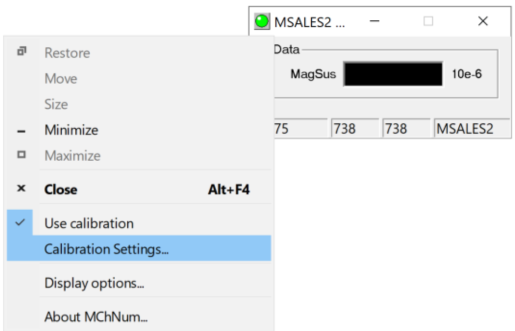


Figure 4-15 *Open Calibration Settings window from MChNum*

3. The probe should be suspended in air, approximately 1.5 m (5 feet) above the ground and at least 3.3 m (10 feet) from any metallic or conductive objects. If the operator is manually holding the probe above the ground surface during the calibration, be sure to remove all metal from pockets. This represents a zero magnetic susceptibility reference.

4. Enter **0** as the **Reference** for the **First Point** in the **Calibration Settings** window (**Figure 4-16**). Click **Sample….** Wait until the bar loads. After loading, a new value will appear in the **Value** for the **First Point**.

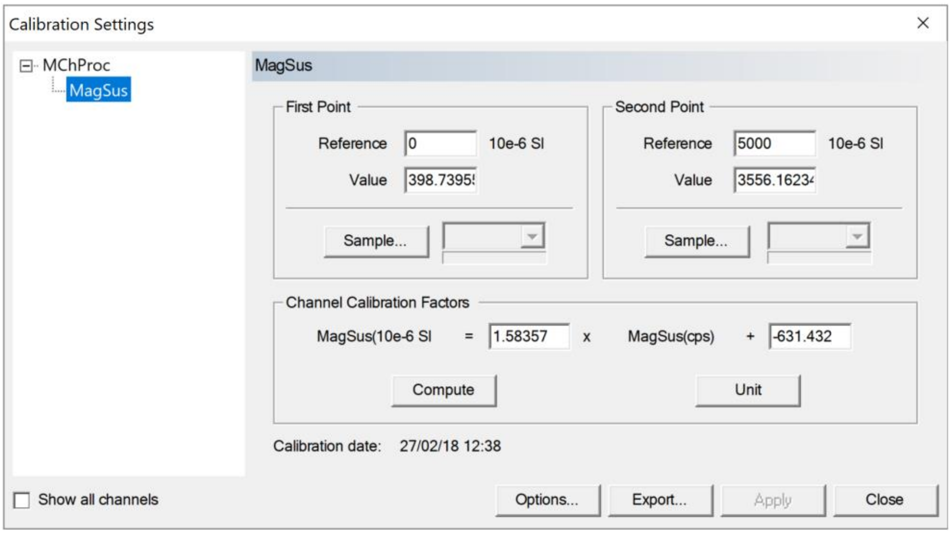


Figure 4-16 *Calibration Settings window*

5. Screw the high calibration puck into the calibration plate.
6. Slide the calibration plate onto the probe until the calibrator is centered on the red dot (**Figure 4-17**).

Figure 4-17 *QL40-HM-453 with 5 x 10^{-3} SI calibration puck in place.*

7. Enter **5000** (or the value stamped on the puck) as the **Reference** for the **Second Point** in the Calibration Settings window (**Figure 4-15**). Click **Sample….** Wait until the bar loads. After loading, a new value will appear in the **Value** for the **Second Point**.

8. Press **Compute** and then **Apply** to store the new calibrations.

9. Close out of the **Calibration Settings** window. On the **Browsers & processors** panel, click **Close All** and then click **Start All**. This should close all windows on the screen and then open them again, to reinitialize the other Browsers/Processors (**Figure 4-18**).

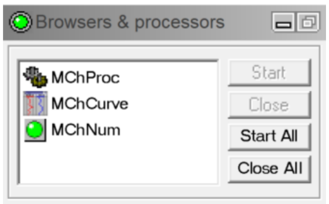


Figure 4-18 *Browsers & processors panel*

10. To test the calibration accuracy, use the QL40-HM-453 with both pucks (**Figure 4-19**) or with the smaller 2.4 x 10^{-3} SI puck (**Figure 4-20**). When using both pucks together, you will need to add the reference numbers (e.g. 5.0 x 10^{-3} SI + 2.4 x 10^{-3} SI = 7.4 x 10^{-3} SI). The **Mag Sus** measurement displayed in the **MChNum** window should display approximately the same amount as the puck or pucks being tested.

Figure 4-19 *QL40-HM-453 with 2.4 x 10^{-3} SI and 5 x 10^{-3} SI calibration pucks in place.*

Figure 4-20 *QL40-HM-453 with 2.4 x 10^{-3} SI calibration puck in place.*

5 Maintenance

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT/Mount Sopris will void the tool warranty.

5.1 General maintenance

The QL40 series tools require periodic maintenance. Make sure the threads on the brass nut on the sub bottom are free of sand, mud or other dirt. A thin layer of anti-seize grease is recommended.

When disassembling the probe string, dry the joint as it is separated to prevent fluid from entering the sub top and getting into the electrical connector inside. After replacing top, it is good to wash the probe off after each use.

Never take the probe apart. This probe is very difficult to disassemble and requires special steps to gain access to the inside of the probe without damaging the electronics. If you have read this after attempting to disassemble the probe, chances are the probe has experienced damage and will need to be sent to the factory to be repaired.

Inspect O-rings occasionally and keep the threads on both ends of the probe clean, to minimize problems in the future. Do not store this probe near a strong magnet, as over time, this could affect the accuracy of the sensors and the resulting measurement.

Remember that the **housing is constructed of fiberglass and is somewhat fragile**. Use care when placing the tool in the borehole and when traveling down into the borehole. Also, store the tool in a secure place, preferably in a shock resistant container. During transport, logging tools typically endure more shock than when in the borehole.

5.2 Locking Ring Assembly Maintenance

Tools required:
1.5 mm Allen wrench
2 each, 40-42 mm spanner wrench
Paper towels or clean rags

Replacement Parts:
ALT26005, Large Threaded Ring, Quantity 2
28-174-995, M2x8 SHCS Screws, Quantity 2

Disassembly:
Unscrew and remove the two M2x8 socket head cap screws (SHCS) and separate the two halves.
Four guide pins align the two ring halves and tend to hold them together after the screws are removed.

To pry the halves apart you can use a pair of spanner wrenches inserted into the pin holes on opposite sides of the ring mating surfaces to pull them apart slightly.
Do this carefully to prevent bending the guide pins.

Figure 5-1 *Disassembly of the treaded ring*

Place something small in the opening and move the spanners to the other side and pry it open slightly.
This should be enough to release the two rings as below.

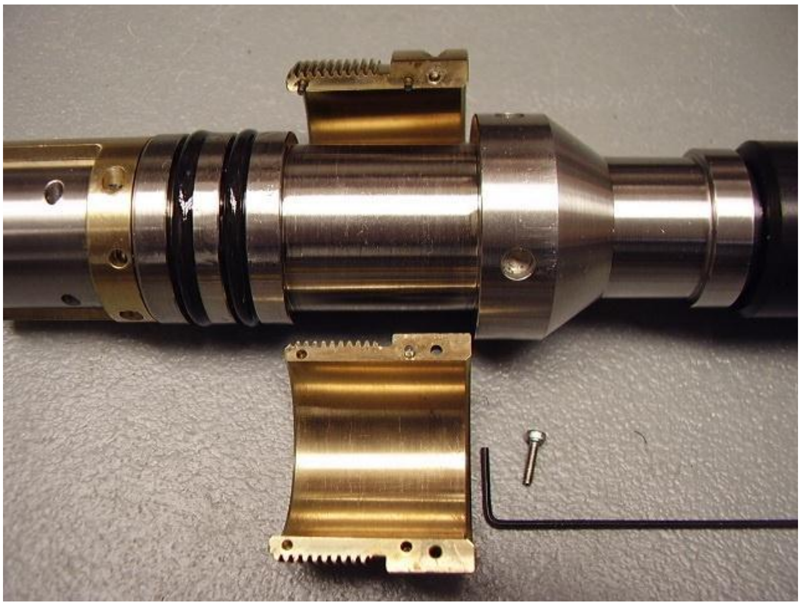


Figure 5-2 *Halves rings when pulled apart*

Clean inside surfaces thoroughly and reassemble, coating the inside with a very light film of anti-seize compound. Nickel based compounds are best, to prevent any sticking between the brass and steel surfaces.

6 Troubleshooting

In the event the tool develops a problem, follow the troubleshooting procedure listed below.
WARNING: ***NEVER DIS-ASSEMBLE THE PROBE WITHOUT KNOWLEDGE OF PROCEDURE***

Observation	To Do
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been installed with the LoggerSettings application (refer to LoggerSettings and LoggerSuite manuals for more information)
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 4.2 and 4.3) and store the new settings as default. Apply the appropriate tool settings for your logging run.
Tool panel - No current.	- Verify that the wireline armor is connected to the logging system. Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Test the interface cable between winch and data acquisition system. - Verify cable head integrity. Cablehead should have more than 20 Mega Ohm resistance electrical isolation. - Check wireline conductor and armor continuity. - Verify DC voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately turn off the tool !** **-** Possible shortcut (voltage low, current high): Check for water ingress and cable head integrity. - Verify cable head isolation integrity. Cablehead should have more than **20 Mega Ohm** resistance electrical isolation. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of the short circuit. - If the above shows no issues, use test cable (optional) provided by ALT or MSI to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 4.2 and 4.3). - If problem cannot be resolved, contact support@alt.lu or tech.support@mountsopris.com

Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC cannot receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - Check bandwidth usage and telemetry error status.

7 Appendix

7.1 Replacement Parts

Item No.	Qty	MSI Part No.	Description
1	1	17-202-160	Mag Susc. Calibration Puck, .5 x 10-3 SI units
2	1	17-202-175	Mag Susc. Calibration Puck, 2.4 x 10-3 SI units
3	1	17-202-176	Mag Susc. Calibration Puck, 5 x 10-3 SI units
4	1	17-202-177	Mag Susc. Calibration Puck 2 x 10-1 SI units
5	1	16-201-007	Silicone Lubricant Cartridge 14.1 oz.
6	1	54-203-216	Grease Gun #4BY69 for 14.1 oz.
7	1	17-202-178	Mag Susc. Calibration Puck Mount
8	1	54-101-921	C-Spanner Wrench
9	1	ALT26305	Q40 Plastic Female Plug
10	1	ALT26306	Q40 Plastic Male Lid

7.2 Other Parts

Item No.	MSI Part No.	Description
1	QL40-GO1	QL40-Go1 tool top
2	QL40-GO4	QL40-Go4 tool top
3	QL40-GO7	QL40-Go7 tool top
4	QL40-MS1	QL40-MSI tool top

8 Probe Tops - Standard Configurations

8.1 QL40-GO4 Four Conductor Tool Top

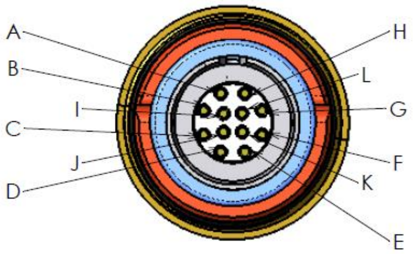


Figure 9-1 *Bridle bottom connection to tool*

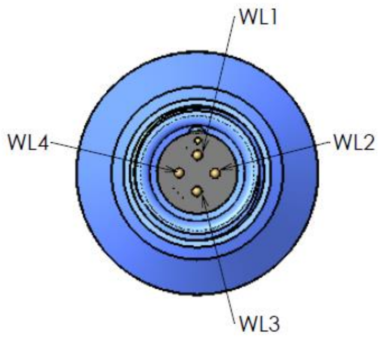
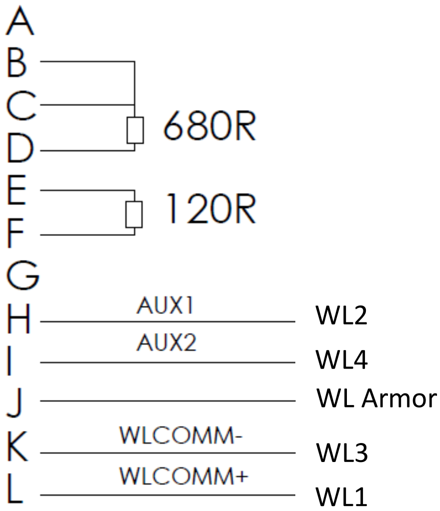


Figure 9-2 *Bridle top connection to cable head*



8.2 QL40-MSI and QL40-GO1 Single Conductor Tool Tops

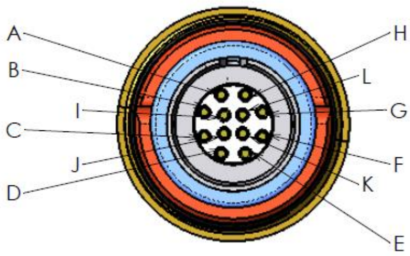


Figure 9-3 QL40-IS1 and IS2 Bridle bottom connection to tool

Figure 9-4 QL40-IS1 Bridle top connection to cable head

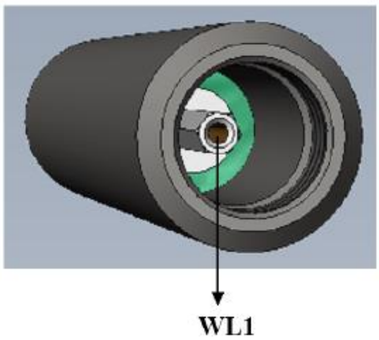
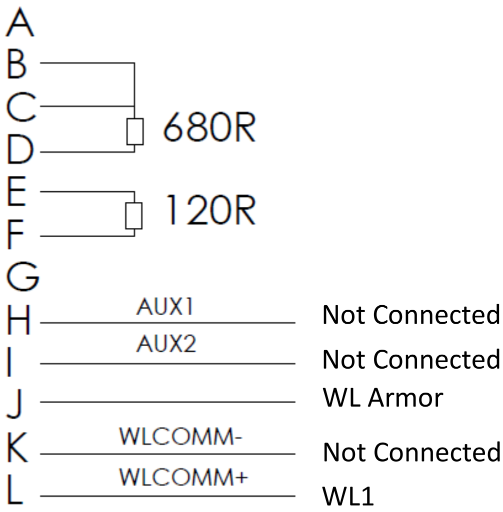


Figure 8-5 QL40-IS2 Bridle top connection to cable head



2SNA-1000-S
DX Series Spectral Gamma Probe

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
October 5, 2001

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General Information

Overview

The 2SNA-1000-S DX series spectral gamma probe section is a versatile tool that can be used in a wide variety of logging applications. The tool section measures natural gamma spectra, single point resistance, and spontaneous potential. Since the tool is part of the DX family of probes, it can be operated with any DX probe section. In this manner, additional measurements (such as density) can be added to the tool string.

Users can select from three operational modes (256, 512, or 1024 channel) based on their survey needs. The tool section is offered with several different options. The standard 2SNA-1000-S uses a 0.875 by 3 inch NaI(Tl) scintillator. The probe section is available with a BGO scintillator (2SNA-1000-SB) for more efficient detection of high energy gamma particles (and poorer energy resolution and accuracy).

The 2SNA-1000-S provides real time temperature compensation. The response from conventional tools drifts as temperature changes. This drift is extreme when using a BGO scintillator. The 2SNA-1000-S has been calibrated at the factory using several different sources and a swept temperature bath. Calibration coefficients resulting from these tests are stored inside the tool so that real time temperature compensation can be performed.

Controls, Connectors, and Layout

The 2SNA-1000-S probe section must be connected to a 2SMA-1000 modem section to make up the minimal tool string. Additional sections (such as a 2GDA-1000 density section) may be inserted in the tool string.

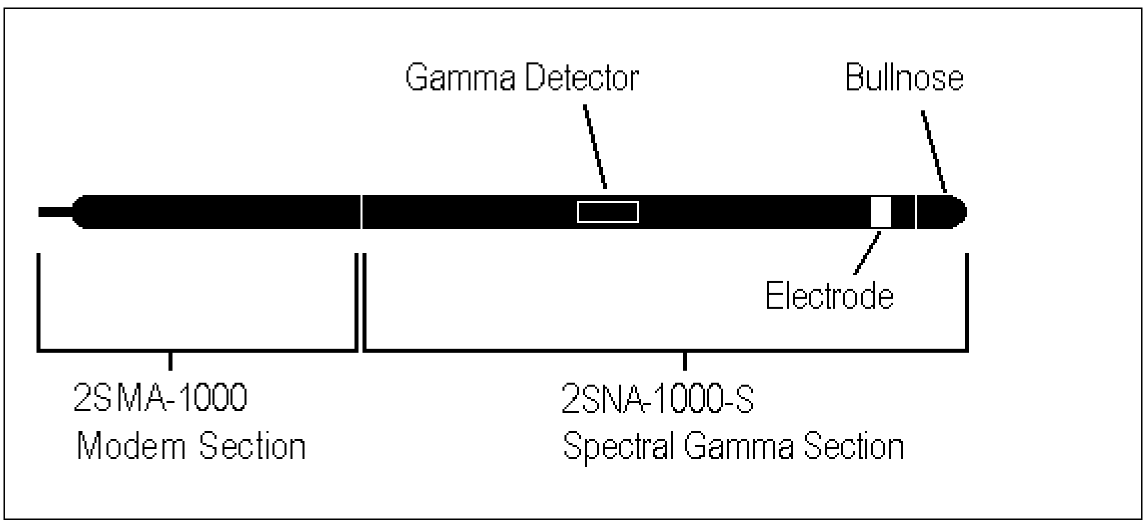

Figure 1: Diagram of the 2SNA-1000-S probe.

The DX series probe sections utilize keyed 10 pin connections. For example, to connect the 2SMA-1000 and the 2SNA-1000-S sections, insert the male end (lower end) of the 2SMA-1000 into the female end (upper end) of the 2SNA-1000-S. Rotate one of the sections until the alignment pin engages. Carefully press the two sections completely together. There may be some resistance when joining the sections together due to the O-ring seals in the connection. After the connection is fully seated, anchor the joint with the three hex head screws.

Theory of Operation

Naturally occurring radioisotopes emit many types of subatomic particles. Alpha, beta, and gamma particles are among the most common types of radiation and are seemingly well understood. When gamma particles travel through matter, they can interact with matter in one of three types of reactions: photoelectric, Compton scattering, and pair production. If a photon (gamma particle) survives one of these reactions, then it's energy will be less than it's pre-reaction energy. Figure 2 shows the resultant spectrum from a standard ^{137}Cs source which emits 662 KeV photons. The sharp peak that appears at 662 KeV is called the photopeak. The gamma rays that produced this peak did not react with matter as they traveled from the source to the detector, and they were totally absorbed by the gamma detector. The two smaller peaks to the left of the main peak are referred to as the Compton edge and the backscatter peak respectively. Gamma rays producing this part of the spectrum have been involved in Compton scattering reactions. Some of these reactions may have caused the particle to not be totally absorbed by the detector (scintillator crystal). The point that this simple example illustrates is that oftentimes, the particles from natural emitters will likely be involved in one or many reactions that complicate the resulting spectrum. This topic can be quite complex; and the reader can learn more from the many available textbooks on modern physics or particle physics.

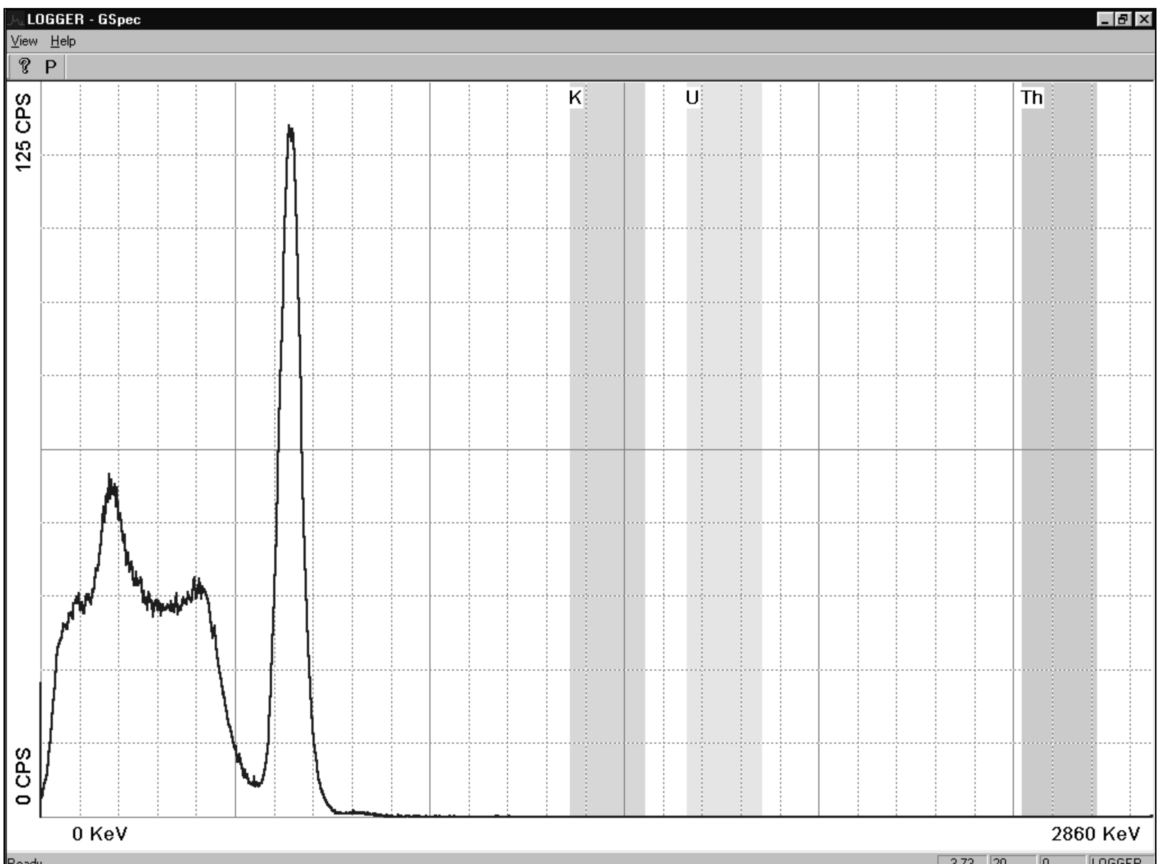

Figure 2: A typical spectrum from ^{137}Cs standard source showing a peak at 662 KeV.

The radius of investigation for the gamma detector is a function of the energy of the natural gamma radiation and the density of the surrounding medium. Higher energy particles tend to travel further before being completely absorbed through various reactions. A more dense formation will cause the natural radiation to be attenuated more quickly. Generally speaking, the radius of investigation is on the order of one to two feet (30-60 cm).

The gamma detector is made from a scintillator crystal and a photomultiplier tube. When a gamma particle is absorbed by the scintillator, the scintillator emits a small flash of light. The intensity of the light flash is proportional to the amount of energy absorbed by the scintillator. The light pulse is converted into an electric current and amplified by the photomultiplier tube. The amplitude of the electric current resulting from the incident photon is measured. A spectrum is built using the measured amplitude from many incident gamma particles. This spectrum is sent to the surface when the current time or depth digitize interval set by the operator has elapsed.

The 2SNA-1000-S performs real time temperature compensation. This is necessary because the amount of light produced by the scintillator varies with temperature. In fact, the temperature output from a BGO crystal varies by over 50% over the operating temperature range. Temperature compensation is based on calibration data stored inside the probe. The calibration data are determined at the factory by cycling the temperature over the operating range using several different radioactive standards.

Single point resistance is simply the resistance between the electrode at the bottom of the probe (the survey current source), and a fixed survey current return. The survey current return is usually either a fixed electrode on the surface (the surface electrode or mudplug), or the logging cable armor. The 2SNA-1000-S uses the logging cable armor. Since the survey current returns on a large area of the armor, the current density is low at the return and essentially all of the change in response comes from different resistances near the source electrode on the tool. The survey current is an AC current to prevent electrolysis of the survey electrodes. The radius of investigation for the single point resistance electrode is approximately 6-8 inches (15-20 cm).

Spontaneous potential is the DC potential between the probe electrode and a reference electrode located an infinite distance from the probe electrode. Since it is impossible to place an electrode at an infinite distance from the probe electrode, the reference electrode is often placed on the surface to reference the formation potential. The SP measurement then measures the potential difference between the borehole fluid and the non-invaded formation. The potential difference is, from a simplistic view, due to salinity differences between the borehole fluid and the non-invaded formation fluid. Most textbooks on geophysical logging contain a thorough review the causes of excursions on SP logs. The 2SNA-1000-S uses the armor as the reference electrode. Due to the long length of the armor, the potential on the armor is the average potential presented by the formation over the long length of exposed armor. Using the armor as the reference may change the offset value for the SP log, but not the amplitude of the individual excursions in the log.

Specifications

Maximum pressure .... 3000 PSI
Operation temperature range .... 0 to 60 degrees C
Storage temperature .... -40 to 70 degrees C

Natural gamma energy range .... 0 - 3 MeV
Natural gamma energy accuracy .... 2% of full scale
Natural gamma energy resolution .... 10% full width half maximum
Sensor location (from bottom of probe).. 22.83 inches (58 cm)

Single point resistance range.. 0-1000 ohms
Single point resistance accuracy... 1% of full scale
Single point resistance resolution.. 0.5 ohm
Sensor location (from bottom of probe).. 5.11 inches (13 cm)

Spontaneous potential range .... -2000-2000 mV
Spontaneous potential accuracy .... 1% of full scale
Spontaneous potential resolution.. 0.5 mV
Sensor location (from bottom of probe).. 5.11 inches (13 cm)

Length (assembled) .... 46.61 inches (118.4 cm)
Diameter .... 1.5 inches (3.81 cm)
Weight.. 11 lbs (4.99 kg)

Length (when connected to a 2SMA-1000) .... 71.26 inches (181 cm)
Diameter .... 1.5 inches (3.81 cm)
Weight.. 17 lbs (7.71 kg)

Installation

Installing the 2SNA-1000-S

The DX series probe sections must use MSLog as the data acquisition program. If you do not have the MSLog acquisition software, contact Mount Sopris Instruments. After MSLog is installed on the acquisition PC, and configured for your winch and logging cable, the 2SNA-1000-S probe drivers need to be installed. Use the MSLConfig utility to install the necessary probe drivers. Note that there will be different probe drivers for each specific 2SNA-1000-S model, and also the probe sections that will be connected to the 2SNA-1000-S.

The MGX II logger must have either the 5PMA-1000 or 5TMA-1000 modem installed. These modems are only available on the 5MCA-1000 consoles. Units with the modems installed will have the extension /TMA or /PMA appended to the model number. The model number is shown on the logger nameplate located near the power connector. If you don't have the proper modem installed, contact Mount Sopris Instruments.

Setting up Isolation for the Resistance and Self Potential Measurements

In order for the resistance and self potential measurements to function properly, the part of the tool and logging cable above the electrode (near the bottom of the 2SNA-1000-S section) must be electrically isolated. The 2SMA-1000 is wrapped in a neoprene sleeve. Before logging, make sure that any metal exposed above the electrode is well covered with several layers of PVC electrical tape. Cover any exposed metal from the electrode to the probe top. Remember that the tool may be rubbing against the side of the borehole, so make the isolation robust. If there is any break in this insulation, the resistance and spontaneous potential measurements may not record accurate, calibrated data.

Operating Procedure

Operation

The outline shown below describes the procedure that should be used for most logging operations. For a more detailed description of software operation, consult the MSLog user manual. This manual is available as 'help' in MSLog. To access the MSLog 'help', right click on the MSLog dashboard and select Help Index.

1. Connect the logging cable head to the 2SMA-1000 modem and the rest of the probe string. For the Mount Sopris single conductor cable head, rotate the probe instead of the cable head to make the connection. Inspect the cable head O-ring before making the connection. Make sure that it is not worn, nicked or cut. Apply silicon grease to the o-ring surface. Insure that the mating parts of the cable head and the probe top are clean.
2. In order for the resistance and self potential measurements to function properly, the part of the tool and logging cable above the electrode (near the bottom of the 2SNA-1000-S section) must be electrically isolated. The 2SMA-1000 is wrapped in a neoprene sleeve. Before logging, make sure that any metal exposed above the electrode is well covered with several layers of PVC electrical tape. Cover any exposed metal from the electrode to the probe top. Remember that the tool may be rubbing against the side of the borehole, so make the isolation robust. If there is any break in this insulation, the resistance and spontaneous potential measurements may not record accurate, calibrated data.
3. Start the acquisition software (MSLog), select the proper probe driver, and power up the tool. Usually the tool calibrations will be verified at this point. This is outlined in the next section.
4. Place the tool in the borehole. Zero the tool at the zero depth reference. Lower the tool until it is submerged. Wait for the tool to thermally equilibrate to the borehole fluid temperature. It is important to allow the tool to thermally equilibrate so that the real time calibrations are accurate. Allow 15-20 minutes for the tool to equilibrate.
5. Using MSLog, set the desired depth digitize interval, set the digitizing mode to 'depth up', 'depth down', or 'time' and start recording a data file. Log the borehole as desired. You may wish to log the entire borehole slowly. Alternatively, you may want to log in 'time' mode at a fixed depth for a particular zone of interest. As a rule, the logging speed should be fairly slow (~3 ft./min or ~1 m./min.) for reasonable statistics and repeatability of the recorded spectra. Slower logging be necessary to improve the resolution and repeatability of the data
6. When finished logging, power down the tool, and remove it from the borehole. Place the tool on the ground or a cleaning stand. Wash the probe with water (a portable sprayer works well), making sure that all mud and solids are rinsed away. Inspect the insulating tape for wear. Replace worn insulating tape as necessary.

Performance Checks and Calibrations

Calibration of the **spectral gamma** measurement should not normally be necessary. If calibration is needed, follow the steps below:

1. Connect the probe to the cable head, and power up the tool as outlined the above operating procedure.
2. Place a known gamma reference source as close as possible to the probe at a distance of 22.8 inches (58 cm) from the bottom of the probe.
3. Place the tool and the source in a water bath. Wait 15-20 minutes to allow the tool to thermally equilibrate. If the tool is not submerged, the tool may not warm up evenly, and the resulting calibration may not be valid when the tool is submerged.
4. Set the time digitize interval, then set the sampling mode to 'Time'. The time digitize interval may need to be increased until the spectrum displayed by GSpec is well defined

and repeatable. Place the mouse pointer on the photopeak of the spectrum and press the left mouse button. Record the channel number for this peak.

5. Place a second known gamma reference source as close as possible to the probe at a distance of 22.8 inches (58 cm) from the bottom of the probe.
6. Set the time digitize interval, then set the sampling mode to 'Time'. The time digitize interval may need to be increased until the spectrum displayed by GSpec is well defined and repeatable. Place the mouse pointer on the photopeak of the spectrum and press the left mouse button. Record the channel number for this peak.

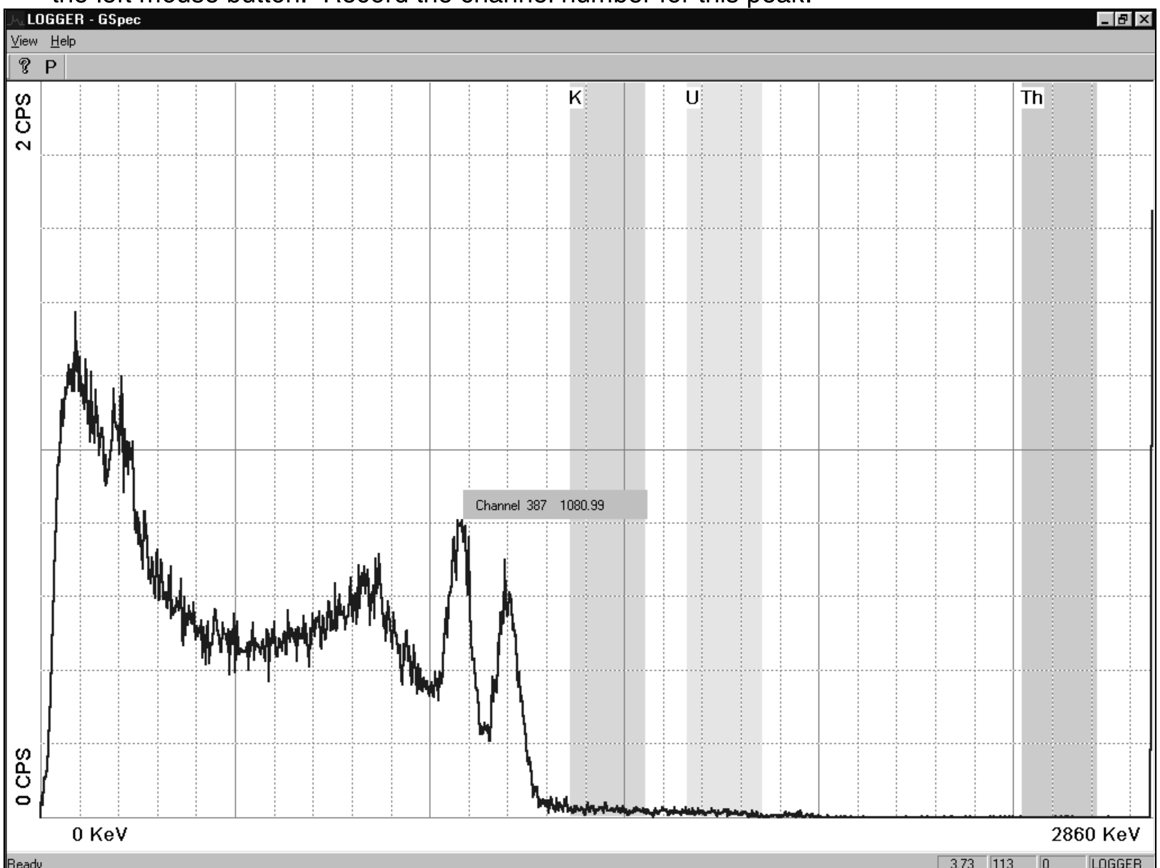

Figure 3: A typical spectrum from ^{60}Co standard source showing a peak at 1173 and 1333 KeV.

7. Click on the SpecProc window. Right click on the 'P' parameter tool bar button. Enter the energy for the first calibration source in the 'First Calibration Point' 'Energy' field (i.e. 662 for ^{137}Cs). Enter the window number recorded in step 3 in the 'First Calibration Point' 'Channel' field (i.e. 222 for ^{137}Cs). Enter the energy for the second calibration source in the 'Second Calibration Point' 'Energy' field (i.e. 1173 for ^{60}Co). Enter the window number recorded in step 5 in the 'First Calibration Point' 'Channel' field (i.e. 387 for ^{60}Co). See figure 4.

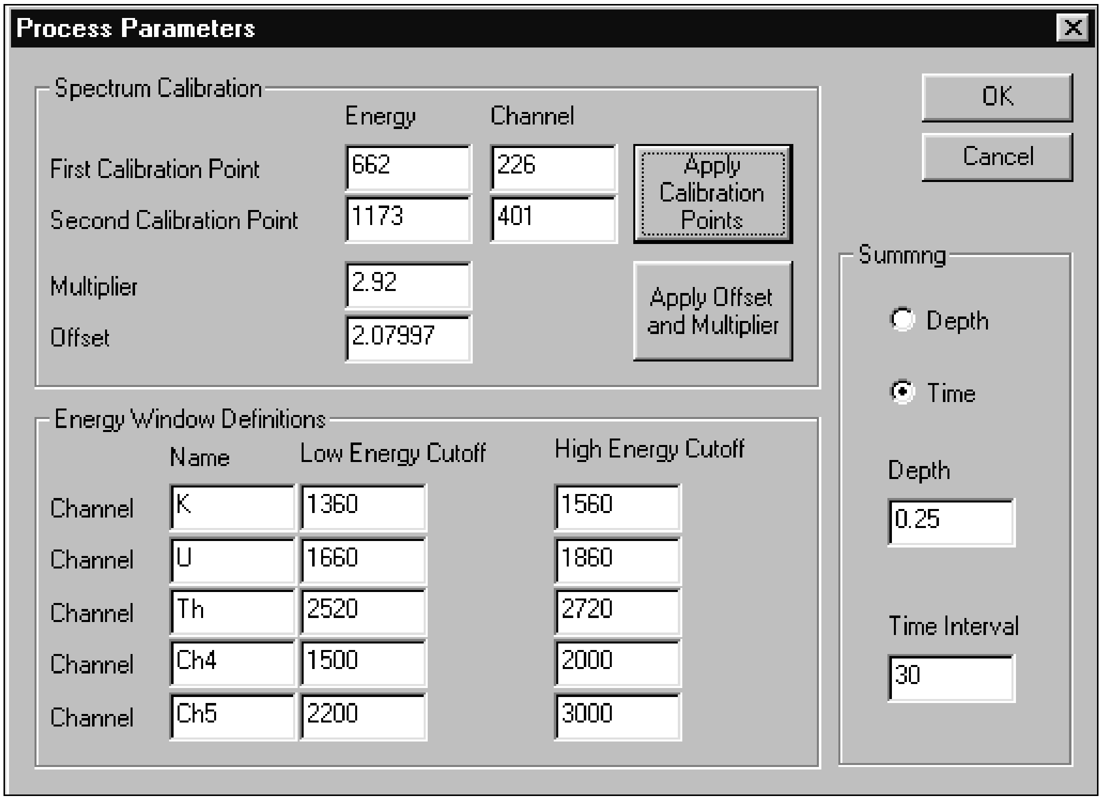

Figure 4: SpecProc calibration dialog box.

8. On the MSLog panel, click the ‘Close All’ button on the ‘Browsers & Processors’ window. Next, restart all processors and browsers by clicking on the name of the browser or processor, and pressing the ‘Start’ button. Note: LASWriter only needs to be started if an LAS output file is desired.
9. Check the calibration by placing a known gamma reference source as close as possible to the probe at a distance of 22.8 inches (58 cm) from the bottom of the probe. Verify that the photopeak appears at the correct energy.

Calibrating the **resistance** and **spontaneous potential** measurements is not necessary. They have been calibrated at the factory and the calibration numbers are electronically stored inside the probe.

Preventative Maintenance

Always keep the probe section connector covered when disconnected. This protects the connectors from mechanical abuse and corrosion. Use the probe section protector caps.

Remember that the gamma detector is fragile. Use care when placing the tool in the borehole and when traveling down into the borehole. Also, store the tool in a secure place, preferably in a shock resistant container. During transport, logging tools typically endure more shock than when in the borehole.

Keep all thread and O-ring surfaces clean and dry. Re-apply grease or silicone compound (O-rings) on a regular basis. Always clean the tool after each use.

Troubleshooting

Problems with the Probe

If electronic troubleshooting becomes necessary, it should only be performed by qualified persons.

If MSLog reports communications errors (such as parity-framing) and no data can be displayed, make sure that the probe is communicating properly. When the logger and the probe are communicating properly, the ‘to probe’ and ‘from probe’ lights should be flashing on the logger.

If communications are not functioning properly, make sure you are using the correct tool driver with MSLog. Also, check the condition of the wireline. The MSLog online help provides detailed instructions on this procedure. When running MSLog, right click on the dashboard and select Help Index. Then choose the Wireline and Cablehead Troubleshooting section.

Disassembly Instructions

To access the inside of the probe, the probe top can be removed from the main housing. To remove the probe top, first remove the three screws just below the section top. You will have to dig out the sealing compound out of the screw heads. This compound is used to discourage inadvertent disassembly. After removing the three probe top screws, gently pull the probe top out of the housing and disconnect the probe top connector from the upper circuit board. Remove the housing locking screw (located just above the resistivity electrode) using an M3 hex wrench.

Next the housing can be unscrewed from the lower section of the probe. The gamma circuit board is located at the top end of the inner housing with the gamma detector just below the circuit board. Disassembly of the gamma detector is <u>not recommended.</u> The lower most circuit board is for the resistance and spontaneous potential.

Common field correctable electronic problems are a broken or shorted wire. A visual inspection of the wiring should be performed before further testing is done.

If electronic testing is to be done, the user should have detailed electronic schematics before proceeding any further.

Schematics

2SNA-1000-S

Drawing Number	Title

Appendix

Suggested QA Procedure

General notes for Quality Assurance (QA) are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. Mt. Sopris acquisition programs record the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedures specify that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

LLP-2676 Neutron Probe

Mount Sopris Instrument Co., Inc.
Golden CO, U. S. A.
April14, 2005

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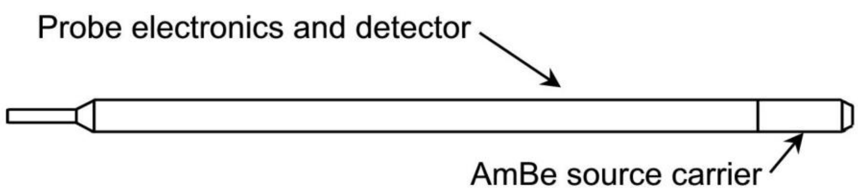
General Information

Overview

The LLP-2676 thermal neutron probe is a simple analog pulse probe, which measures the output of a He^3 detector inside the probe. The He^3 detector is powered by a regulated HV downhole power supply. The probe is powered by 30 VDC on the wire line, and requires ~40 mA of current to operate. The detector sends pulses through a charge sensitive amplifier and pulse shaper to provide 1.25 μsec pulses with ~7 V amplitude to the wire line for transmission up the cable. Depending on the source strength and borehole environment, count rates of between 100 and 10,000 may be expected.

The He^3 detector responds to the intensity of thermal neutron flux it receives from the borehole environment. Thermal neutrons are created by scattering of high energy neutrons emitted by a chemical source that is installed 35 cm below the mid-point of the detector.



Theory of Operation

In general, neutrons logging can be divided into three main categories. High-energy neutrons, from a chemical or electronic source, will react with material surrounding a borehole with several possible results. When neutrons react in elastic collisions (which is most likely to happen with atoms that have about the same mass as the neutron), they are said to be moderated, with each collision resulting in the neutron transferring some energy to the target nucleus. After a number of these collisions, the neutron will finally reach a “thermal” energy level. The Mount Sopris LLP-2676 probe contains a He^3 detector, which detects thermal neutrons quite efficiently.

When high energy neutrons are scattered by target nuclei, but only loose a portion of their energy, this process is known as inelastic scattering. The target nuclei are in an excited state and then will give off a characteristic gamma ray that can be measured by a spectral gamma detector. Such characteristic gammas can be related to the chemical composition of the surrounding formation.

The third type of neutron interaction that is commonly measured in a borehole environment is based on a process called thermal neutron absorption. In this case, the thermal neutrons are captured by a target nucleus, which results in a compound nucleus that de-excites instantaneously, with the emission of a number of characteristic gamma rays. In such a case, the capture gamma flux is measured versus time to produce a decay rate which is related to the capture cross section of the surrounding formation. This measurement can be used to infer which formations may contain salt water and which might contain hydrocarbons.

Neutron Production

There are two general methods used to supply high-energy neutrons in a borehole environment. The most common is with the use of a chemical source. Currently, a mixture of $_{241}$ Americium and Beryllium are used to produce neutrons for thermal and epithermal logging by bombarding the Beryllium with alpha particles supplied by the $_{241}$ Americium . A second method uses an electronic particle accelerator that accelerates deuterium and tritium ions into a target composed of the same material, resulting in a high flux of high-energy neutrons (around 14 MeV). Very high probe voltages are required for this process (>80 kV)

The Mount Sopris LLP-2676 generally uses a 37 GBq (1 Curie) $_{241}$ AmBe source.

Specifications

Diameter	41.3 mm (1.625 inches)
Length	111 cm (44 inches)
Weight	5.5 kg (12 pounds)
Source-Detector spacing	35 cm (15 inches)
Dose rate in shield at 1 meter	<1 mR/hr
Shield dimensions	35.6 cm (14 inc) sphere
Shield Weight	35 kg (78 pounds)
Operating temperature	-25 to 75 degrees C.
Source	37 GBq (1 curie) $_{241}$ AmBe
Detector	$_3$He at 4 atmospheres

Installation

Installing the source on the probe

The probe is delivered with a thread protector that covers the male thread that connects to the neutron source. The neutron source is stored in a shield that includes a spacer and a lock to prevent accidental release of the source from the shield.

The source shield should be locked in a secure area when not being used, and locked to the logging truck during transport. Local safety and transportation rules are the responsibility of the user. For a detailed discussion of source handling and transport regulations, consult the NRC website (or the local regulating body's available documentation).

Prior to loading the source onto the probe, place the source shield near the wellbore. Make sure the wellbore has a cover plate installed, so that the source cannot be accidentally dropped in the hole.

Clear the area of all non-essential personnel. Only persons trained and certified in the handling of radioactive materials should permitted to handle and load sources. The source handling tool is used to remove the source from the shield. Unlock the shield, remove the spacer, and insert the handling tool inside the shield. Turn the body of the handling tool until it fits over the hexagonal mating end of the source. Then turn the knurled handle in the center of the end of the handling tool to lock the source onto the handling tool. Once the source is firmly attached to the handling tool, the source can be then removed from the shield and screwed directly on to the LLP-2676 probe. Once the source is screwed firmly to the probe, the handling tool can be removed. It is normally a good idea to have already screwed the cable head onto the probe, and run the cable through all necessary sheave wheels, etc. before installing the source. However, the user can always re-insert the probe with source installed back into the shield if necessary.

The key to safe handling of radioactive sources during well logging operations is to plan your procedures, check all equipment before removing the source from the shield, and then move as quickly and efficiently as possible to install the source and lower the probe into the hole. Once the top of the probe is a few meters below ground level, there is no further radiation risk to the operator.

If an operator spends 15 seconds during this installation process, and a similar amount of time to remove the source and place it back in the shield, the dose rate will be 30 seconds X 16 mR/hr, or 0.13 mRem. Always remember to cover the hole after removing the probe and before removing the source from the probe.

Operating Procedure

Operation

The LLP-2676 probe is an analog pulse probe, and it is important to remember that the correct wireline length and type should be supplied to the logging system so that pulse discriminators are properly set with the software.

Logging is normally done in the up direction for better depth accuracy. A repeat section should be made in the bottom of the hole, if hole conditions permit. Maximum logging speed for good statistical accuracy is 5-6 m/minute (20 ft/min) maximum. A 10 cm (.2 ft) sample interval is more than adequate for the LLP-2676.

Expect to see a significant change in the neutron count rate at fluid level. The neutron measurement is only slightly affected by the presence of steel casing. It is not affected by PVC casing, although the volume of open hole behind the casing may affect the total count rate in any cased hole geometry.

Performance Checks and Calibrations

The easiest way to check the LLP-2676 before going to the field for a logging job is to install the source and place the source and probe back in the shield. The probe should see a count rate of from 50 to a few hundred cps.

Calibration of the neutron probe is based on measurement of count rates in known lithologies and porosities. The measurement of thermal neutrons is generally related to the amount of hydrogen nuclei in the surrounding material. Hydrogen is most common as a component of water in the borehole, and water in the pore space of the surrounding rock. Some hydrogen may also be present in the clays and other mineral compounds. In general, thermal neutron probes are logged in an attempt to measure fluid filled porosity or moisture content of downhole formations.

There are borehole models available in many parts of the world that can be used to calibrate thermal neutron logging probes. The API (American Petroleum Institute) maintains standard models in Houston, TX USA. Other models exist at the DOE facility in Grand Junction, CO USA. Other sites are available in Europe, Asia and Australia.

Mount Sopris has performed standard calibrations for the LLP-2676 at the API models in Texas, and has checked these results in the Grand Junction models. A secondary field calibrator is available that allows the user to match the master calibration in the field using a simple ratio method. It is not designed as a perfect quantitative calibration, but does allow the user to make good estimates of porosity, if lithology and borehole corrections are properly applied.

An example of the calibration performed at the Houston models is shown in the appendix. If a calibration is desired, consult Mount Sopris Engineering for more details (tech.support@mountsopris.com).

Preventative Maintenance

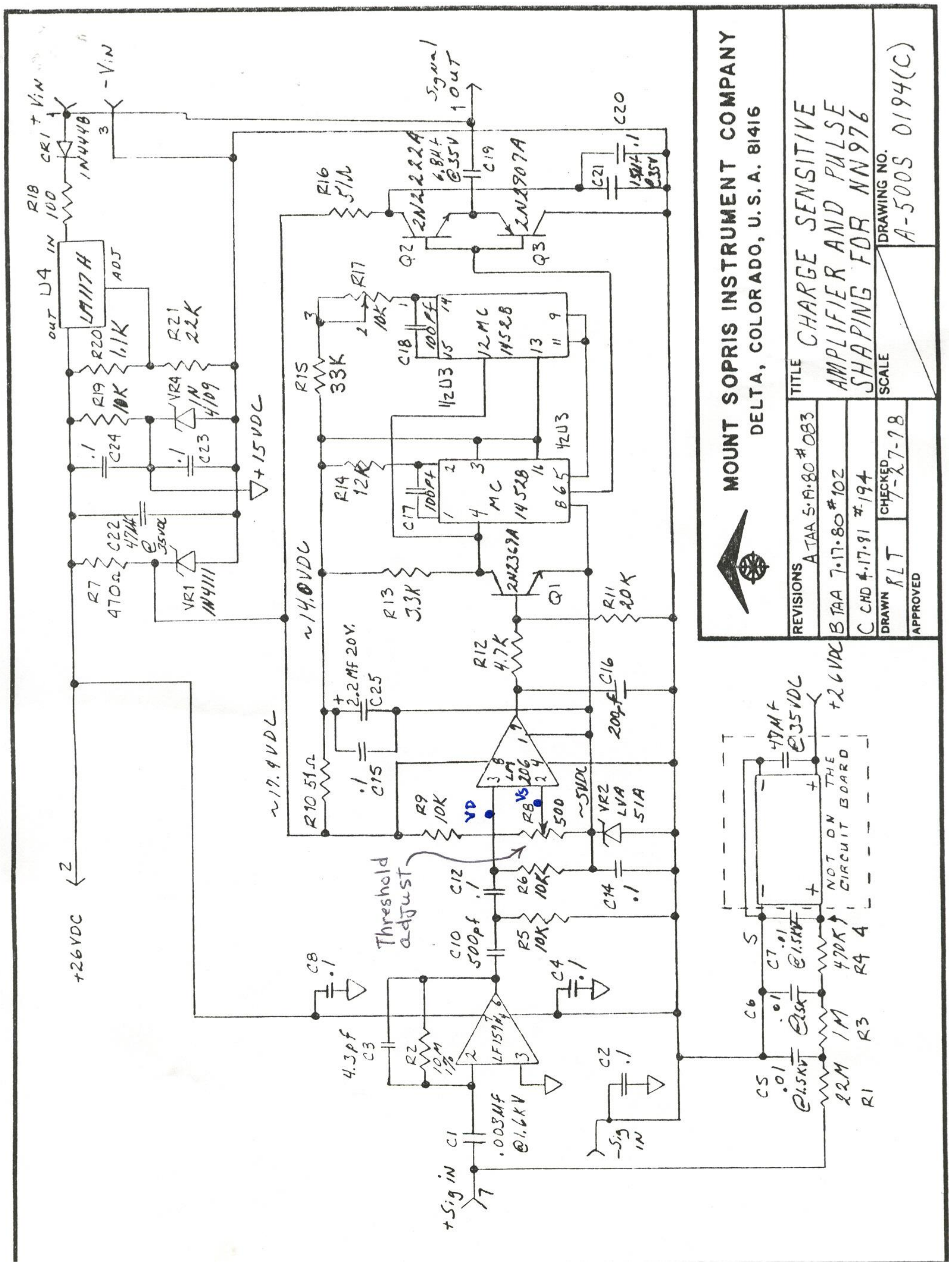
The LLP-2676 has no moving parts, and the only maintenance required is to clean and dry all thread surfaces after each use. This is particularly important on the source end of the probe, to make sure that there will be no problem screwing the source into the female probe thread. The o-ring seal area in the probe top should be wiped out with a clean cloth and dried before replacing the probe protector cap.

Disassembly Instructions

While there are no user serviceable parts inside the probe, the user can inspect the inside of the probe by removing the probe top from the housing. This is done by removing the 4 radial screws at the top of the probe. These screws are 8-32 x 3/8” English screws.

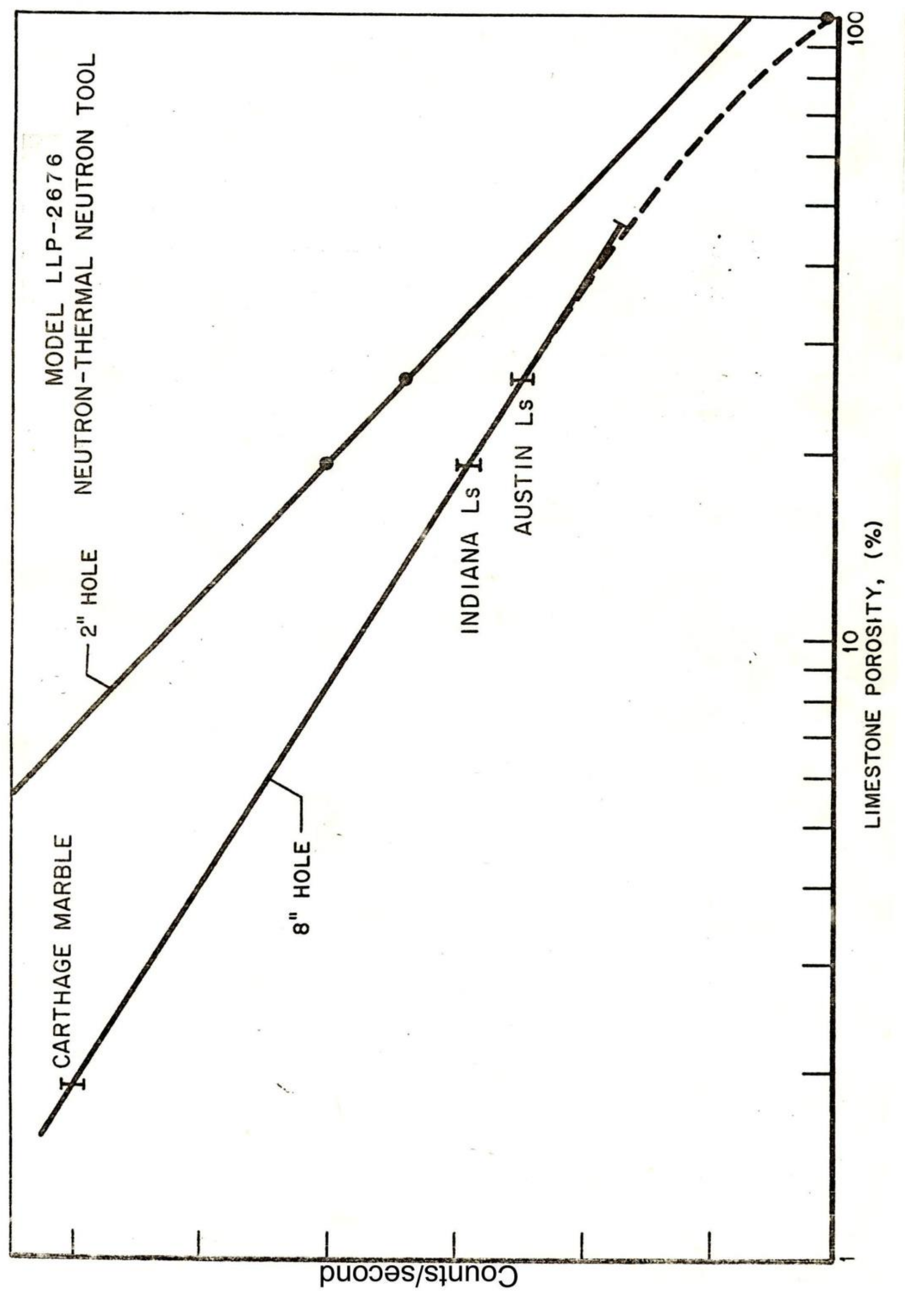
Schematics

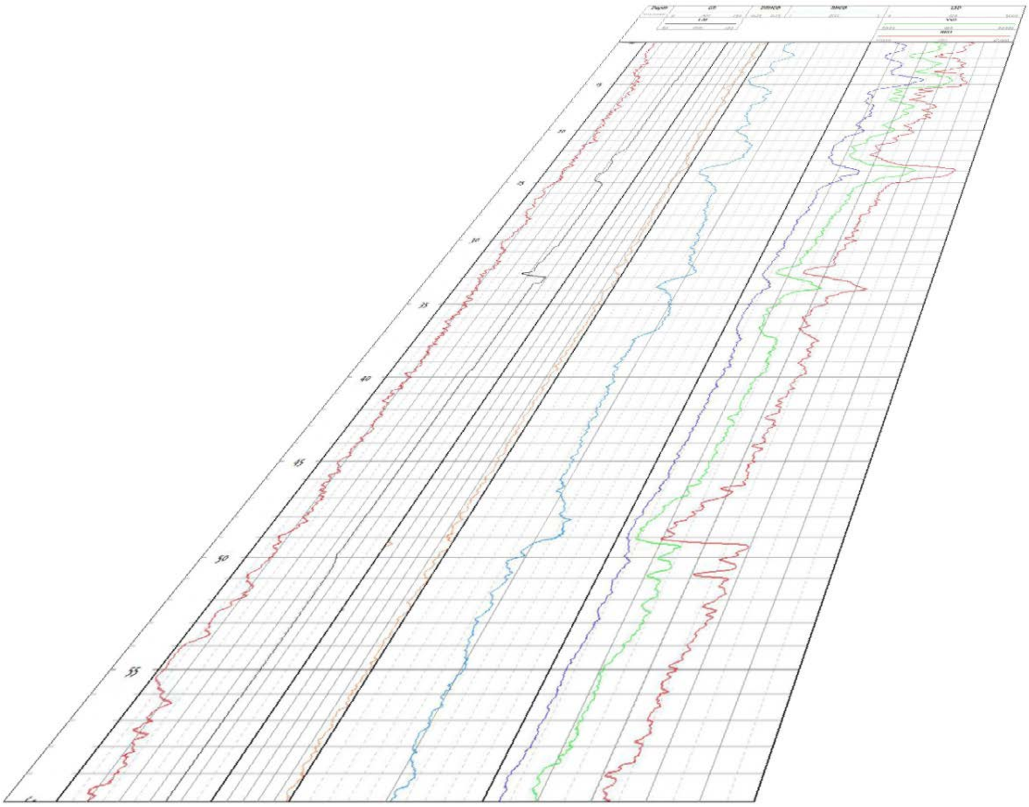
Drawing Number 500S-0194 Title Charge sensitive amplifier and pulse shaper



Appendix

Example of neutron porosity calibration from Houston API models.





User Guide

QL40 DEN – Compensated Dual Density

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V2014.08.01

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1 General Information

The QL40-DEN Compensated Dual Density bottom sub is a versatile wireline tool that can be used in a wide variety of logging applications. Measurements include SSD (short-spaced raw cps and g/cc density), LSD (long-spaced raw cps and g/cc density), Compensated density (dual density), and Caliper. Since the tool is part of the Quick Link family of probes, it can be stacked with any QL inline sub. In this manner, additional measurements (such as natural gamma, deviation, or resistivity) can be added to the tool stack. The tool section is designed for operation in $2^{1/2}$ to $11^{1/2}$ inch (6.3 – 29.2 cm) boreholes.

QL40 Stackable Logging Tool Overview

QL stands for Quick Link and describes the latest line of stackable logging tools. This development is a joint venture of Mount Sopris Instruments (MSI) and Advanced Logic Technology (ALT). Innovative connections between tool elements (subs) allow users to build their own tool strings in the field. The Tool Stack Factory – a sophisticated extension of the acquisition software – provides a convenient way to configure tool strings for operation. For more information about the Tool Stack Factory, see LoggerSuite Manual.

Each sub has a Telemetry and Power supply element, TelePSU, allowing stand-alone operation. A GenCPU card in each sub handles Analog to Digital conversion and/or counting of the measurement signal and formatting data for transmission up hole.

The QL40-DEN bottom sub can be operated as a stand-alone probe or can be stacked below other subs. The stack is completed by adding a Tool Top sub. Varied tool top subs are available. Top subs include an MSI single conductor, GO4 conductor, GOI Single conductor and GO7 conductor. Consult the factory for additional options. The number 40 indicates a nominal OD of 40mm. Over coating and special measurements may make some subs larger in diameter. See their particular specifications.

1.1 Dimensions

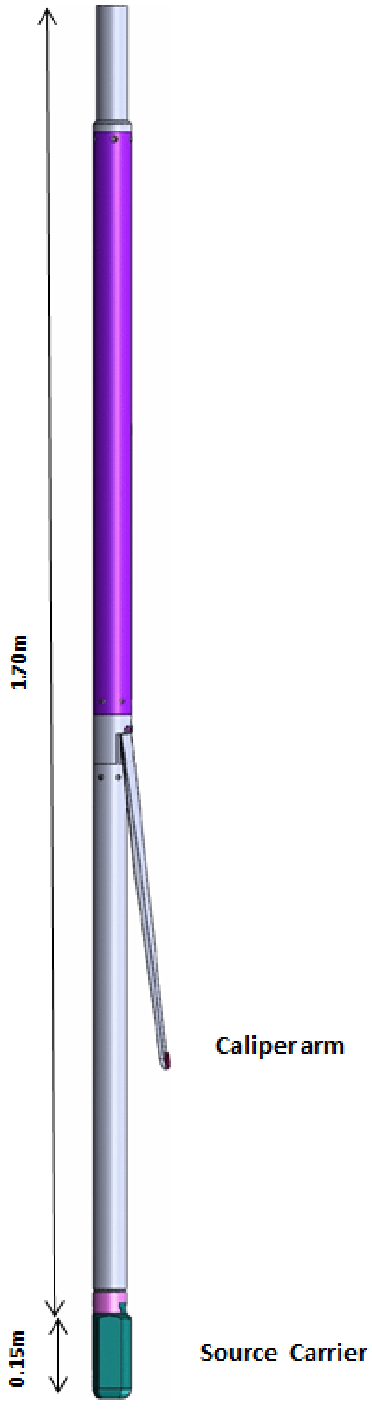


Figure 1-1 *Tool general arrangement*

1.2 QL40-DEN Technical Specifications

Tool:

Diameter:	50.8 mm (2”)
Length:	1.85 m (73”)
Weight:	19.2 kg (42 lbs)
Max. Temperature:	85 °C (185 F)
Max. Pressure:	206 bar (3000 PSI)
Short spaced source – detector (SSD):	20 cm (7.87”)
Long spaced source – detector (LSD):	35 cm (13.77”)

Cable:

Cable type:	Mono, Coaxial, 4 or 7 conductor
Digital data transmission:	Up to 500 Kbits per second depending on wireline
Compatibility:	ALTlogger – BBOX – Matrix

Measurement:

Caliper Max.	29.2 cm ($11^{1/2}$”)
Caliper Accuracy:	2.54 mm (0.1”)
Caliper Resolution:	0.64 mm (0.025”)
Density Range:	1 – 4 g/cc (depends on source)
Source:	100 – 250 mCurie (Cs-137 or Co-60)
Density Accuracy:	0.1 g/cc (100 mC Cs-137)
Density Resolution:	0.05 g/cc (100 mC Cs-137)

Power:

DC voltage at probe top:	Min 80 VDC Max 160 VDC Nominal 120 VDC
Current:	Nominal 25mA

2 Measurement Principle

2.1 Density

The compensated density measurement is accomplished using a radioactive source and two radiation detectors. The detectors are designed for use with a Cs137 source (emits 662 keV gamma particles). They are set to respond to gamma particles having energies of 200 keV or higher (the Compton energy band). Radiation detectors are comprised of two CsI(Th) scintillator crystals coupled to two photomultiplier tubes. The near detector scintillator is 0.5 inches (1.27 cm) long and 0.5 inches (1.27 cm) in diameter; the far scintillator is 1.5 inches long and 0.5 inches in diameter. The detectors are shielded so that they only respond to gamma radiation from the same side of the tool that source energy radiates from. Radiation emanating from the source travels into the formation (into the side of the borehole opposite the caliper), and is backscattered by Compton scattering. The detectors sense this backscattered radiation. Compton scattering results from gamma radiation interacting with the electrons in the formation, so total electron density is measured rather than bulk density.

The detector response is a function of density and the detector offset from the source. As shown in Figure 2, for low densities (typically less than 1 g/cc) and close offsets (typically less than 8 cm for 137Cs), the detector response increases with increasing density. The intuitive explanation of this phenomenon is that when density and spacing are small, more electrons cause more backscattering and more radiation at the detectors. As density and detector offset continue to increase, more of the radiation is absorbed and the response decreases with increasing density and spacing. The detector response at 4 cm from the source is on the positive slope of the curve below; that is, the response increases with increasing density. The response for detectors at 11cm or more from the source has a negative slope. The detector response decreases with increasing density for these offsets.

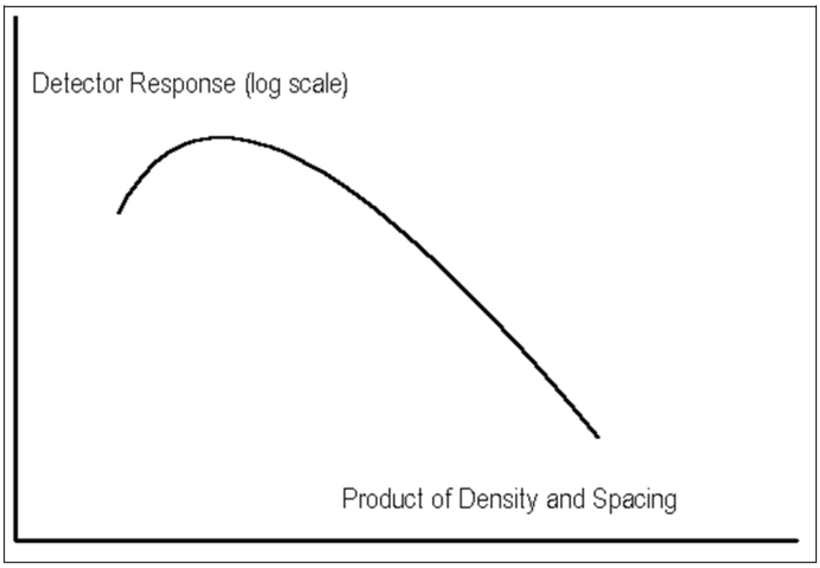


Figure 2-1: *Generalized density detector response*

The volume of investigation for the long offset and short offset density measurements is different. The combination of these two measurements, together with a typical spine and rib chart shown in Figure 3, are used to determine compensated electron density. This method compensates for rugosity and fractures in the borehole wall and any distance the tool may standoff from the borehole wall. The compensation assumes that the borehole is filled with water. The correction is different for air or mud filled holes. Calibration and compensation curves for each QL40-DEN are supplied in a Technical Addendum to this documentation (coming soon). The information presented in the Technical Addendum are obtained by performing a 4th or 5th order multivariate regression on density survey data from the Q40-DEN at the Department of Energy (DOE) pits in Grand Junction, Colorado. During characterization, data are collected at various densities, borehole diameters, and tool standoffs.

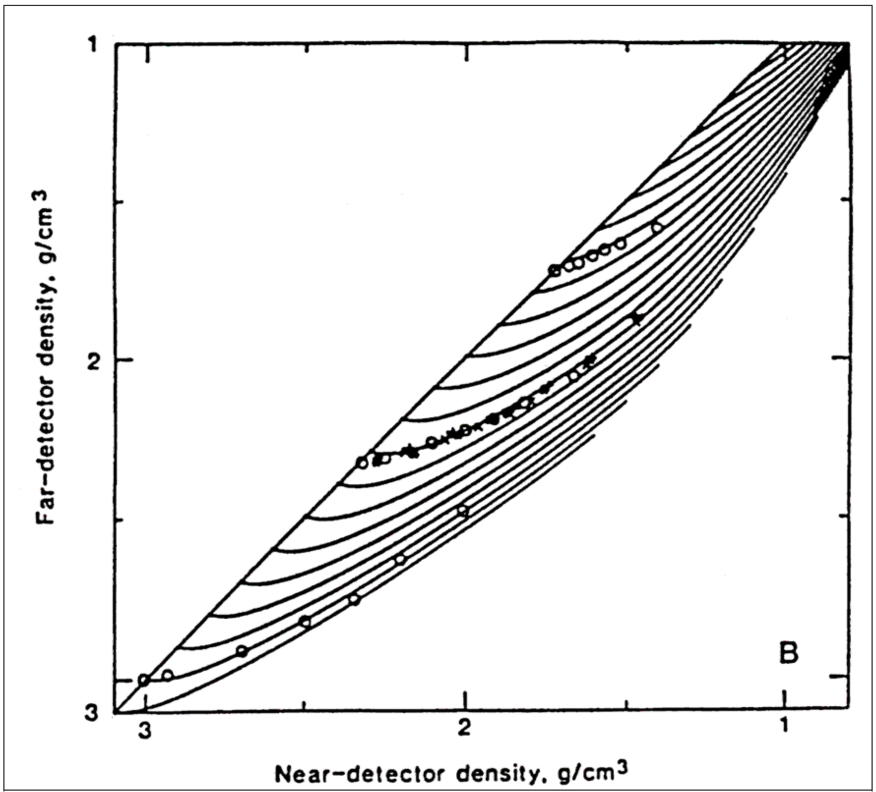


Figure 2-2 *Typical density compensation*

2.2 Caliper

The caliper measurement is straightforward. The arm is actuated by a compressed spring. A position sensor (a linear potentiometer) connected to the caliper arm drive piston measures the actual arm position. The DC output voltage from the wiper of the potentiometer is converted to a frequency linearly related to the borehole diameter. Calibration constants and linearization are stored in the tool specific sub file so that initial user calibration is not normally necessary. Depending on borehole conditions, the wear button on the arm will eventually change size, and re-calibration can be made using the MChNum calibration function and known calibration rings or calibration jig.

3 QL40 DEN assembly and set up

QL stands for **Q**uick **L**ink and describes an innovative connection between logging tools (subs) allowing to build custom tool stacks. QL40 describes a specific family of logging tools. Each sub is equipped with its own Telemetry board, Power supply element and A/D converter allowing an operation as stand-alone tool or as a stack in combination with other subs of the QL product family.
The QL40 probe line deals with two types of subs - Bottom Subs and Mid Subs.

Bottom Sub
A bottom sub is a tool that must have one or more sensors located at the bottom. It can be operated in combination with other QL subs connected to the top but it is not possible to connect another sub below. When used in stand-alone mode the bottom sub only needs a QL40 tool top adaptor, which fits the cable head.

Mid Sub
A mid sub is a tool that can be integrated anywhere within a stack of tools. When used at the bottom of a tool string a QL40 bottom plug must be used to terminate the string. If the mid sub is used as a stand-alone tool it needs a QL40 bottom plug at the lower end and a QL40 tool top adaptor at the top.

3.1 QL40 Tool Stack Assembly

A QL40 tool stack may be terminated by either a QL40 bottom sub or a QL40 bottom plug. At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available; special ones can be made on request.

To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.

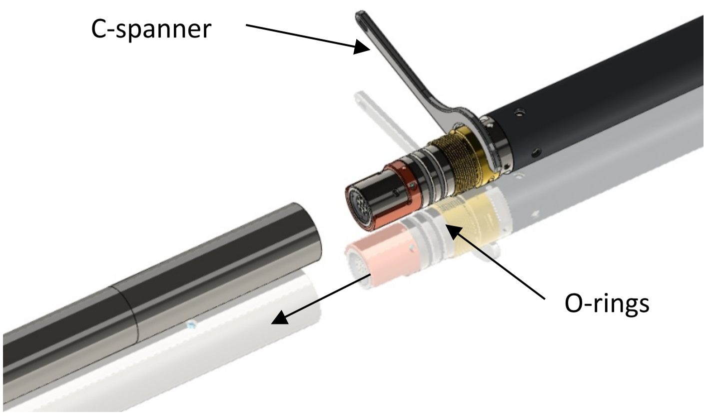


Figure 3-1 *C-spanner and O-rings of QL connection*

The following example of a QL40-ABI, QL40-GAM and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GAM sub stand-alone.

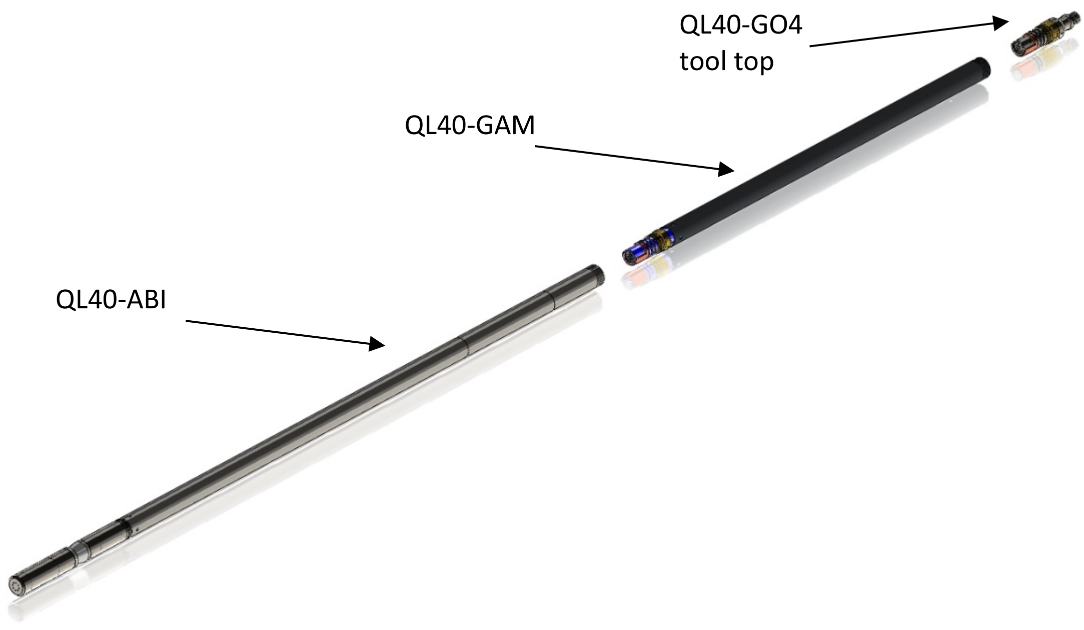


Figure 3-2 *Tool stack example*

To remove the QL40-ABI bottom sub attach the C-spanner to the thread ring as shown in Figure 3-3, unscrew the threaded ring, (anticlockwise about the tool axis when looking towards the bottom of the tool), and remove the QL40-ABI bottom sub.

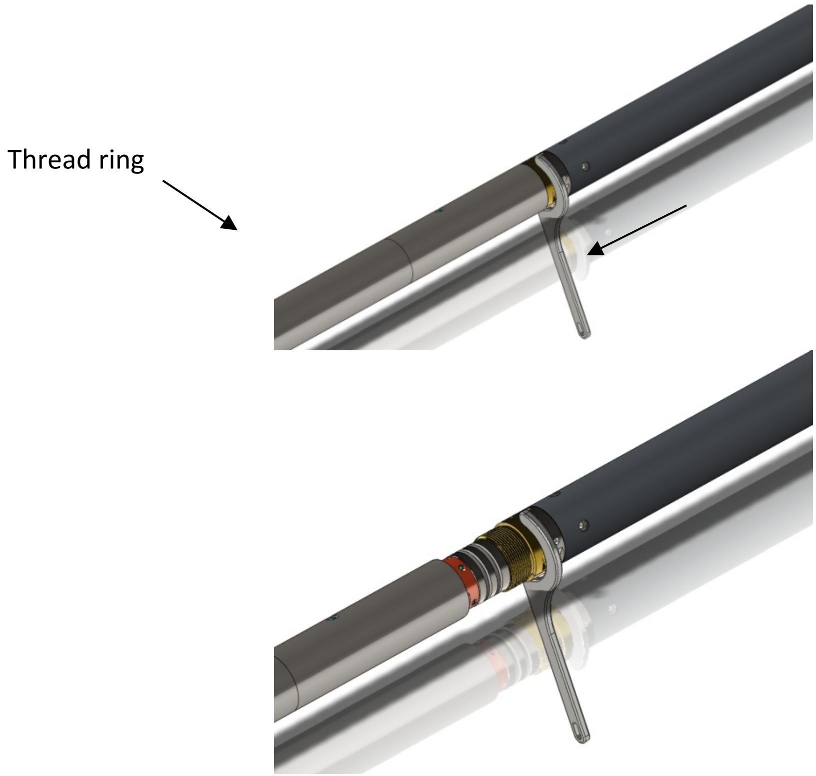


Figure 3-3 *Unscrewing the thread ring and removing the bottom sub*

After checking the O-ring integrity, align and slip the QL40-Plug over the exposed QL connector (Figure 3-4), attach the C-spanner and screw the threaded ring until the plug draws up tight to the ring.

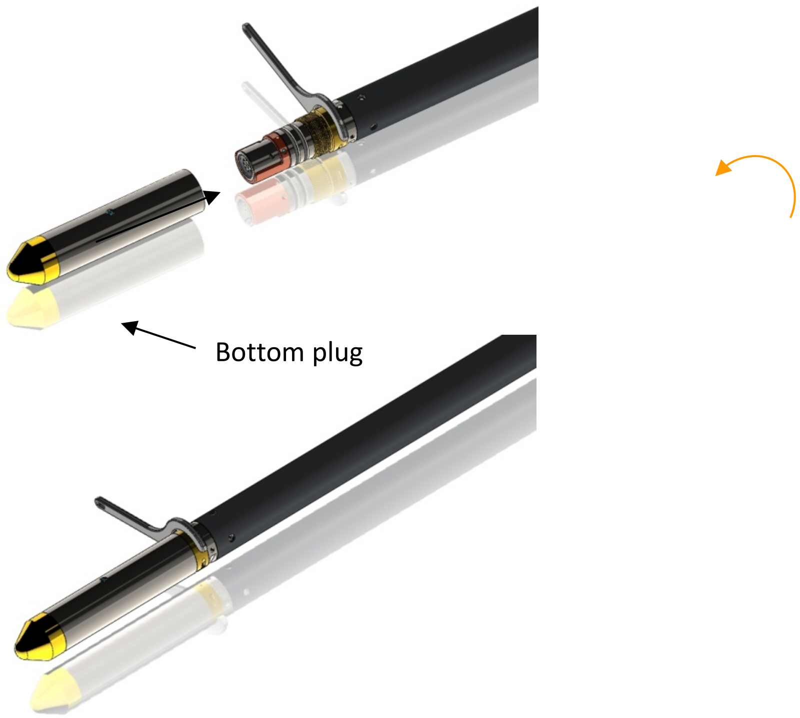


Figure 3-4 Attaching the QL40-Plug

The QL40-GAM can now be run stand-alone (Figure 3-5).

Figure 3-5 *QL40-GAM mid sub with tool top and bottom plug*

3.2 Radioactive source installation

If the radioactive source has not been installed in the source carrier, it should be done using the following procedure. Handling of radioactive materials is normally only allowed by persons trained and authorized by government license. It is assumed that this task, and insertion and removal of the source holder from the QL40-DEN probe will be handled by such qualified personnel.

Locate the necessary components before attempting to install the source. Items needed include a portable radiation counter to monitor source activity, a *medium strength*, thread locking compound (such as “blue LocTite”), tongs, dovetail mount tungsten source carrier, source installation tool, source handling tool, long handled screwdriver, the source retainer screw, the source shield, and the radioactive source in its transport container.

Place all components on a solid table, in an area where unauthorized personnel cannot enter. The standard practice of minimizing time and maximizing distance from the source should be followed. All unnecessary personnel should be asked to leave the area.

The source is machined with an 8/32 thread, which will be mated to a matching 8/32 set screw that is installed in the source retainer screw. Normally, the set-screw is pre-installed in the source retainer screw, leaving about 4-5 threads exposed for connection to the source. The photograph at right shows the source retainer screw with set-screw exposed. Ensure the O’Ring is in place on the retainer screw. The radioactive source capsule is threaded onto the set-screw (after first applying a small amount of Blue Loctite to the set screw on the Source Retainer screw).
Prepare the source retainer screw and set screw first.

Figure 3-6 *Source retainer screw*

Figure 3-7 *Tong with source*

Figure 3-8 *Detail of source in tongs*

Then, the source should be loaded in the tongs with the 8/32 threaded hole up. The person loading the source then screws the source retainer screw on to the source, using the source installation tool shown below

Figure 3-9 *Source Holder, Source Installation Tool, and Retainer Screw*

Figure 3-10 *Screw with Source Screwed On*

After the source is screwed on to the source retainer screw, the retainer screw is then screwed in to the source carrier, as shown below. Ensure O-ring is on Retainer Screw.

Figure 3-11 *Retainer Screw with Source being screwed into Source Carrier*

Figure 3-12 *Source carrier with Source Installed*

The Source Carrier is then loaded into the source shield with the source handling tool, where it is stored when not in use.

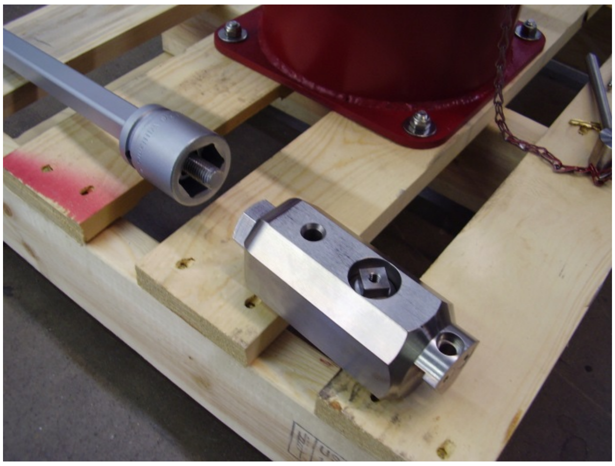


Figure 3-13 *Source Carrier and Source Handling Tool*

Figure 3-14 *Shield with source and source carrier installed*

3.3 Installation of Source Carrier onto QL40-DEN Probe

To load the source from the shield into the probe, the following procedure should be followed:

1. Clear the area of all non-essential personnel.
2. Connect the probe to the cable head, leaving plenty of slack cable to handle the probe.
3. Place the source shield near the probe. **Make sure the borehole is covered!**
4. Lay out the required handling tools (source handling tool, long handled screwdriver).
5. Remove the source holder screw from the dovetail mount at the bottom of the QL40-DEN probe.
6. Insert the source handling tool onto the source carrier within the shield. Rotate source handling tool onto the carrier until it is locked into place. Unlock the shield and remove the source carrier.
7. Insert the source carrier into the mating tapered dovetail mount on the bottom of the QL40-DEN.

Figure 3-15 *Installing Source Carrier onto probe with Source Handling Tool*

8. Next, insert the locking screw using the long-handled screwdriver, and snug up the screw into the far side of the dovetail mount. Do not over tighten, but make sure the bottom of the screw comes to the outside of the dovetail mount. Remove the screwdriver from the lock screw. Remove the source handling tool from the end of the source carrier.

Figure 3-16 *Inserting locking screw into the Source Carrier*

9. Remove the long-handled screwdriver and then lift the probe from the caliper area, keeping the source carrier at least 3 feet (1 meter) away from you. Carefully lower the probe into the borehole. It is best if two people perform this operation, but one person can do this if they plan their movements in advance.

10. To remove the source carrier after logging, clean the bottom section off to remove any mud or debris from the lock screw and dovetail mount area.

11. Lay the probe on a firm surface. Cover the borehole!

12. With the probe caliper facing up, attach the source handling tool to the bottom of the source carrier and twist the handle clockwise to lock the carrier to the handling tool.

13. Remove the source locking screw with the long handled screwdriver.

14. Slide the source carrier out of the dovetail mount with the handling tool and return it to the shield.

15. Lock the source in the shield.

16. Remove the handling tool by unscrewing it counter clockwise.

17. Clean the bottom of the QL40-DEN dovetail mount area, so it will be ready for the next job.

3.4 Estimated Exposure during Source Installation and Use

The 100 mCi ^{137}Cs source used with the Mount Sopris QL40-DEN emits gamma radiation. The user of this probe should be trained in the recommended safe practices for handling radioactive material during a well logging operation. Licensing authorities normally require users to maintain and follow a standard procedure. Contact Mount Sopris or ALT if you need any additional information on this subject.

The source capsule will only be handled during initial installation in the source carrier. From that time forward, it should not be necessary to directly handle the source capsule. When performing wipe tests, it may be necessary to remove the source holder screw, but this process should normally not provide any more exposure than a normal logging operation.

For a normal logging operation, the source handling tool will be used to move the source carrier from the lead shield to the probe source mount. When in the lead shield, the radiation exposure at the sides and bottom surface is ~ 0.2 mRem/hr. At the source spacer end it is ~ 1 mRem/hr.

During source transfer, the thickest shielding of the source carrier is on the side of the carrier where the source retainer screw is located. The strongest radiation field is on the opposite side of this screw. When handling the source, try to keep the source retainer screw up so the strong field is pointed toward the ground. This means the probe will be positioned so that the caliper arm side of the probe is pointing up.

When the source carrier is out of the lead shield, the exposure rate at one meter is about 44 mRem/hr. Using 30 seconds to transfer the source to the probe and lower it into the borehole to a safe distance (a meter or so), the transfer exposure rate would be 1/120 = 0.367 mRem. For one complete logging operation (2 transfers), the exposure would be 0.733 mRem. Using this rate, an operator could perform nearly 7000 logging operations per year before exceeding the recommended maximum annual exposure of 5 Rem.

4 Operating Procedure

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the **LoggerSuite** acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

4.1 Quick Start

Insure that the caliper section is properly cleaned and greased. See the maintenance section for more information. Refer to the following section on **Radioactive Source Installation** to install source

2. Connect toolstack to cablehead and lower into the borehole. Start LoggerSuite acquisition software

3. Select the relevant QL40-DEN tool from the drop down list (***Figure 4-1***) in the software's **Tool** panel (if your tool is not listed check that your tool configuration file is stored in the designated folder on your computer).

Figure 4-1 *Tool panel*

4. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure. (Setup tool communication as explained in chapter **4.4** if error message is displayed.)

5. Click the extend icon  in the **Depth** panel and press **Zero Tool**

6. Lower the QL40-DEN to the bottom of the borehole. Open the Caliper arm using the **Settings/Commands** button. Do <u>**NOT**</u> open the caliper while running downhole, as damage to mechanical and electrical parts may result.

7. In the **Acquisition** panel (***Figure 4-2***) select the sampling mode (Depth Up). Click on **Settings** and specify the corresponding sampling interval. Switch on the sampling (click the **ON** button).

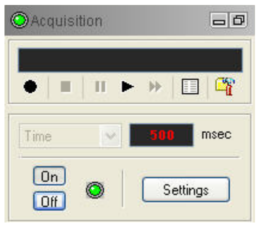


Figure 4-2 Acquisition panel

8. Press the **Record** button in the **Acquisition** panel (***Figure 4-2***), specify a file name and start the logging.

During logging observe the controls in the **Telemetry** panel (***Figure* 4-3)**:

- Status must be valid (green light);
- Bandwidth usage in green range;
- Memory buffer should be 0%;

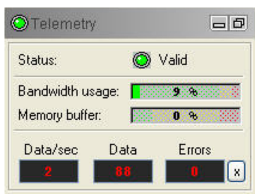


Figure 4-3 *Telemetry panel*

- Number of **Data** increases and number of **Error**s negligible.

9. To end the logging procedure press the **Stop** button in the **Acquisition** panel

10. Turn off the “Depth” sampling mode (click **OFF** button). Select the “Time” sampling mode and turn it on (click **ON** button) to control the closing caliper operation

11. In the **Tool** panel close the caliper arm using the **Settings/Commands** button

12. Turn off the “Time” sampling mode and turn off the tool power

13. Place the tool on the ground or a cleaning stand so that the caliper arm is up and the radiation is exiting the source holder down towards the ground. Rinse off the source section quickly and remove the source, following the procedure in **Radioactive Source Installation**.

4.2 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on  to display the **Configure Tool Telemetry** dialog box ***(Figure 4-4)***.
A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse is true for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate** to the desired value and observe that the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialisation sequence successfully the next time it is turned on.

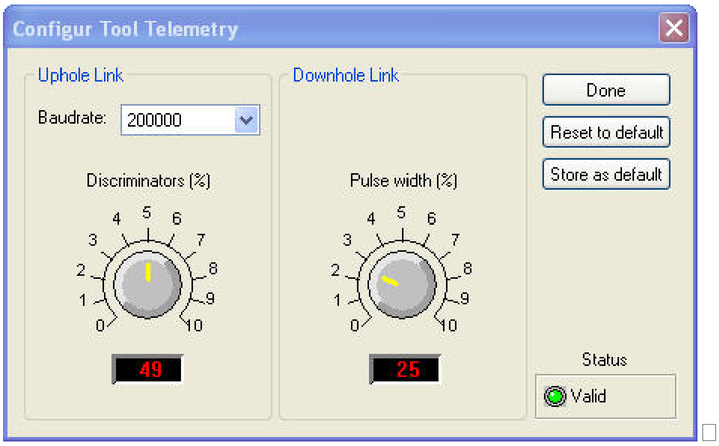


Figure 4-4 *Tool communication settings*

4.3 Tool Communication with MATRIX

The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on , the operator has access to the **Configure ALT Telemetry** dialog box (***Figure 4-5***) providing various controls to adjust the telemetry settings and monitor its current status.

The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.

The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.

The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually. In general, the gain setting should not be left in the automatic mode once a valid setting has been determined. Uncheck the box to disable automatic gain.

For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see ***Figure 4-5*** for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.

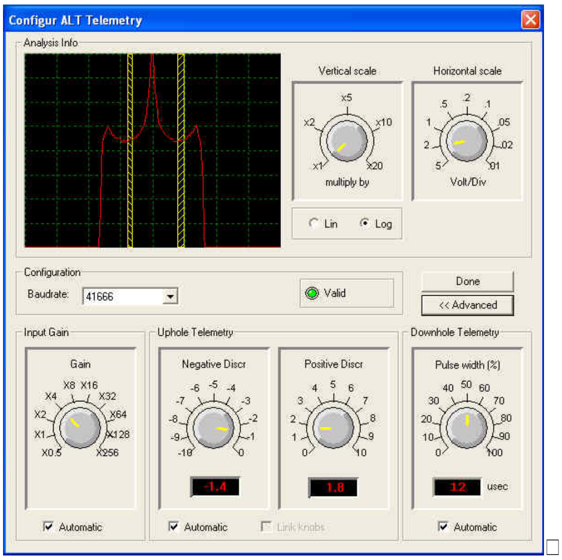


Figure 4-5 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in "Valid" status the next time the power is turned on.

4.4 Recorded Parameters, Processors and Browsers

4.4.1 Recorded parameters

The following channels are recorded by the QL40-DEN tool:

RHOB	**Compensated Density calculated from short and long detectors - g/cc**
DRHO	**Compensated Density minus Long Spaced Density (RHOB-RHOLSD) - g/cc**
CAL	**Caliper - cm**
RHOSSD	Short Spaced Density - g/cc
RHOLSD	Long Spaced Density - g/cc
Time	Sampling Time - sec
TCPU	Temperature (recorded on CPU board) - ºC
MOT	Caliper Motor Status - Opening/Closing/Idle
HV	High Voltage monitor
SSDCNT	Short spacing Density Counts
LSDCNT	Long spacing Density Counts
CALCNT	Caliper Counts
SSDCPS	Short spacing Density - counts per second
LSDCPS	Long spacing Density - counts per second
CALCPS	Caliper - counts per second

***Table 1** QL40-DEN recorded channels*

4.4.2 MChNum Browser

The **Figure 4-6** shows a typical example of the numerical values displayed in the MChNum browser window during operation.

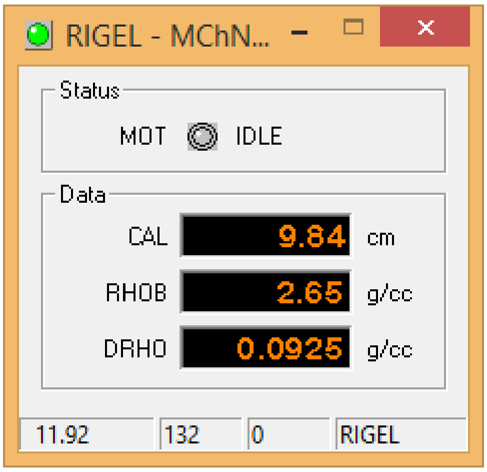


***Figure 4-6** MChNum browser window*

MOT	Caliper Motor Status
CAL	Borehole diameter (in centimeters)
RHOB	Compensated Density (in g/cc)
DRHO	Compensated Density minus Long Spaced Density (in g/cc)

The other parameters listed in **Table 1** can be displayed in real time if required. Right click on MChNum browser and click on "**Display options**" from the menu.

Select in the "Display options properties" dialog box and add the additional channels to display.
It is possible to change the format of decimal digits displayed for a channel. Select the channel and click on "Settings" to configure the number of digits after the period.

4.4.3 MChCurve Browser

The MChCurve browser ***(Figure 4-7)*** displays the recorded parameters by means of curves in real time.

The user is allowed to modify the curve presentation by double clicking on the log title (colors, column position, scale, filter, grids, etc.).

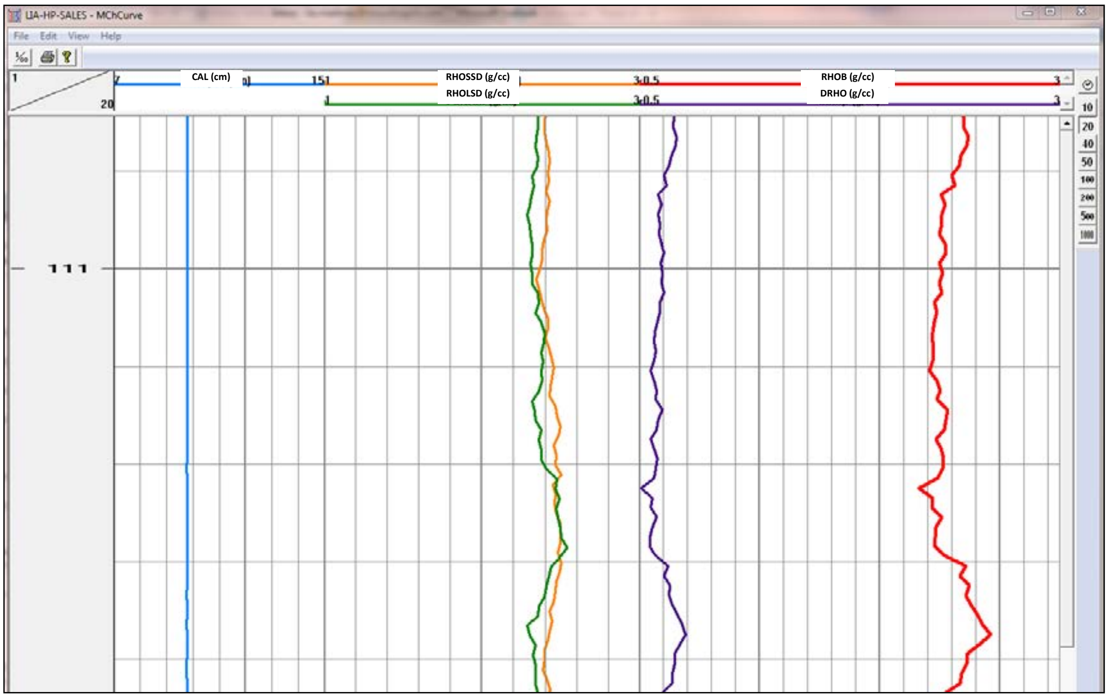


Figure 4-7 *QL40-DEN MChCurve browser*

5 Performance Check & Calibration

5.1 Density

Good practice requires regular validation of the measurements. This is can be achieved by comparison of tool readings and blocks of known density. Calibration of the **density** measurement is not complicated, but requires two calibration standards. Nylon (Density 1.26 g/cc) and Aluminum (Density 2.60 g/cc) are optionally available from Mount Sopris Instruments or ALT (p/n Q40DEN-1800 and Q40DEN-1700). Follow the steps below:

1. Connect the QL40-DEN probe to the cable head, and power up the tool as outlined the above operating procedure.

2. Grasp the tool near the probe top (to minimize radiation exposure) and place it on the **nylon** density calibration block. A long table or probe stands will be needed to allow the probe to rest horizontally in the calibration blocks with no stress on the probe housings. Lay out the aluminum and nylon blocks so that the probe can be easily moved between the two blocks and adjusted to rest horizontally in either block. See below:

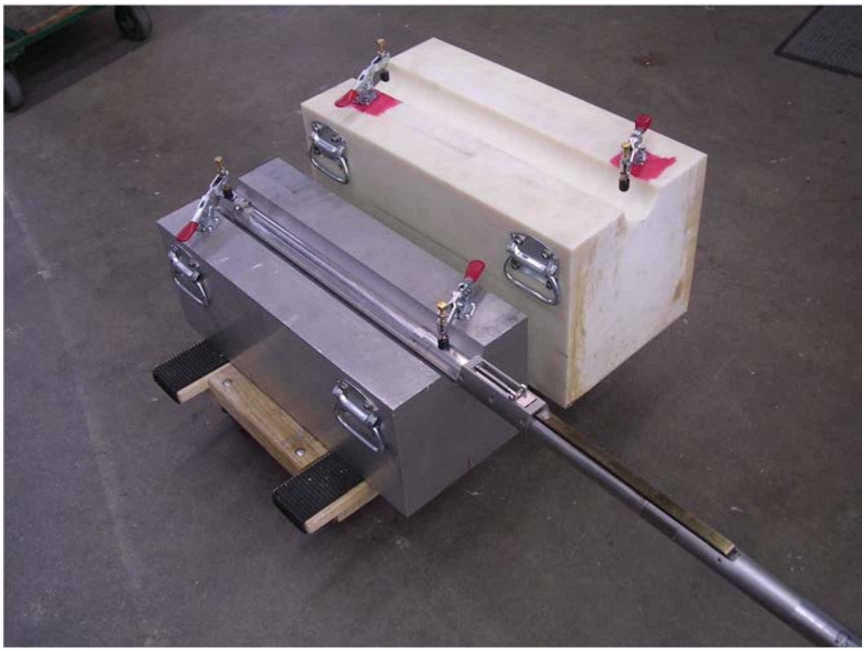


Figure 5-1 *QL40-DEN resting on its calibration block*

3. Slide the bottom of the probe out the end of the block and place the source shield near the end of the probe. Install the source as per the **Source Installation Procedures** section.

4. Insert the probe into the calibration block with the caliper pointing straight up. It is not necessary to open the caliper for calibration. Make sure that the <u>probe rests perfectly flat in the grooved radius in the block.</u>

5. Use the clamps to secure the probe to the calibration block. They can be adjusted by turning the hex nuts to allow a secure lock when the handles are pressed down. See detail in the next figure.

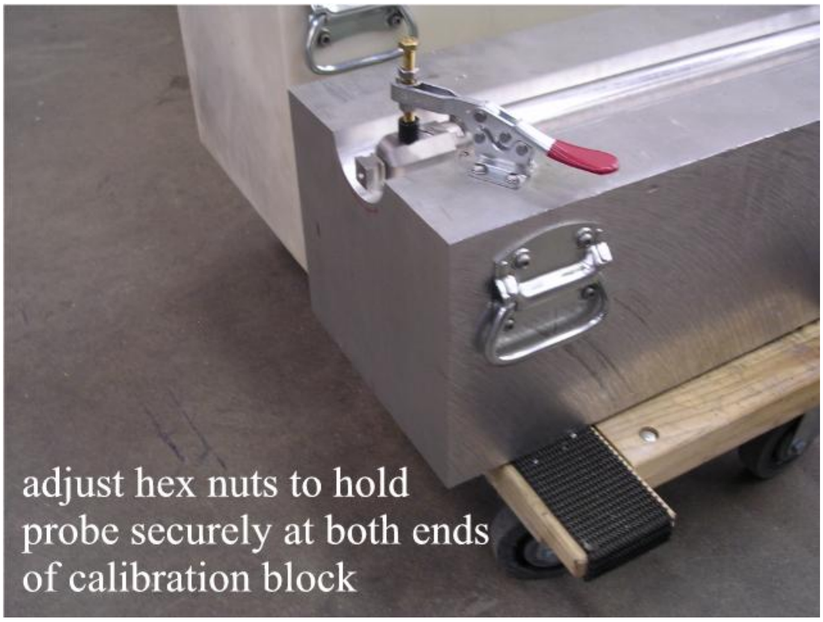


***Figure 5-2** Probe secured on the calibration block*

IMPORTANT: The probe <u>MUST</u> be supported at the probe top end with a suitable probe stand so that there is no stress on the probe housings and joints. This allows the density detector section to rest completely flat in the calibration groove, and minimizes strain on the caliper and modem sections of this probe.

6. Right click the Green LED o the MCHNum Browser window or right click the top pane to display the MCHNum context menu.

7. Select **Calibration Settings**. The calibration window will pop up.

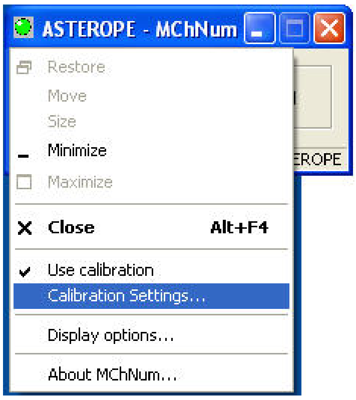


***Figure 5-3** MChNum – access to the calibration settings*

8. Set the time sampling interval, and then set the sampling mode to 'Time'. The time digitize interval may need to be increased until the RHOSSD and RHOLSD repeat within 1 or 2 percent. A value of 1000ms for the sampling rate and 100 samples should be sufficient to compute the average RHOSSD & RHOLSD counts in cps. The

number of samples can be edited by clicking on “options” in the calibration page – refer to Figure 5-4).

9. On the calibration window, click on the ‘**RHOSSD**’ tab. Type ‘**1.26**’ into the Reference edit box for the First Point. Click the **Sample** button for the first calibration point and wait until the sampling is completed (sampling time will be function of the number of samples and sampling rate defined by the user). This will cause the natural logarithm of the counts to be entered into the first point value edit box.

   Click on the ‘**RHOLSD**’ tab and repeat. For the far detector, the natural logarithm of the far counts is entered into the edit box.

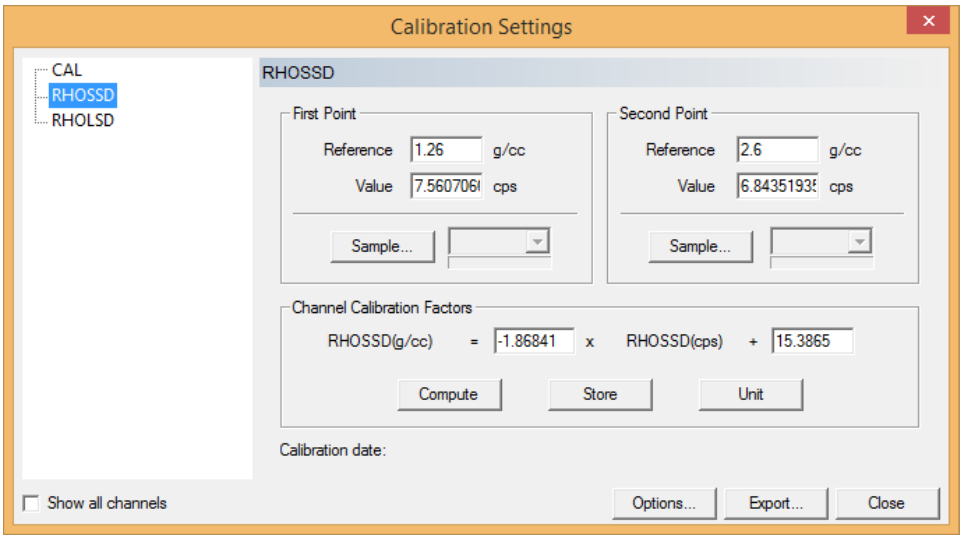


Figure 5-4 *calibration example*

10. Place the tool on the **aluminum** calibration block, again grasping the tool near the cable head to minimize exposure to radiation.

11. Click on the ‘**RHOSSD**’ tab. Type ’**2.60**’ into the Reference edit box for the Second Point. Click the **Sample** button for the Second Point and wait until the sampling is completed (sampling time will be function of the number of samples and sampling rate defined by the user). This will cause the natural logarithm of the counts to be entered into the second point value edit box. Click on the ‘**RHOLSD**’ tab and repeat. For the far detector, the natural logarithm of the far counts is entered into the edit box.

12. Click ‘**Compute**’ and then click ‘**Store**’ for each tab, ‘RHOLSD’ and ‘RHOSSD’.

13. On the Logger Dashboard, click the ‘**Close All**’ button on the ‘Browsers & Processors’ panel. Next, restart all processors and browsers by clicking on the ’**Start All**’ button. This will implement the new calibrations.

5.2 Caliper

Calibration of the **caliper** measurement generally is not necessary. The caliper has been calibrated at the factory and the calibration numbers are electronically stored in the sub file. If small adjustments need to be made to the caliper calibration, follow the steps below.

1. Connect the probe to the cable head, and power up the tool as outlined in the above operating procedure.

2. Place the probe on a table or stand that will allow the caliper arm to open fully without any external resistance.

3. Use **Settings/Commands** to open the caliper arm. This will take ~60 seconds.

4. Right click on the MChNum window and then click on **Calibration Settings**. The calibration window will open.

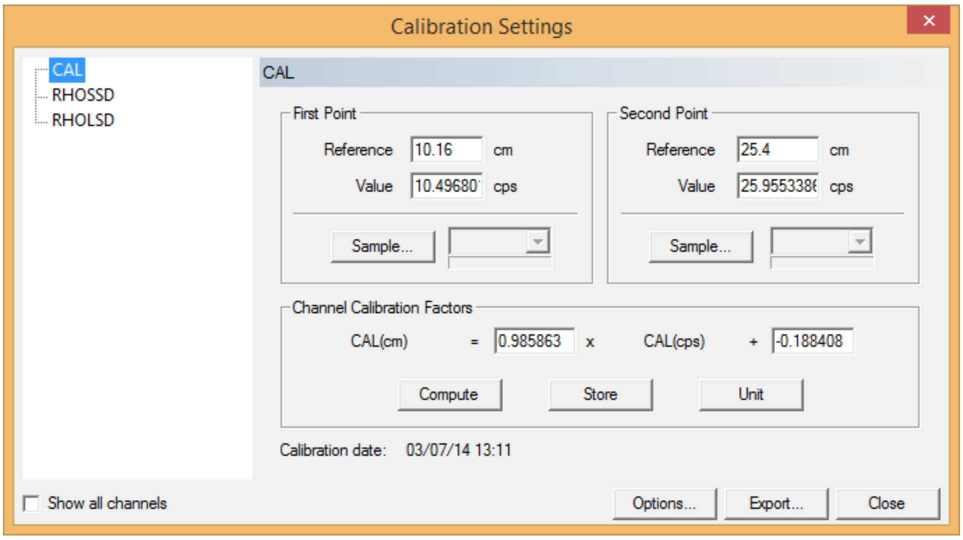


Figure 5-5 *Caliper calibration page*

5. Set the time sampling interval (set to 500 ms), then set the sampling mode to ‘Time’.

6. Place the caliper calibrator around the tool and slide it along the tool until the calibrator can engage the caliper arm. Set the caliper arm to the **four inch** position on the calibrator.

7. On the calibration window, click on the ‘**CAL**’ tab. If calibrating in inches, type **‘4.00’** (or ’10.16’ cm) into the reference edit box for the First Point. Click the First Point **Sample** button and wait until the system has returned a value.

8. Next, set the caliper arm to the **ten** inch position on the calibrator. If calibrating in inches, type **‘10.00’** into the reference edit box for the Second Point, otherwise type ’25.4’ (cm) into the reference edit box. Click the Second Point **Sample** button and wait until the system has returned a value.

9. Press the **Compute** and then **Store**.

10. On the **Browsers & Processors** panel click **Close All** then **Start All** to refresh the other Browsers and Processors. This must be done as they only read the calibration constants from the configuration file when they start.

11. Check the calibration by setting the caliper arm to the **six** inch position and verifying the result indicated by MChNum's Caliper field is **6.00 inches +/- 0.1 inches** (15.24 cm +/- 0.254 cm).

5.3 Density Compensation Notes

Density for the near and far detectors (RHOSSD, RHOLSD) is calculated as the log of the raw detector counts. Compensated Density (RHOB) is then calculated by the formula:

(2.975327597445237 x RHOLSD) - (1.971171233098749 x RHOSSD) - 0.014985496037274

This channel is calculated at a depth offset of 0.1575 meters from the bottom of the tool.

The Compensation channel displayed in MChNum, labeled as DRHO, uses the same depth offset as the RHOB channel. The formula for it is: (RHOB – RHOLSD)

6 Maintenance

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT/MSI will void the tool warranty.

6.1 General maintenance

The QL40 series tools require periodic maintenance. Make sure the threads on the brass nut on the sub bottom are free of sand, mud or other dirt. A thin layer of anti-seize is recommended. When disassembling the sub string, dry the joint as it is separated to prevent fluid from entering the sub top and getting into the electrical connector inside.
After replacing top and bottom protectors it is good to wash the probe off after each use. ***Never take the probe apart. This probe is very difficult to disassemble and requires special steps to be taken in order to gain access to the inside of the probe without damaging the electronics. If you have read this after attempting to disassemble the probe chances are the probe has experienced damage and will need to be sent to the factory to be repaired.*** Inspect o-rings occasionally and keep the threads on both ends of the probe clean, to minimize problems in the future.

Remember that the **gamma detectors are fragile**. Use care when placing the tool in the borehole and when traveling down into the borehole. Also, store the tool in a secure place, preferably in a shock resistant container. During transport, logging tools typically endure more shock than when in the borehole.

Keep the caliper mechanism filled with grease at all times. By pumping more grease into the caliper, old dirty grease is flushed out. Continued use of a dirty caliper mechanism may cause the tool to leak. Before and after each usage of the probe, using a standard automotive grease, apply grease to the two grease ports. These are located immediately above and below the arm pivot point. Close the arm to apply grease to the upper fitting and open the arm to apply grease to the lower fitting. After each log, when possible, clean and flush mud and or contaminants out of the caliper arm assembly.

6.2 Locking Ring Assembly Maintenance

Tools required:
1.5mm Allen wrench
2 ea 40-42mm spanner wrench
Paper towels or clean rags

Replacement Parts:
ALT26005, Large Threaded Ring, Qty 2
28-174-995 M2x8 SHCS, Qty 2

Disassembly:
Unscrew and remove the two M2x8 socket head cap screws and separate the two halves. Four guide pins align the two ring halves and tend to hold them together after the screws are removed.
To pry the halves apart you can use a pair of spanner wrenches inserted into the wrench holes on opposite sides of the ring mating surfaces to pull them apart slightly.
Do this carefully to prevent bending the guide pins.

Figure 6-1 *Disassembly of the treaded ring*

Place something small in the opening and move the spanners to the other side and pry it open slightly.
This should be enough to release the two rings as below.

Figure 6-2 *Halves rings when pulled apart*

Clean inside surfaces thoroughly and reassemble, coating the inside with a very light film of anti-seize compound. Nickel based compounds are best, to prevent any sticking between the brass and steel surfaces.

6.3 Upgrading firmware

In accordance with the ALT policy of continuous development the tool has been designed to allow firmware upgrades.

Firmware upgrade procedure is as follows:

1. Confirm that the communication is valid.
2. Upgrade firmware

6.3.1 Checking the communication

1. Connect the tool to your acquisition system.
2. Start ALTLog/Matrix software.
3. In the **Tool** panel select the appropriate tool and turn on the power.
4. In the **Communication** panel, select **Settings**. Check **baud rate** is set to **41666** and **communication status** is **valid** (Figure 6-1 or Figure 6-2).

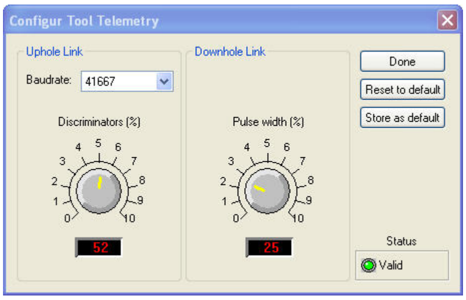


Figure 6-3*Tool communication settings - ALTLog*

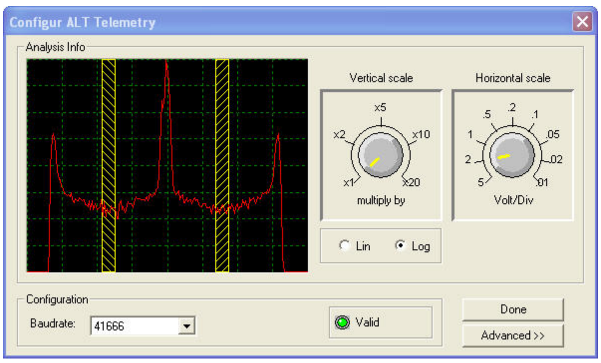
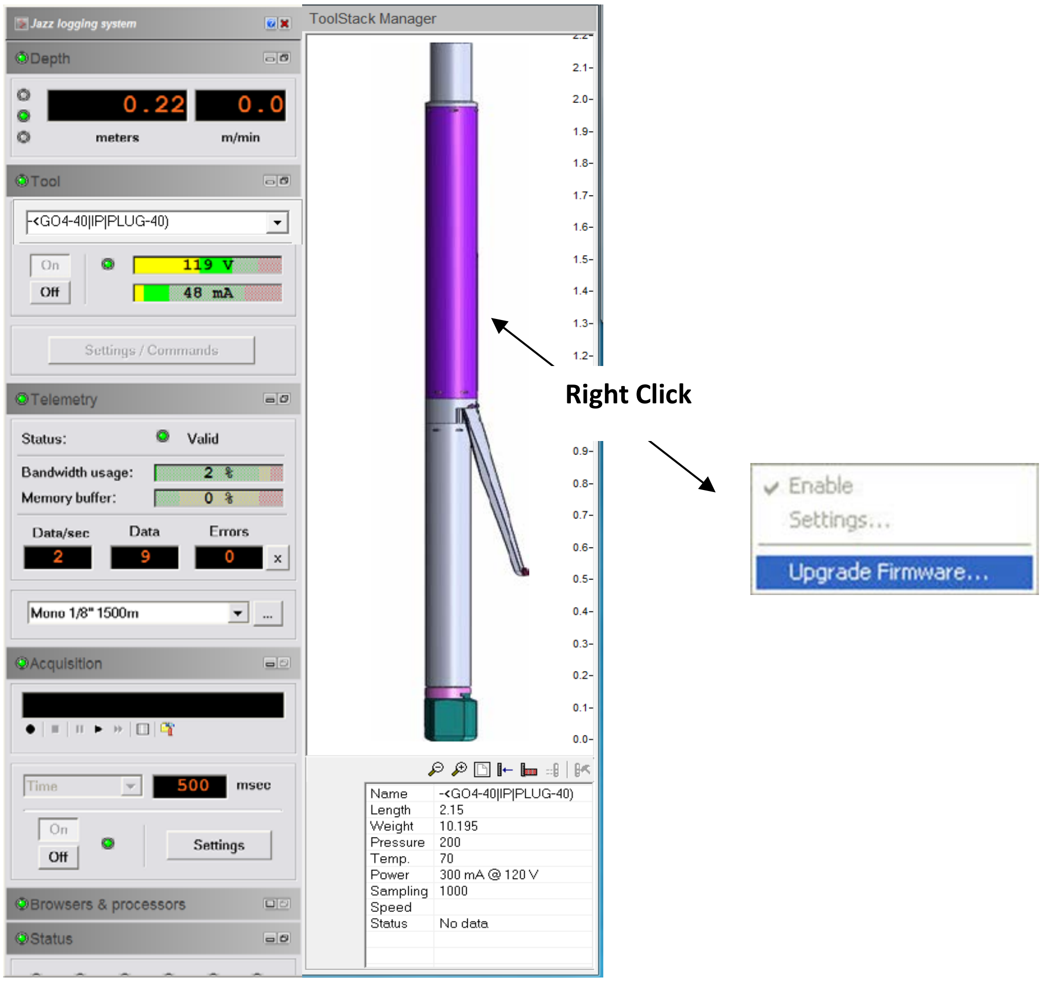


Figure 6-4 *Tool communication settings - Matrix*

Warning: Telemetry must be tuned properly. Bad communication may abort the upgrade of the firmware!

6.3.2 Upgrading the firmware

1. **Right Click** on the tool preview in the **ToolStack Manager** view and select **Upgrade Firmware** from the context menu.



2. The following message will appear (Figure 6-5). Click **Yes** to validate your choice.

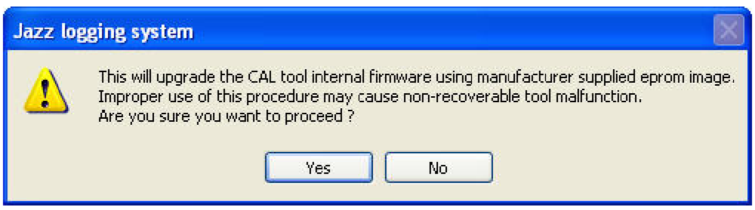


***Figure 6-5** Warning Message during firmware upload*

3. Select and open the appropriate **.hex** file provided. The upgrade will start.
4. During the upgrade procedure, the following message is displayed:

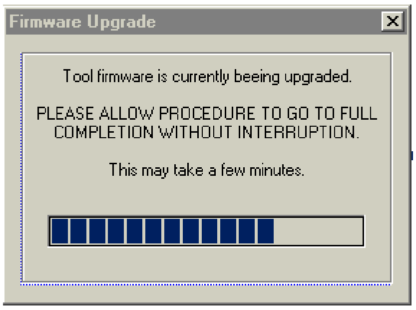


Figure 6-6 *Firmware upgrade progress window*

5. Once the upgrade has been successfully completed (Figure 6-7), click on **OK** to turn off the tool.

Figure 6-7 *Successful upgrade*

6. Power on the tool to start the upgraded firmware.

Note that the following error message (Figure 6-8) will appear at the end of the procedure when the tool firmware upgrade has failed or has been aborted. Verify the tool communication settings in this case.

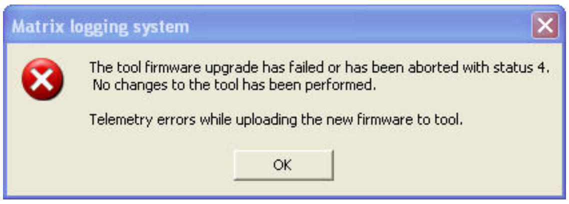


Figure 6-8 *Error message*

7 Troubleshooting

In the event the tool develops a problem, follow the troubleshooting procedure listed below.
WARNING: ***NEVER DIS-ASSEMBLE THE PROBE WITHOUT KNOWLEDGE OF PROCEDURE***

Observation	**To Do**
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been installed with the LoggerSettings application (refer to LoggerSettings and LoggerSuite manuals for more information)
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 3.4).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** **-**Possible shortcut (voltage low, current high): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of the short circuit. - If the above shows no issues, use test cable provided by ALT to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - If problem cannot be resolved contact support@alt.lu or tech.support@mountsopris.com
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can't receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - Check bandwidth usage and telemetry error status.

8 Appendix

8.1 Replacement Parts

Item No.	Qty	MSI Part No.	Description
1	1	Q40DEN-0560	Caliper Wear Button
2	1	16-201-007	Silicone Lubricant Cartridge 14.1 oz.
3	1	2GDA-1400	Caliper Calibrator
4	1	28-175-627	Retainer Screw
5	1	54-203-216	Grease Gun #4BY69 for 14.1 oz.
6	1	54-101-921	C-Spanner Wrench
7	1	ALT26306	Q40 Plastic Male Lid

8.2 Other Parts

Item No.	MSI Part No.	ALT Part No.	Description
1	17-202-092	ALT 26312-A	QL40-Go1 tool top
2	Q40GO4-1000	ALT 26074-A	QL40-Go4 tool top
3	17-202-079	ALT 26310-A	QL40-Go7 tool top
4	Q40MS1-1000	ALT 26084	QL40-MSI tool top
5	Q40DEN-1700	-	Aluminum Calibration Block
6	Q40DEN-1800	-	Nylon Calibration Block

9 Probe tops - standard configurations

9.1 QL40-GO4 four conductor tool top

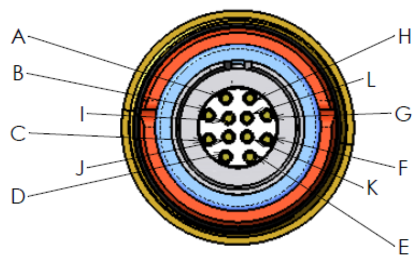


Figure 9-1 Bottom connection to tool

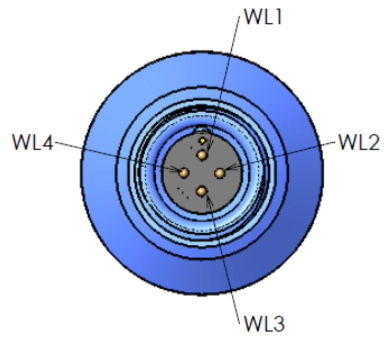
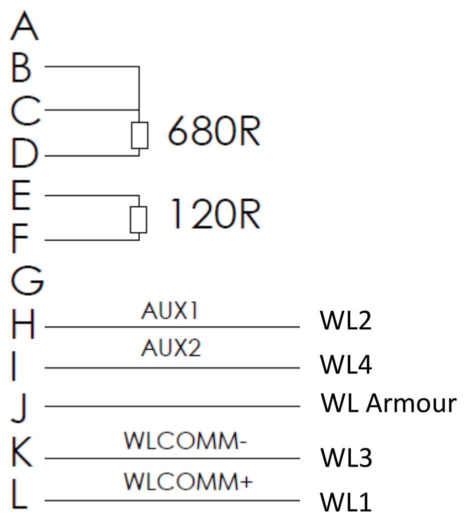


Figure 9-2 Top connection to cable head



9.2 QL40-MSI and QL40-GO1 single conductor tool tops

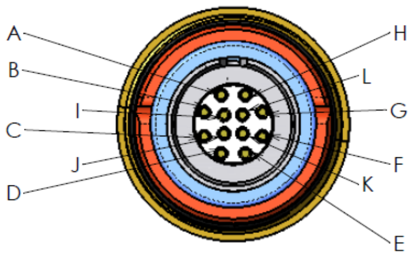


Figure 9-3 *MS1 and GO1 bottom connection to tool*

Figure 9-4 *MS1 top connection to cable head*

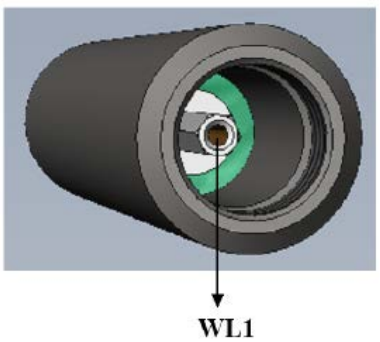
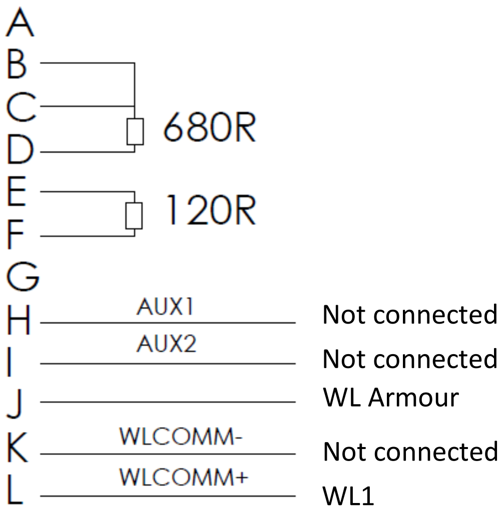
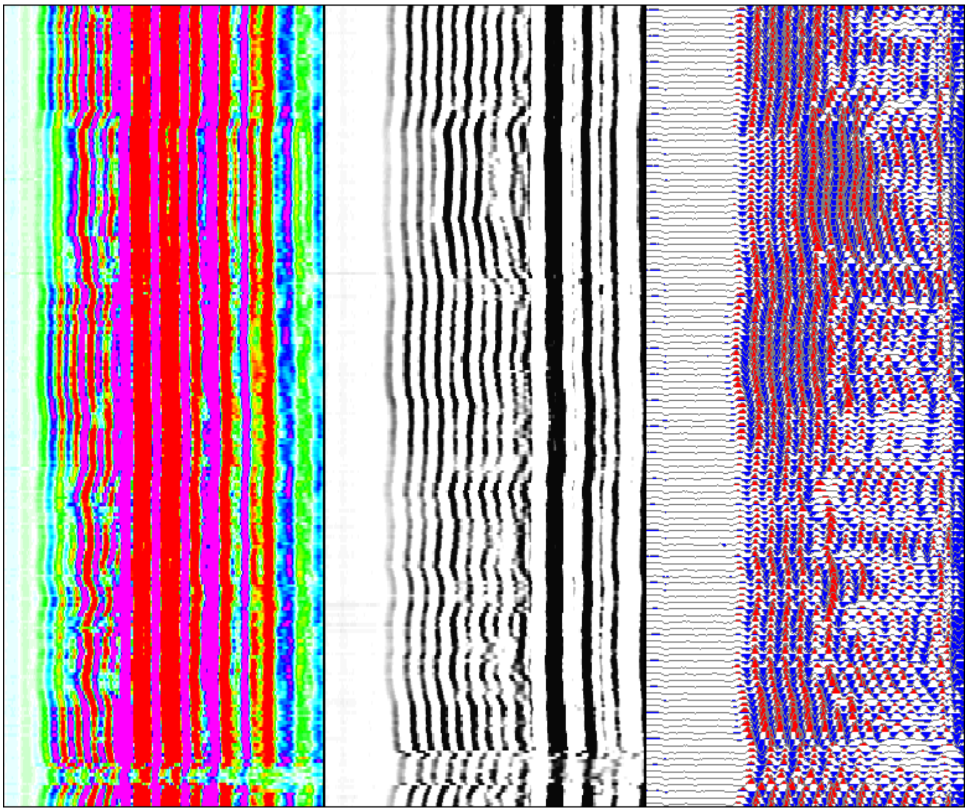


Figure 9-5 *GO1 top connection to cable head*





User Guide

QL40 FWS – Full Waveform Sonic

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V13.12.06

Table of Contents

1 General Information

The ALT QL40-full waveform sonic tool is mainly dedicated for the water, mining and geo-technical industries. Its specification makes it ideal for cased-hole and open-hole applications and to carry out fractures identification.

Sonic logs are widely used, often in combination with other logs, to provide porosity, permeability and geo-mechanical properties of the rocks. Under suitable borehole conditions and formations, Compressional (P), Shear (S), Stoneley and Tube waves arrivals can be detected.

The QL40-FWS tool is optimized for such purpose. It implements a high energy source generated by a ceramic-piezoelectric transducer which excites the formations in such a way that waves of different frequencies are developed and propagated. Real time analysis and process of the full wave form are performed by the tool to enhance the picking of the different wave propagation modes.

The tool can only be operated in a fluid-filled hole. Logging speed depends on tool configuration and acquisition parameters.

Applications:

- Cased-hole:
  - Cement bond logging (CBL)
- Open-hole:
  - Porosity and permeability
  - Lithology identification
  - Variation of rock strength
  - Elastic moduli
  - Indication of fractures and formation permeability in hard rocks

1.1 Dimensions

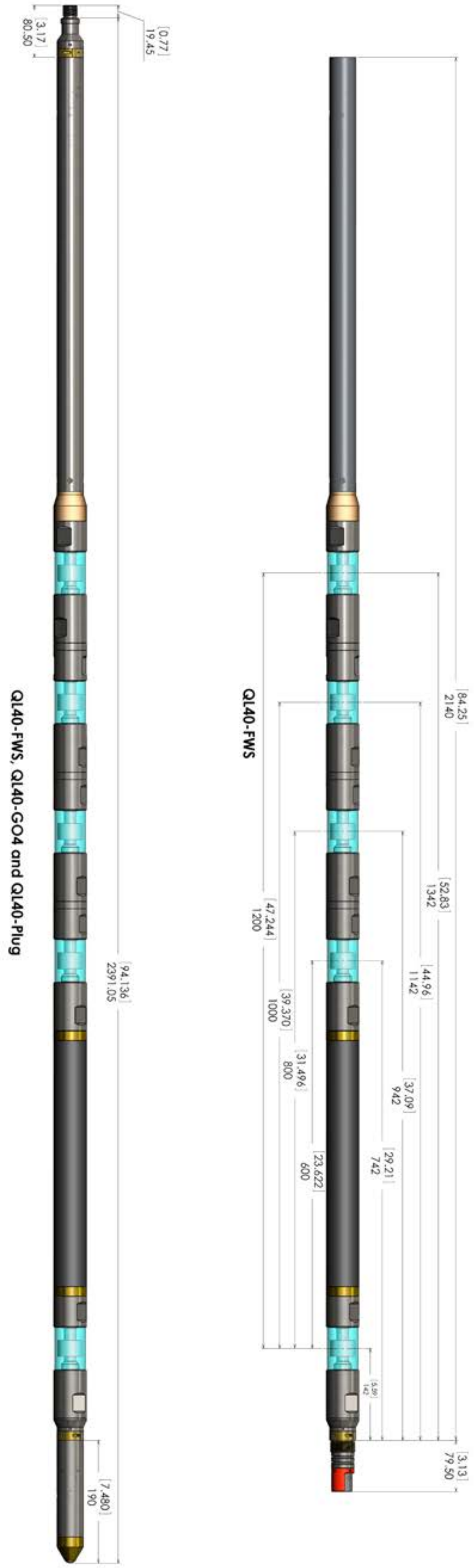

Figure 1-1 *QL40-FWS dimensions*

1.2 Technical Specification

Tool

Diameter:	Max 50mm
Length:	Standard configuration: 1TX – 4RX @ 0.2m RX separation : 2.14m
Measurement point:	Transmitter location
Max. Temp:	70°C
Max.Pressure:	200bar

Cable:

Cable type:	Mono, Coaxial, 4 or 7 conductor
Digital data transmission:	Up to 500 Kbits per second depending on wireline
Compatibility:	ALTLogger – BBOX – Matrix

Sensors:

Transducers:	Ceramic piezoelectric with 6 KHz resonant frequency
Sonic Wave Sampling Rate:	Normal Mode: 4 µs Extended Mode: 20 µs
Sonic Wave Dynamic Range:	16 bits
Sonic Wave Sample Length:	Normal Mode: up to 4 ms Extended Mode: up to 16 ms

2 Measurement Principle

The QL40-FWS tool measures the time it takes for a sound pulse to travel from a piezo electric transmitter to a receiver at a defined distance. Transmitter and receiver are mounted on the same tool. The acoustic pulse generated by the transducer travels through borehole fluid and rock in various different forms while undergoing dispersion and attenuation.
When part of the energy of the emitted sound pulse arrives at a receiver it does so at different times in form of different types of waves (**Figure 2-1**).

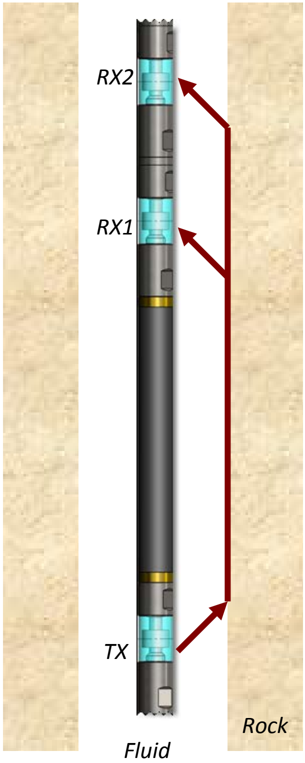

Figure 2-1 *Typical wave path for a 1 transmitter and 2 receiver tool*

Usually it is the compressional wave (P-wave) that travelled through the rock (or pipe) that arrives first followed by shear waves (S-wave), Rayleigh, Stoneley and mud waves. **Figure 2-2** shows a typical sonic trace with received wave forms.

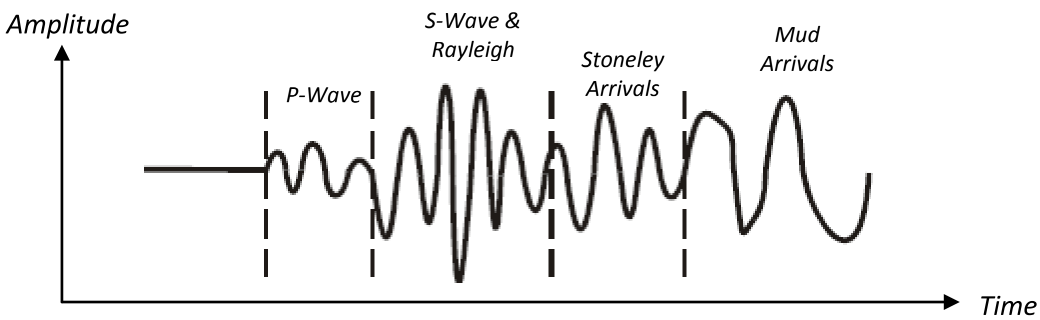

Figure 2-2 *Typical sonic trace with wave form arrivals*

The P-wave is usually the fastest wave but has small amplitudes. The next wave to arrive is the S-wave, which is slower than the P-wave but usually has higher amplitudes. After them come Rayleigh and Stoneley waves, which are associated with energy moving along the borehole wall. The last arrival (mud wave) is a pressure wave that travels through the borehole fluid in the borehole. They can be of high amplitude but always arrive after the two main waves – P- and S-wave.

In cased wells, common application of the sonic tool is the measurement of the degree of cementation of steel casing. It is generally called "Cement Bond Logging".
It is often important to know how much cement is present in the annulus between casing and formation. The sonic tool is used to measure whether there is cement in contact with the outside of the casing and whether that cement is in contact with the formation.
This can be achieved by measuring the amplitude of the first compressional arrival. Just one transmitter and one receiver is needed for this. The amplitude of the first arrival is linked to the amount of cement bonded to the casing. If there is no cement outside the casing, the sonic wave will travel almost entirely through the casing and return to the receiver with a high amplitude. If there is good, solid cement outside the casing, a large proportion of the sonic wave will be refracted into the cement and formation. The amount of energy returning to the receiver will be less and is corresponding to a low amplitude of the first compressional arrival.

3 Operating Procedure

3.1 Tool setup and handling

<u>Note on centralisers :</u> Tool centralization is mandatory for Cement Bond application. For open hole application, tool centralization is strongly recommended as it helps the detection of the different wave propagation modes and thus full wave sonic processing.

One set of slip over centralisers is supplied with the tool.

The standard assembly comprises upper and lower mounting rings with sets of bowsprings for different borehole diameters. The lower mounting rings are equipped with a teflon ring and bowsprings are covered with polyolefin sleeves in order to eliminate the road noise caused by the friction of the centralisers against the borehole wall.

Two C spanners are also provided for tightening the locking rings.

<u>The following points relating to the use of centralisers should be considered:</u>

The centralisers should be fitted before mating the tool with the wireline cable head. One centraliser should be placed at the top of the tool and the second one on the tool sub located at the bottom of the QL40-FWS. A “dummy” sub can also be supplied upon request to fix a centraliser at the bottom of the tool.

The compression ring of the centraliser, i.e. the one that is screwed tight, should always be fixed toward the **top** end of the sonde. This is to avoid catching on a downhole obstruction when winching up.

Use the C spanner to fasten the fixing rings but take care not to cross thread or over tighten them as this could damage the pressure housing

(The weak point of the bowsprings is the welded bearing pin. Take care during assembly as the weld can be broken by reverse bending.)

<u>Note on tool handling :</u> when the QL40-FWS is stacked with other subs, special care should be taken when handling the tool string. On the rig site, it is recommended to lift the tool string using the logging wireline. During this operation, care should be taken and operator must avoid to apply too much flexion on the spacer section of the QL40-FWS.

3.2 Quick Start

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the LoggerSuite acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

1. Connect the QL40 FWS to your wireline and start the data acquisition software.

2. Select the relevant QL40 FWS tool from the drop down list (**Figure 3-1**) in the software's **Tool** panel (if your tool is not listed check that your tool configuration file is stored in the designated folder on your computer).

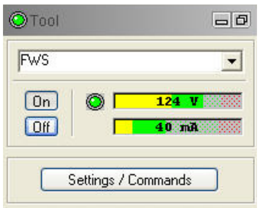

***Figure 3-1** Tool panel*

3. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings. The configuration returned by the tool is also checked during this procedure.
   Setup tool communication as explained in chapter **3.2** and **3.3** if error message is displayed)

4. On the **Tool** panel (**Figure 3-1**) click the **Settings / Commands** button to configure your tool. (see chapter **3.4** for details).

5. In the **Acquisition** panel (**Figure 3-2**) select the sampling mode (depth or time). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button).

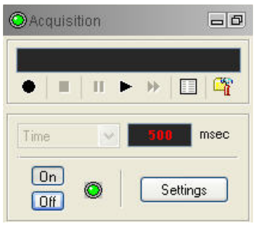

***Figure 3-2** Acquisition panel*

6. Press the **Record** button in the **Acquisition** panel (**Figure 3-3**), specify a file name and start the logging.

7. During logging observe the controls in the **Telemetry** panel:
   - Status must be valid (green light);
   - Bandwidth usage in green range;
   - Memory buffer should be 0%;
   - Number of **Data** increases and number of **Errors** negligible.

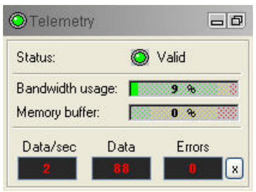

***Figure 3-3** Telemetry panel*

8. To end the logging procedure press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

9. In the **Tool** panel power off the tool.

3.3 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on **Settings** to display the **Configure Tool Telemetry** dialog box (**Figure 3-4**).

A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate**, check the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialization sequence the next time it is turned on.

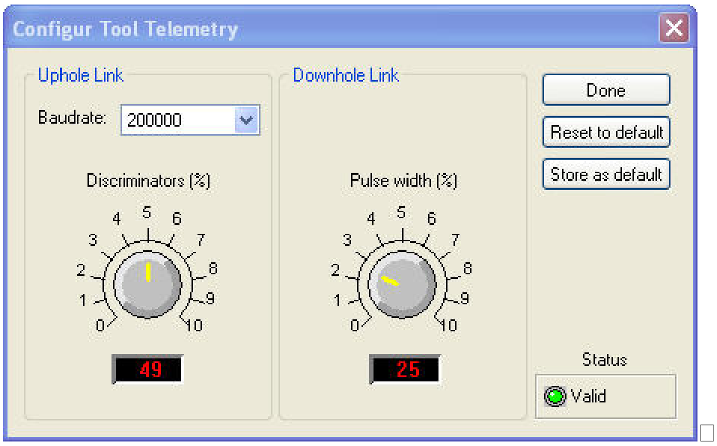

Figure 3-4 *Tool communication settings*

3.4 Tool Communication with MATRIX

The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (**Figure 3-5**) providing various controls to adjust the telemetry settings and monitor its current status.
The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.
The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal

is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.
The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.
For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see **Figure 3-5**) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.

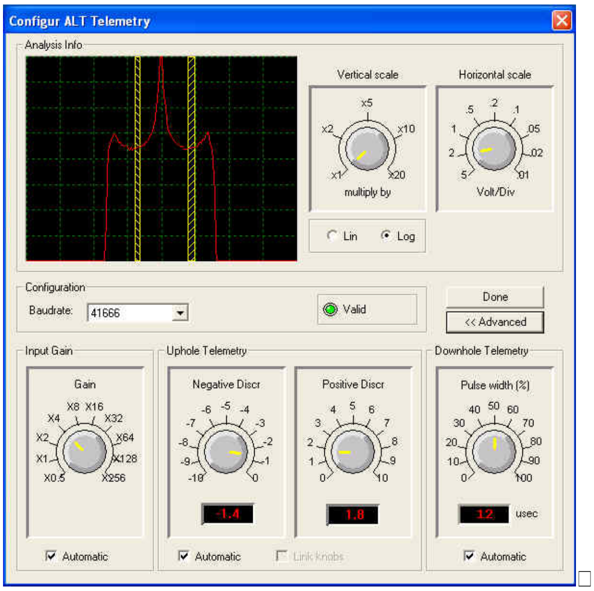

Figure 3-5 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in “Valid” status the next time the power is turned on.

3.5 Configuring Tool Parameters

The **Configure FWS Tool Parameters** dialog box (**Figure 3-6**) can be accessed by clicking on the **Settings / Command** button on the dashboard's **Tool** panel (**Figure 3-1**).

3.5.1 Transmitter Selection

If your FWS tool is fitted with two transmitters you can choose to operate only one transmitter or both by turning the Transmitter Mode knob (**Figure 3-6**). Turn it to position A or B to operate only a single transmitter or set it to A & B to fire both transmitters in alternance. Transmitter A is the one located closest to the bottom of the tool.

3.5.2 Receiver Selection

The Configure FWS Tool dialog box provides two tabs – TXA and TXB - to choose the receivers to be used with each transmitter. With each transmitter the maximum number of receivers available on the tool can be used.

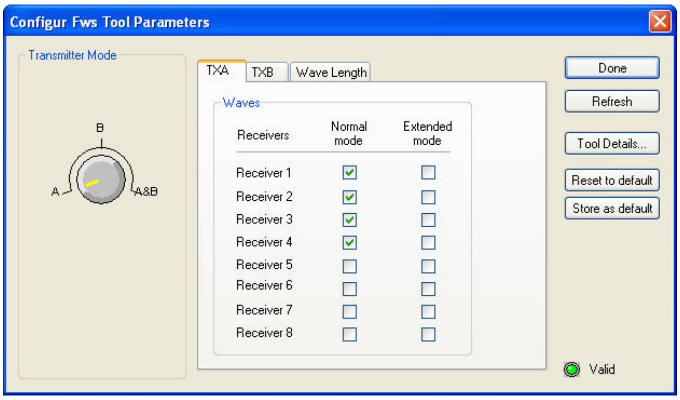

***Figure 3-6** Receiver Selection per transmitter*

Receivers can be operated in different modes:
Normal Mode: A receiver in **Normal** mode samples the received sonic signal in 4 µs steps up to the maximum recording time specified in the Wave Length tab (see section 3.4.3).

Extended Mode: One receiver can be chosen to operate in **Extended** mode. The selected receiver will sample the sonic trace in 20 µs steps up to the maximum recording length. This might be useful when looking for reflected tube waves.

Note: Only one receiver can be chosen for transmitter A and B to operate in **Extended** mode.

3.5.3 Selecting the recording time

The third tab in the Configure FWS Tool dialog box – Wave Length (**Figure 3-7**) – allows the user to set the maximum recording time and hence the length of the recorded full waveform trace in Normal and Extended mode. A maximum length of 16 ms is possible in Extended mode.

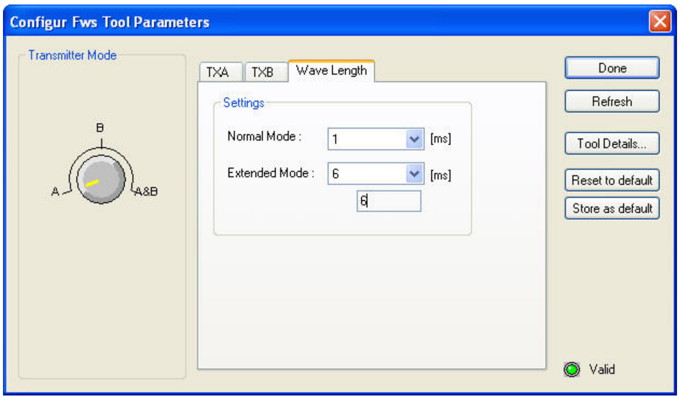

Figure 3-7 *Definition of recording time*

Click on the **Store as default** button to save the new settings into the internal memory of the tool and make the default for future measurements.

3.5.4 Tool Details

Click the **Tool Details** button in the **Configure FWS Tool** dialog box to display a dialog box showing the tool's serial number, firmware and hardware versions, and the transmitter-receiver configuration (**Figure 3-8**). None of the items shown is editable.

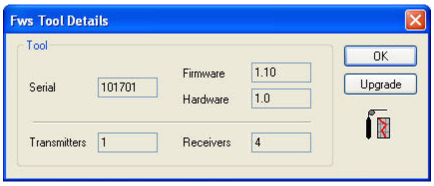

Figure 3-8 *Tool Details displayed*

3.6 Recorded Parameters, Processors and Browsers

The QL40-FWS in combination with the **FwsProc** processor provide in real time three different "Full Wave Form" and "Variable Density Log" outputs corresponding to four operating modes listed hereafter:

- **"Wide Band" -** is the preferred wave output for picking the first arrival of the compressional and shear waves. It will be used preferentially for velocity analysis, Cement Bond analysis, porosity evaluation, rock mechanical properties and lithology identification.

- **"Chevron" -** is the preferred wave output for performing fractures analysis. It is used to help User to detect the fractures in the borehole, to evaluate their extension and hydraulic properties.

- **"Tube" -** this wave output could be used as a permeability index and may help also for the lithology identification. Amplitude should be function of the permeability.

3.6.1 Recorded parameters

For each operating mode, the following data channels are recorded by the tool. Depending on the number of transmitters and receivers used and the chosen receiver mode the number and naming of the recorded data channels may vary.

RX1-1A-Wide Band	Amplitudes of the sonic trace recorded at transmitter A and recorded at receiver 1 (Normal mode) with the Wide Band recording mode
RX2-1A-Wide Band	Amplitudes of the sonic trace recorded at transmitter A and recorded at receiver 2 (Normal mode) with the Wide Band recording mode
RX1-1B-Wide Band	Amplitudes of the sonic trace recorded at transmitter B and recorded at receiver 1 (Normal mode) with the Wide Band recording mode
RX1-2A-Wide Band	Amplitudes of the sonic trace recorded at transmitter A and recorded at receiver 1 (Extended mode) with the Wide Band recording mode

…

The naming convention for the data channels is:

RX*n-mT- operating mode*

where ***n*** is the receiver number, ***m*** defines the receiver mode (1 : normal, 2 : extended) and ***T*** defines the transmitter which generated the wave (A or B).

Please note that additional data channels can be produced by the FwsProc processor. Please refer to the following chapter.

Note: None of the data channels recorded has been shifted in depth. The transmitter location is considered as measurement point.

3.6.2 FwsProc Processor

Processors perform real time operations on the recorded data. For the QL40 FWS tool two processes are supported: picking of the First Arrival and Cement Bond log processing. The FwsProc window (**Figure 3-9**) informs about the running status of the processes.

***Warning!* The FwsProc window must always be active when operating the QL40-FWS. Closing the FwsProc window will stop the record of the full wave forms and will stop all associated real time operations. No data will be recorded!**

If the processor window is not started automatically choose the **FwsProc** entry from the **Browser & processors** panel (**Figure 3-10**) and click on the **Start** button.

Figure 3-9 *FwsProc window*

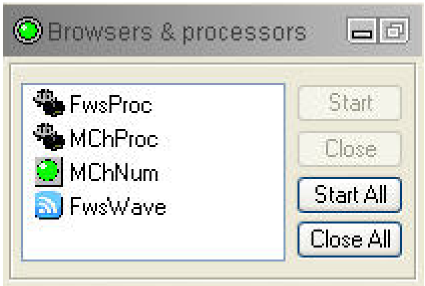

Figure 3-10 *Start the processor from the Browser & processors panel*

To start or stop a process right click on the title bar of the FwsProc window and select the **Parameters** option from the context menu.
The **Parameters** dialog box will open providing a tab to adjust the processing parameters for each process (**Figure 3-11** and **Figure 3-13**).

First Arrival Pickup

To start the **First Arrival Pickup** process, check the corresponding box in the lower left edge of the dialog box.
User must also select from the drop down list the **full wave form output** (Wide Band, Chevron or Tube) on which the first arrival picking should be applied.

The preview window shows the recorded trace at the first receiver and the determined first arrival pick (red vertical line). The number displayed at the beginning of the trace is the maximum amplitude span found in the actual trace.
The first arrival time will be picked for each selected receiver and output as a data channel. The resulting data channels can be used in formulas to compute P-wave slowness and velocities.

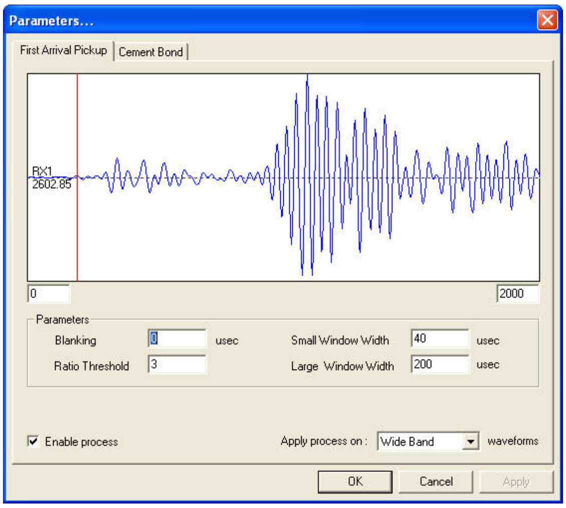

***Figure 3-11** First Arrival Pickup process options*

The process iterates through each trace in the time dimension. For each data point the average of the data values in a time window centered on the actual data point (Small Window = signal window) will be calculated. Another average value will be calculated from the data points falling into a time window preceding the actual data sample (Large Window = noise window). The ratio of small window average and large window average (signal to noise) will be compared against a user specified threshold value. The first time sample for which the computed signal to noise ratio exceeds the threshold will be considered as first arrival intercept.

$$\frac{\text{Small Window Average}}{\text{Large Window Average}} > \text{Ratio Threshold}$$

Blanking

In the edit box, enter the time period in micro-seconds for which the first arrival detection will be skipped. Using this option, you can blank out noise occurring in the beginning of the traces.

Small Window Width

In the edit box, enter the Small Window time width in micro-seconds.

Large Window Width

In the edit box, enter the Large Window time width in micro-seconds.

Ratio Threshold

In the edit box, enter the Ratio Threshold value.

The following additional data channels will be created by the first arrival pickup process:

RX1-1A - dt	First arrival pick (in µs) at receiver 1
RX2-1A - dt	First arrival pick (in µs) at receiver 2
RX3-1A - dt	First arrival pick (in µs) at receiver 3
RX4-1A - dt	First arrival pick (in µs) at receiver 4

Cement Bond

To start the Cement Bond process, check the corresponding box in the lower left edge of the dialog box.
If a FWS tool is run in borehole with cemented casing, the quality of the bond from casing to cement can be evaluated. The emitted acoustic signal travels through the casing, cement and formation before it reaches the receivers. The sonic waves travelling along the casing are attenuated when energy is lost to the environment behind the casing due to conversion of P- to S-waves, i.e. when the bond is good. As the compressional wave travelling through the casing is generally the first one to reach the near receiver, the Cement Bond Log is the recording of the amplitude of the first arrival of energy on the near receiver.
The first three peaks of the signal at the receiver are traditionally labeled E_1, E_2 and E_3 (**Figure 3-12**).

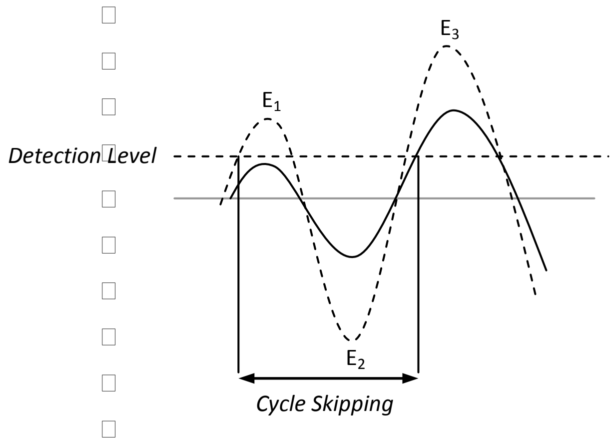

Figure 3-12 *Naming of signal peaks and principle of cycle skipping*

It is the goal of the Cement Bond processing to extract the amplitude of the E1 peak, which leads to judgment of the cement bond quality (low amplitude = good bond, high amplitude = bad bond).
In the case when the bond leads to amplitudes of E_1 so low that they are below the detection level, the first arrival pick would be triggered by E3 instead of E1. This is referred to as cycle skipping (**Figure 3-12**).

Two processes (**Fixed** and **Floating Gate**) will be run in parallel to extract the desired amplitude. In general the maximum amplitude within a time window (also referred to as gate) will be determined. The gate can be opened always at the same fixed time for all traces (**Fixed Gate**) or it can be opened at the time provided by a first arrival pick log (**Floating Gate**) – in the last case the starting time varies from trace to trace. If cycle skipping occurs the Fixed Gate method would return small amplitudes and the Floating Gate method high amplitudes, altogether indicating a very good bond (the E_1 amplitude was so low that the higher E_3 amplitude was detected by the Floating Gate method; **Figure 3-12**).

The Cement Bond options dialog box shows a preview of the sonic trace seen by the first receiver (**Figure 3-13**). The upper part of the preview shows the first receiver trace with the fixed gate start position and width as defined in the corresponding edit boxes. The lower part of the preview shows the trace with the Floating Gate configuration.

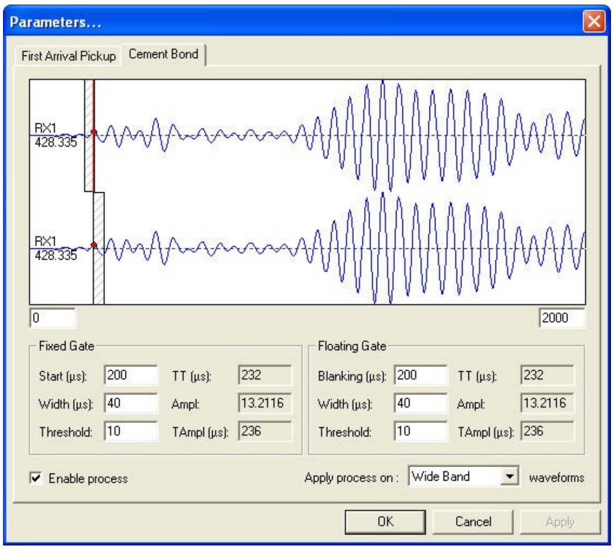

Figure 3-13 *Cement Bond processing option*

From the drop down list, User must first select the **WideBand** wave form output on which the gates and first arrival picking will be applied.

<u>For the Fixed Gate configuration you can enter:</u>

Start(µs): Starting point of the detection gate.
Width(µs): Width of the gate.
Threshold: Amplitude of detection level.

Only signal amplitudes within the gate limits and above the defined detection level will be extracted and recorded.

<u>For the Floating Gate configuration you can adjust the following parameters:</u>

Blanking(µs): Only first arrival times beyond the blanking period are considered as valid starting point for the gate.
Width(µs): Width of the gate.
Threshold: Amplitude of detection level.

For each gate the gate starting time (**TT(µs)**), extracted amplitude (**Ampl**) and intercept time of the amplitude (**TAmpl(µs)**) are displayed.

The following additional data channels will be created by the cement bond process:

TT**0**	Start time of fixed gate (in µs)
TAmpl0	Time at which fixed gate amplitude was derived (in µs)
Ampl0	Amplitude from fixed gate
TTX	Start time of floating gate (in µs)
TAmplX	Time at which floating gate amplitude was derived (in µs)
AmplX	Amplitude from floating gate

About FwsProc
When right clicking on the FwsProc window title bar the **About FwsProc** dialog box can be opened.

The dialog box provides information about the software version and the names of the recorded data channels.

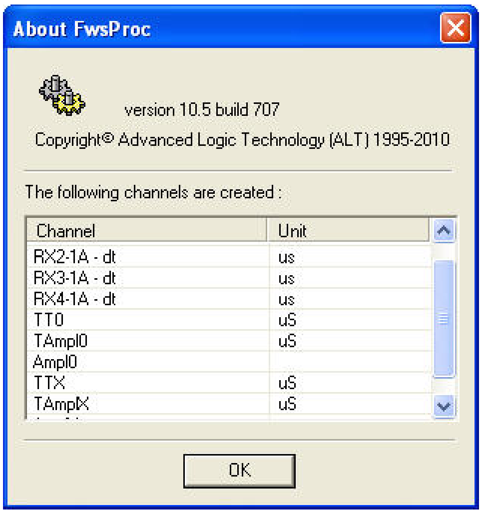

Figure 3-14 *FwsProc version and channels produced*

3.6.3 FwsWave Browser

The FwsWave browser displays the waves acquired on each receiver in real time. The **1**, **2**, … **8** toolbar buttons allow selection of the waves detected by the different receivers to be displayed. The **A** and **B** toolbar buttons allow display of the received waves fired by the transmitter **A** or **B** respectively. The Extended Wave is displayed in the bottom part of the window.
User can also choose between one of the four full wave form output (Wide Band, Chevron or Tube).

All these options are either available from the toolbar or from the menu.

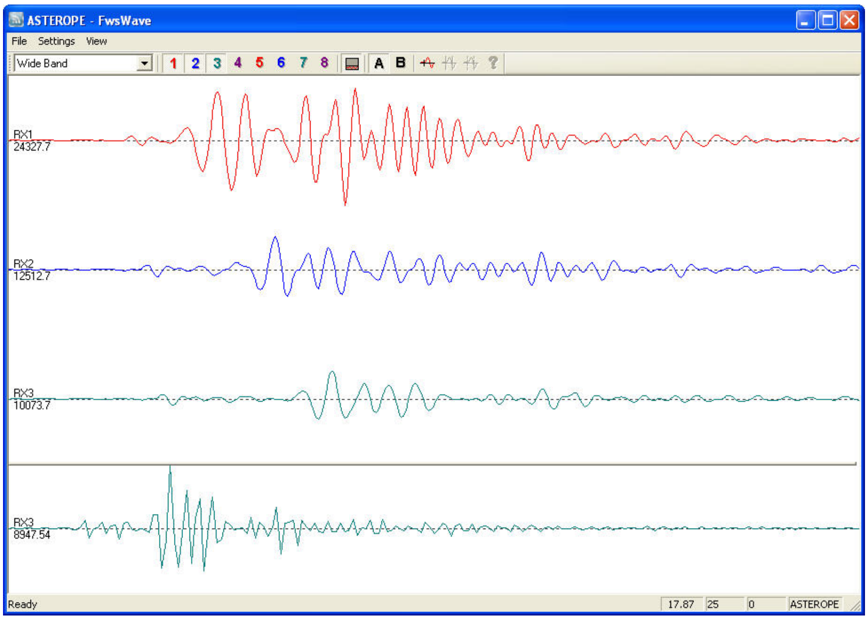

Figure 3-15 *FwsWave browser - Receivers 1 to 3 from Transmitter A – Extended mode on Rx3 – "**Wide Band" wave output***

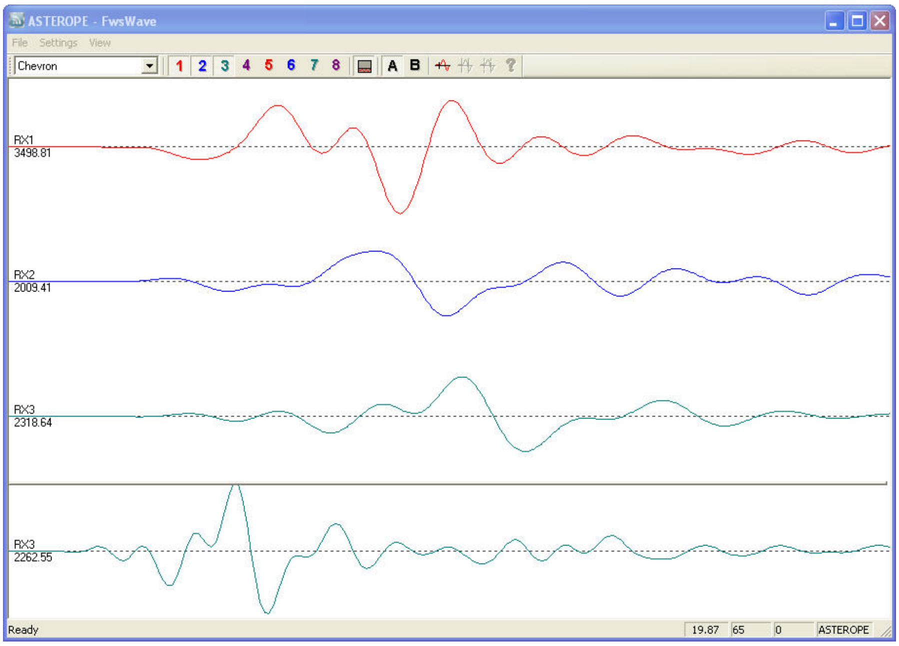

Figure 3-16 *FwsWave browser - Receivers 1 to 3 from Transmitter A – Extended mode on Rx3 – "**Chevron" wave output***

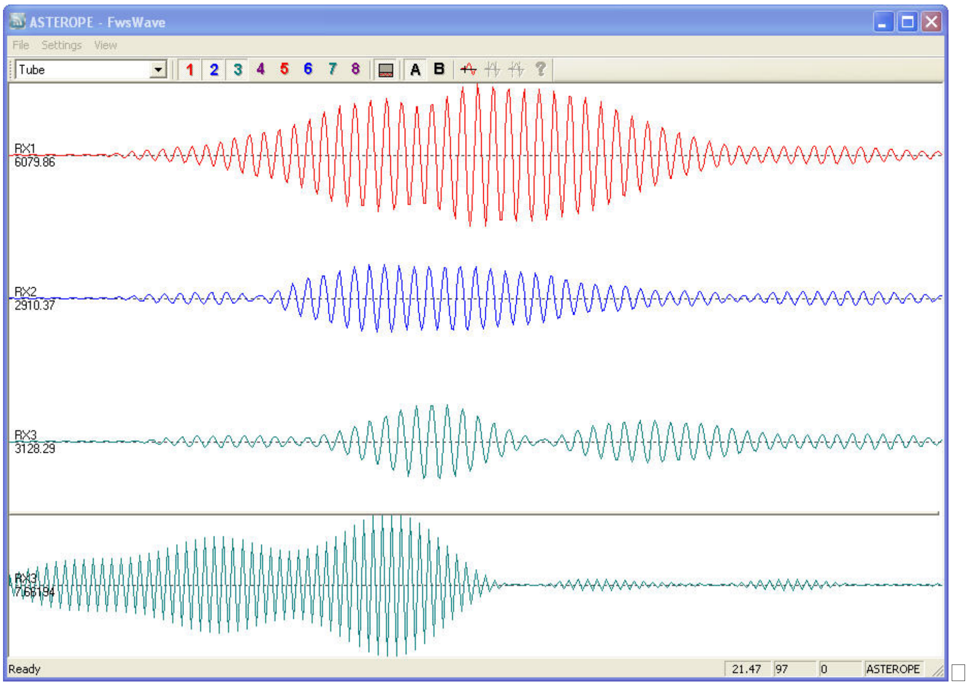

Figure 3-17** FwsWave browser - Receivers 1 to 3 from Transmitter A – Extended mode on Rx3 – **“Tube” wave output

3.6.2 MChNum Browser

Figure 3-15 and **Figure 3-16** show a typical example of the numerical values displayed in the MChNum browser window during logging. The display can be modified by right-clicking on the browser window and selecting the **Display options** entry.
From the **Display options properties** dialog box add or remove the channels to display.
It is also possible to change the format of decimal digits displayed for a channel. Select the channel and click on “Settings” to configure the number of digits after the period.

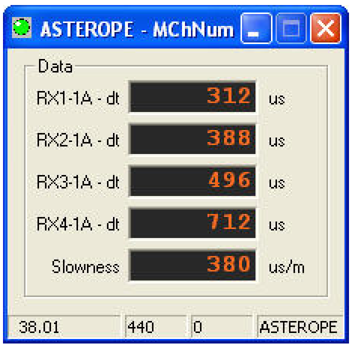

***Figure 3-18** MChNum browser (OpenHole display)*

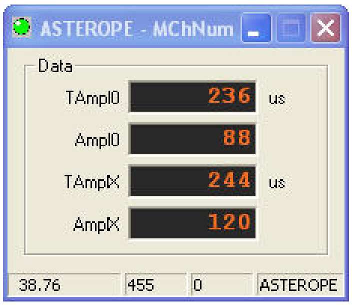

Figure 3-19 *MChNum browser (Cement Bond display)*

3.6.3 WellCad Browser

The **WellCAD Browser** is an add-on module allowing WellCAD software to be connected to ALT acquisition systems. While logging, WellCAD borehole documents will receive the data stream in real time offering the operator all WellCAD data edition capabilities for preprocess or quality check operations. Data can be saved, additional data loaded and templates can be applied.

More specifically when operating the QL40-FWS tool, WellCad browser offers the possibility to display in real time the full wave forms recorded by each receiver as "**Variable Density Logs**" – **Figure 3-20**.

In addition, when combined with **WellCad Full wave sonic module**, User can access to various Full wave sonic process options.

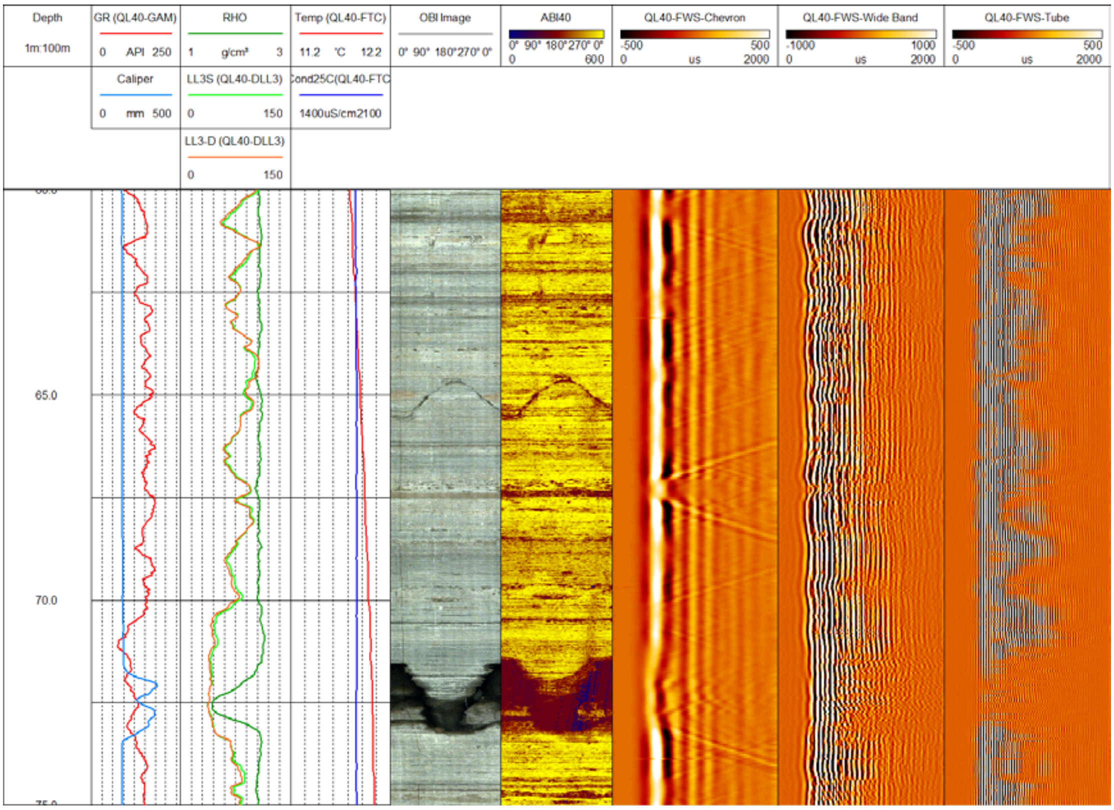

Figure 3-20 *Example of WellCad browser display*

4 Performance Check & Calibration

There is no specific performance check or calibration procedure recommended by ALT. When starting the sampling after powering on the tool the firing of the transmitter pulse should be heard even in air. A test borehole or water filled pipe could be used to check the correct operation of the tool over time.

5 Maintenance

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT will void the tool warranty.

5.1 Upgrading QL40 FWS firmware

In accordance with the ALT policy of continuous development the QL40-FWS has been designed to allow firmware upgrades. The current version of firmware installed in a tool may be verified in the **Tool Details** window opened from the **Tool Settings** dialogue box.

Firmware upgrade procedure is as follows:

1. ***Checking the communication is valid.***
2. ***Upgrading firmware***

5.1.1 Checking the communication

1. Connect the QL40 FWS tool to your acquisition system.
2. Start LoggerSuite software.
3. In the **Tool** panel select the appropriate tool and turn on the power.
4. In the Communication panel, select Settings. Check baud rate is set to 41666 and communication status is valid.

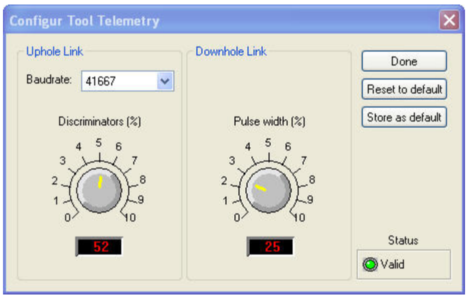

Figure 5-1Tool communication settings - ALTLog*

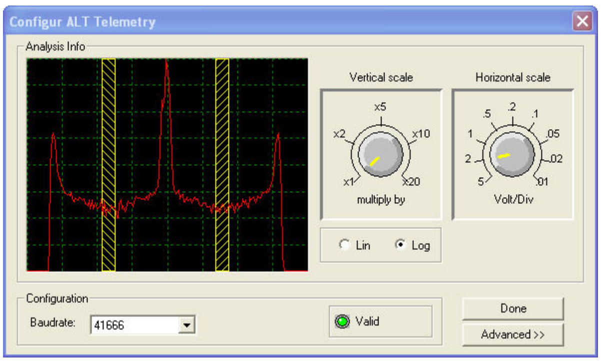

***Figure 5-2** Tool communication settings - Matrix*

Warning: Telemetry must be tuned properly. Bad communication may abort the upgrade of the firmware!

5.1.2 Upgrading the firmware

In the **Tool** panel, select **Tool settings/commands**. Check that the communication status is valid.

1. Click on **Tool Details**. Note that the firmware version currently in use is displayed in the firmware box. Click on the **Upgrade** button.
2. The following message will appear. Click **Yes** to validate your choice.

Figure 5-3 *Warning Message during firmware upload*

3. Select and open the appropriate **.hex** file provided. The upgrade will start.
4. During the upgrade procedure, the following message is displayed:

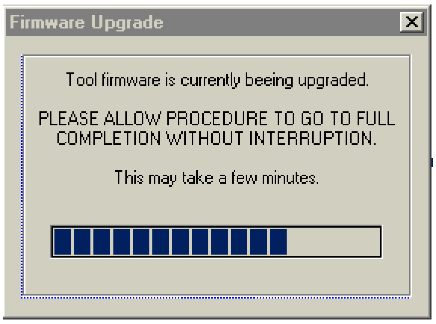

Figure 5-4 *Firmware upgrade progress window*

5. Once the upgrade has been successfully completed, click on **OK** to turn off the tool.

Figure 5-5 *Successful upgrade*

6. Power on the tool to initialize the upgraded firmware. Check in **Tool settings/commands** and **Tool details** that the firmware version has been changed with the new one.

Note that the following error message will appear at the end of the procedure when the tool firmware upgrade has failed or has been aborted. Verify the tool communication settings in this case.

Figure 5-6 *Error message*

6 Troubleshooting

Observation	To Do
Tool not listed in Tool panel drop down list.	- Do you have a tool configuration file? - Has the tool configuration file been copied into the correct folder? Refer to LoggerSuite manual about details of the directory structure.
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 3.4).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V for ALT tools).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** **-**Possible shortcut (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of a shortcut. - If the above shows no issues, use the test cable provided by ALT to verify the tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - If problem cannot be resolved contact support@alt.lu .
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can't receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed, decrease tool resolution, adjust tool parameters and/or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - Check bandwidth usage and telemetry error status.

7 Appendix

7.1 Parts list

7.1.1 Tool delivery kit QL40-xxx (ref. 209-016)

Item No.	Qty	Part No.	Description
1	1	210-002	Silicone grease Molykote111
2	2	211-004	C-spanner 40-42 (QL40-43)
3	6	AS215-V-75°	Oring-V 26.57 x 3.53 75°
4	1	210-003	Grease Lubriplate L0034-086

7.2 Technical drawings

The following technical drawings are available on request:

- Acquisition system wiring diagram.
- QL40 FWS Wiring Diagram.

Index

QL40-ELOG4/IP
QL40-Normal Resistivity PROBE
QL40-Induced Potential PROBE

Advanced Logic Technology s.à,

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August 13, 2010

Table of Contents

General Information

QL40 Stackable Logging Tool Overview

QL stands for Quick Link and describes the latest line of stackable logging tools. This development is a joint venture of Mount Sopris Instruments and ALT. Innovative connections between tool elements (subs) allow users to build their own tool strings in the field.
The Tool Stack Factory – a sophisticated extension of the acquisition software – provides a convenient way to configure tool strings for operation.

Each sub has a Telemetry and Power supply element, the TelePSU, allowing them to operate individually without a separate telemetry sub. As a result all QL subs can be operated as standalone probes or in combination with other subs. The GenCPU card in each measurement handles Analog to Digital conversion and/or counting of the measurement signal and formatting of the data for transmission up hole.

When used as a standalone or stack of active subs the tool is completed by adding a Tool Top sub and where applicable a Tool Bottom sub. At present two Top subs are available, a MSI single conductor and GOI 4 conductor. Consult the factory for additional options. In addition, for the QL40-ELOG and QL40-IP subs, isolation bridles replace the Tool Top Sub.

The number 40 indicates a nominal OD of 40mm. Over coating and special measurements may make some subs larger in diameter than this. See their particular specifications.

Minimum requirements:

Matrix v10.XX software with appropriate Matrix Logger firmware
See the installation instructions for Matrix software for more information.

Connections, and Layout

Connections for the tool are as follows. The QL40-ELOG and QL40-IP subs must use an isolation bridle as their top connection.

The probe injection current injection electrode (“A”) returns to cable armor (“B”). Once again, this is the primary reason that an isolation bridle is required for a valid measurement.

Probe Top sub connections:

Q40ISI- single conductor bridle

Pin	Signal	Origin
Bridle top housing	Tool power ground	Armor
Center pin in bridle top	Tool power positive	Center conductor
Isolated bridle electrode	Measure Voltage Reference	

Q40IS4-four conductor bridle

Pin	Signal	Origin
Probe top housing	Tool power ground	Armor
1	Tool power positive	Com A&B
2-4	No Connection	No Connection
3	Tool power positive	Com C&D
Isolated bridle electrode	Measure Voltage Reference	

QL40-ELOG

The QL40-ELOG sub provides 4 normal resistivity measurements, plus spontaneous potential (SP) and single point resistance. The QL40-ELOG can be operated as a stand-alone probe with isolation bridle and bottom sub or can be stacked above or below another sub on a MATRIX logging system. In general, the isolation bridle must be located directly above the QL40-ELOG sub. Isolation from armor is a critical requirement that cannot be overemphasized when running any resistivity probe. Incorrect measurements will result if isolation is not adequate.

QL40-IP

The QL40-IP sub provides 4 normal resistivity measurements, plus spontaneous potential (SP) and single point resistance. In addition, the IP function provides 2 digital IP channels. The IP uses the 16 and 64 inch electrodes as receivers, and the current electrode as an IP charging source. The probe measures the injection and relaxation voltages on both measure electrodes as a function of time. This measurement is digitized and presented as 10 channels of time based data per depth interval for each spacing. In addition, a high resolution A/D further breaks each channel into 10 more discrete samples, providing a “full wave” presentation of the injection and relaxation decay. The resultant data are combined with data from other subs (if present in the stack). The data is then transmitted up the wireline using a pulse coded digital data protocol.

QL40-ELOG Specifications:

Power Requirements

DC voltage at probe top. MIN. 80 VDC MAX. 160 VDC Nominal 120VDC
Current 38 mA nominal, 60 mA max
Current source electrode in probe outputs 32V pp square wave (+/- 16V) at up to 500 mA

Electrode details

Current Electrode 50 mm 304 stainless
Measure Electrodes 18 mm 304 stainless

Electrode reference measuring point (from bottom of bronze knurled ring)

SP 1.689 m up from bottom of locking ring
8” normal 0.164 m up from bottom of locking ring
16” normal 0.266 m up from bottom of locking ring
32” normal 0.469 m up from bottom of locking ring
64” normal 0.875 m up from bottom of locking ring
SPR 0.063 m up from bottom of locking ring

Operating temperature range

32 to 158 degrees F 0 to 70 degrees C

Pressure rating

2900 psi 200 bars

Dimensions

Length	74.6 inches	189.5 cm (add 29.3 cm for standalone operation)
Diameter	1.63 inches	41.4 mm with neoprene heat shrink and PVC electrical tape
Weight	19.4 lbs	8.8 kg

Measurement Specifications

SP Range: +/- 18 V
Resolution: 0.5 mV
Accuracy: +/- 2.5 mV

SPR and 8”, 16”, 32” and 64” Normal Resistivities

Range: 0.1 to 100,000 ohm-m

Resolution: <0.04% of measured value (24 bit/0.5 msec ADC with real-time downhole digital filtering

Accuracy: <1% of measured value from 10 to 1000 ohm-m
<5% of measured value from 1 to 5000 ohm-m

See graph below for accuracy range versus resistivity:

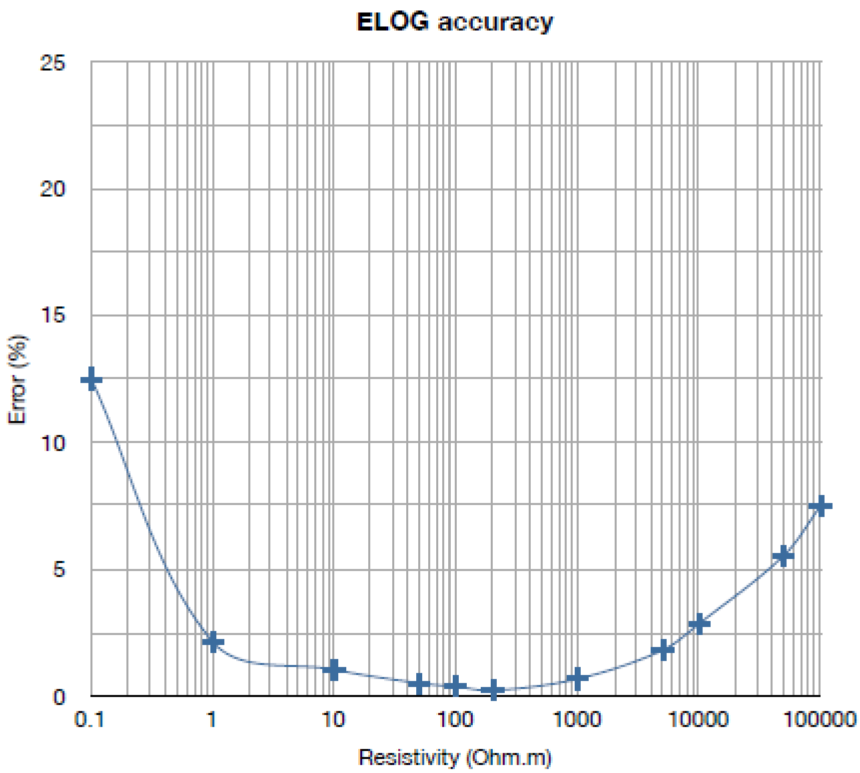


Figure 1

Principal of Operation-QL40-ELOG in E-LOG mode

The QL40-ELOG has 5 electrodes which are used for measuring normal resistivity at 4 spacings, spontaneous potential, and single point resistance. The QL40-ELOG sub **must have** an isolation bridle placed above it to provide a remote reference electrode for the normal resistivity channels, and a remote return for the injection current.

The **SP** (spontaneous potential) is measured between the 64" normal measure electrode and armor. The data recorded as SP or VSP measures the natural voltages sensed by this electrode. These voltages can be related to both electrochemical and electrokinetic forces in the borehole. The electrochemical SP is developed when there is a difference between the formation fluid and borehole fluid salinities, and occurs normally when the measure electrode passes a clay or shaly zone, which acts as an ion selective membrane. The resulting current flow in a "cell" comprised of those three elements provides a negative SP if the borehole fluid is less conductive than the formation fluid. In fresh water zones, the SP is often positive. The electrokinetic SP can occur when borehole fluid mechanically invades porous and permeable formation, causing a current flow.

The **SPR** is measured between the **"A"** current injection electrode on the bottom of the probe and the isolated cable armor above the bridle. This SPR is a qualitative indication of the electrical resistance of the formation material immediately adjacent to the current electrode. The principal of measurement follows Ohm's law, where R=V/I. As the current flows toward the armor return, the current density (I/cross-sectional area) decreases dramatically. This means that the majority of the resistance measured is influenced by the material closest to the current electrode. For this reason, the SPR is very sensitive to small changes in resistance close to the borehole.

The four **Normal Resistivity** measurements are made at the halfway between the "A" current electrode and each of the 4 "M" normal resistivity electrodes. The normal resistivity measurement includes a reference electrode, called "N", which is assumed to be at electrical infinity compared to the measure electrodes. In this special application of Ohm's law, V=IR still applies, but is re-written as R=V/I.

$$\frac{V}{I} = R = \frac{\rho \cdot l}{A} \quad \text{or} \quad \rho = \frac{A \cdot V}{l \cdot I} \quad \text{or} \quad \rho = G \cdot \frac{V}{I}$$

Where G is called the geometric factor, and is related to the A-M spacing between electrodes. In metric units, G is approximately 12.5 * AM spacing. Note that for normal resistivity measurements, the result is true resistivity, ρ, expressed in ohm-m^2/m. It is important to remember that this application of Ohm's law assumes that the formation is homogenous and infinite. Corrections for borehole size, borehole/formation fluid ratio, and bed thickness should be applied to get true formation resistivity. See appendix for references.

The SPR and normal resistivity measurements are made using a 50 msec long +/-16V square wave downhole current generator, which can supply up to 500 mA of survey current. The polarity of the current is alternated between + and – relative to armor to prevent polarization of the electrodes.

Setting up the QL40-ELOG/IP and support equipment

Before operating the QL40-ELOG/IP sub, determine if the sub will be used in a stand-alone configuration, or if it will be used in conjunction with another QL Series sub. Remember that an isolation bridle **MUST BE USED** for proper E-LOG measurements

The subs are connected by threading the male end of the top sub into the next lower one. Note the key way.

Remove the bottom protector from the Top sub. The GOI-4 Top sub is shown below, and the Q40IS1 and Q40IS1 and 4 isolation bridles have the <u>same lower configuration</u> as the GOI4 Top sub.

Figure 2

Locate the spanner wrenches as shown below:

Figure 3

Align the top sub with the key way inside the female housing of the next section. Inspect all O-rings for defects and make sure threads are clean. Threads and O-rings should be lightly greased. When connecting subs, it is best to balance each sub section on a tool stand so that the ends join with no load. See photo below.

Figure 4

Slide the top sub in until the threads meet the mating ones inside the housing. Start turning the brass nut by hand until the threads engage. Slightly raise or lower the joint so the pieces mate evenly and the threads turn easily. **Warning: Do not force the threads! When properly aligned they should turn smoothly.** Use the spanner wrenches to tighten the threads until the brass nut is fully engaged. **Do not use cheater bars on the spanner wrenches.**

The threads should go on smoothly. If they are binding adjust the supported location top or bottom section so they are level and evenly aligned.

Figure 5

QL-ELOG stand alone mode

In order to operate the sub as a stand-alone probe, the isolation bridle and a bottom sub must be connected to the sub. After the bridle and bottom sub are connected, it is imperative that any steel or brass surfaces, OTHER THAN THE 5 ELECTRODES, must be completely covered with insulating tape. Failure to do this will result in incorrect resistivity values. DO NOT tape the 50 mm current electrode or any of the four 18 mm measure electrodes. A properly prepared probe will show only those 5 electrodes exposed, with no other conductive surfaces showing. Figure 6, below, shows how the isolation bridle should be connected to the top of the QL-ELOG probe. Figure 7 shows how to connect the bottom sub or plug. We do not recommend operating any bottom sub below the QL-ELOG which is not completely isolated with insulated tubing for at least 70 cm. This means you should **not connect** a QL-CAL three arm caliper below the QL-ELOG. QL40-GAM and QL40-FTC can be connected if they are insulated with tubing.

Figure 6

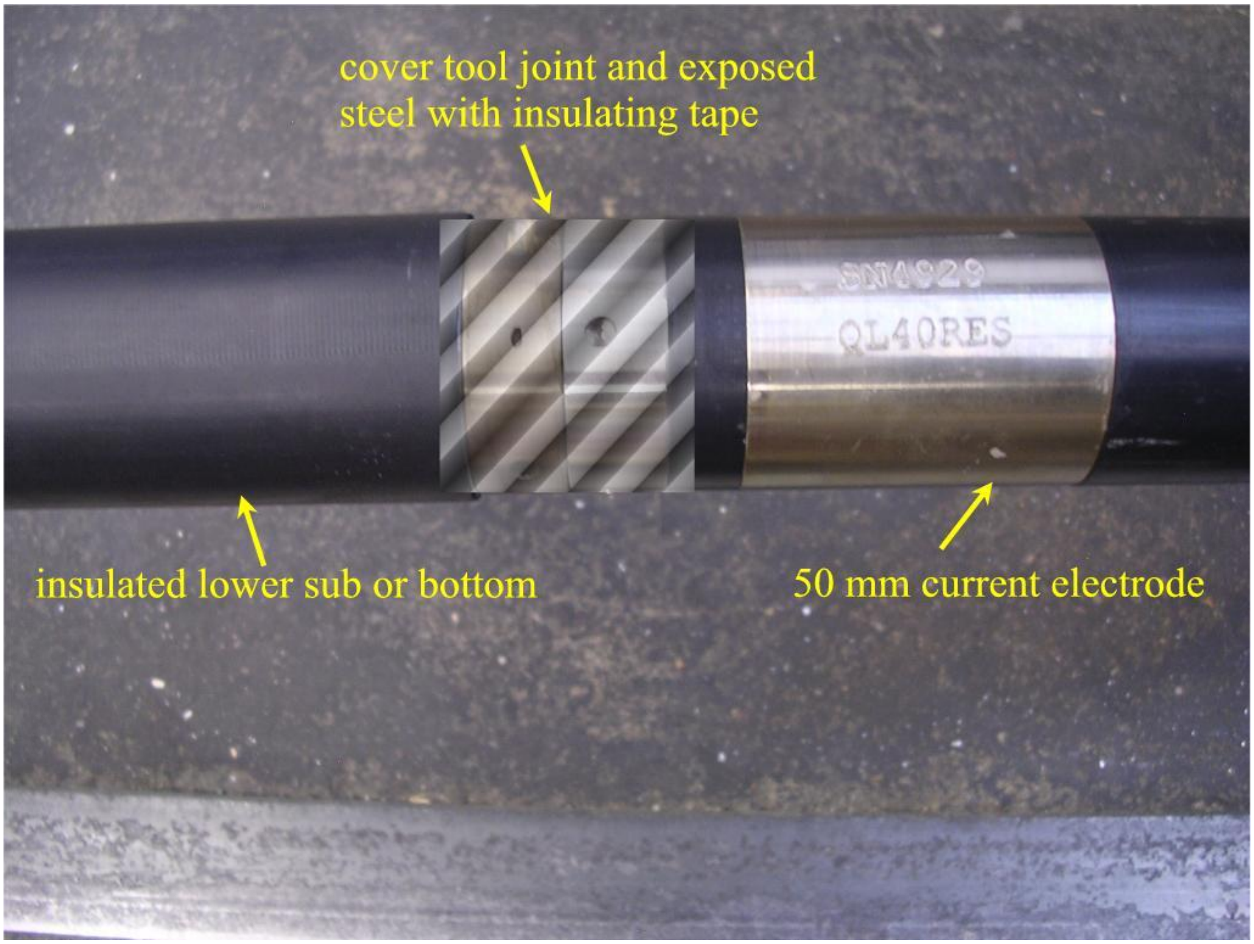


Figure 7

If the probe is to be operated in stand-alone mode, the correct stand-alone tool configuration file should be chosen from the pull down menu for the Matrix (or ALTlog) dashboard.

A Mount Sopris 4RSP-1000 calibration box can be used for this procedure. It provides necessary wires and resistors, plus an SP voltage source to allow complete calibration of this probe. When operating the probe in QL mode, linked with QL40-GAM or QL40-FTC, it may be necessary to recalibrate the tool to improve accuracy.

QL40-IP Specifications:

Note: The QL40-IP probe, in addition to providing two IP measurements, also supplies the same 6 measurements that the QL40-ELOG probe provides. However, these measurements can be affected by the injection and release settings used for the IP measurement and may not provide optimum ELOG performance.

Power Requirements

DC voltage at probe top. MIN. 80 VDC MAX. 160 VDC Nominal 120VDC
Current 38 mA nominal, 60 mA max
Current source electrode in probe outputs 32V pp square wave (+/- 16V) at up to 500 mA

Electrode details

Current Electrode 50 mm 304 stainless
Measure Electrodes 18 mm 304 stainless

Electrode reference measuring point (from bottom of bronze knurled ring)

16” spaced IP 0.266 m up from bottom of locking ring

64” spaced IP 0.875 m up from bottom of locking ring

Operating temperature range

32 to 158 degrees F 0 to 70 degrees C

Pressure rating

2900 psi 200 bars

Dimensions

Length	74.6 inches	189.5 cm (add 29.3 cm for standalone operation)
Diameter	1.63 inches	41.4 mm with neoprene heat shrink and PVC electrical tape
Weight	19.4 lbs	8.8 kg

Measurement Specifications for IP

User selectable injection/release times (100-250-500 msec)
10 equal time window chargeability per spacing
Digitally controlled 8 watt downhole current generator
Simultaneous full-wave digitizing of electrode voltages for both spacings
24 bit/0.5 ms ADC with downhole real-time filtering and processing
Resolution: 1.3 μvolts
Input impedance: 1.4M-ohm

Operating Procedure

Operation

To use the QL40-ELOG or IP probe, with the MATRIX logging system, make sure the correct sub files are installed in the C:\Logger\Tools\QL40-12 directory. The files are most easily installed using **LoggerSettings.exe** utility program supplied with the software installation. QL40 sub files are may be found on the installation or separate CD.

In the case of the Matrix logger, the power settings are set to default values that are used for all probes equipped with the QL TelePSU downhole power supply. Different wirelines may require some adjustment to the telemetry. These settings are accessed by pressing the **Settings** button in the **Telemetry** panel of the Matrix dashboard. The user may also view the pulse stream on the cable line by pressing on the **Scope** button. Select the correct winch/wireline from the Pull-down menu in the Telemetry Selection Scheme window. To view/change telemetry settings, press the **properties** button. The **Configure ALT Telemetry View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.
The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry. The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.
For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see **Error! Reference source not found.**) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly

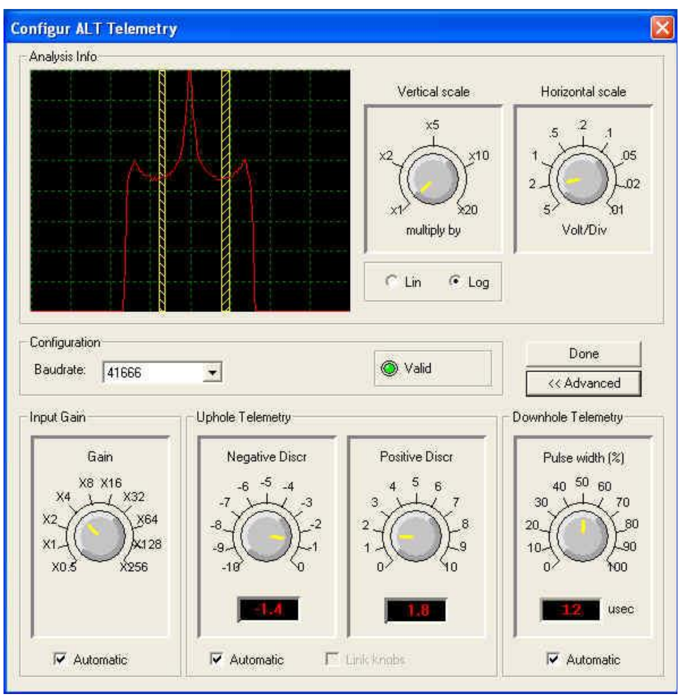


Figure 8

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in "Valid" status the next time the power is turned on.

IP Probe Configuration and Operation

The IP-enabled version of this probe provides a 16" and 64" IP measurement. In addition, this configuration also provides 8", 16", 32" and 64" normal resistivities, SP, and SPR. The isolation bridle **MUST BE USED** to get valid data for all measurements. Follow the same procedures for preparing the probe (and any other stacked subs) which are presented in the QL-ELOG section above.

In the IP mode, the downhole current generator supplies a +/- 16VDC square wave pulse at up to 500 mA, to each electrode. The user can select from 3 different injection/release times. The selection of the injection/release time depends on the chargeability of the formation. For highly chargeable rock, the 100 msec time is appropriate. The 250 msec setting should be used for average rock/mineral environments. For investigation of shales and other materials with low chargeability, the 500 msec setting may be appropriate.

To access this setting, click on the Tool Settings button on the Tool section of the dashboard:

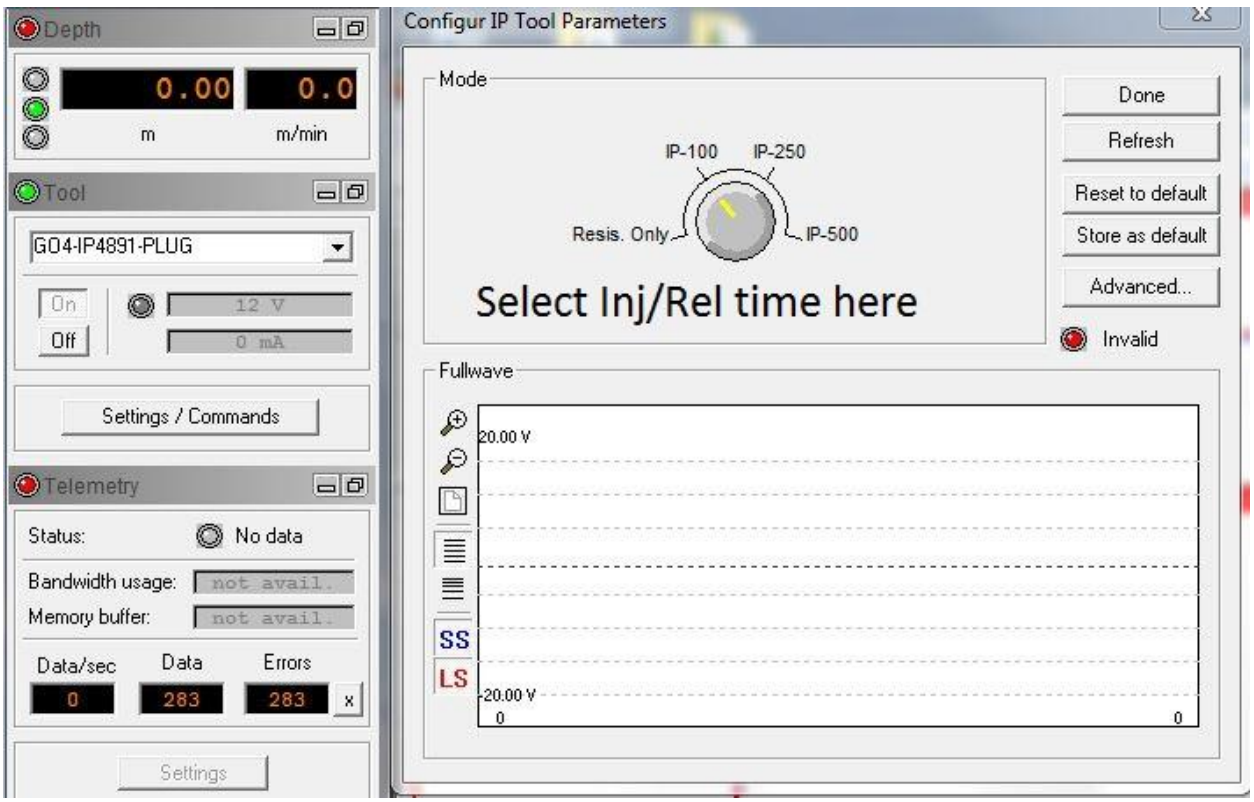


Figure 9

Note: The user can also operate the probe in Resistivity ONLY mode by selecting Res Only on the Configur IP Tool Parameters knob. This will produce a normal resistivity log with 4 spacings, generated by a 50 mS +/- 16VDC square wave. This setting is recommended for the best normal resistivity data, when using the IP/Elog combination probe.

The IP data can also be displayed as a full waveform (using a high resolution A/D to further digitize the injection and release data. To enable this feature, click on the ADVANCED settings on the Configur IP Tool Parameters window:

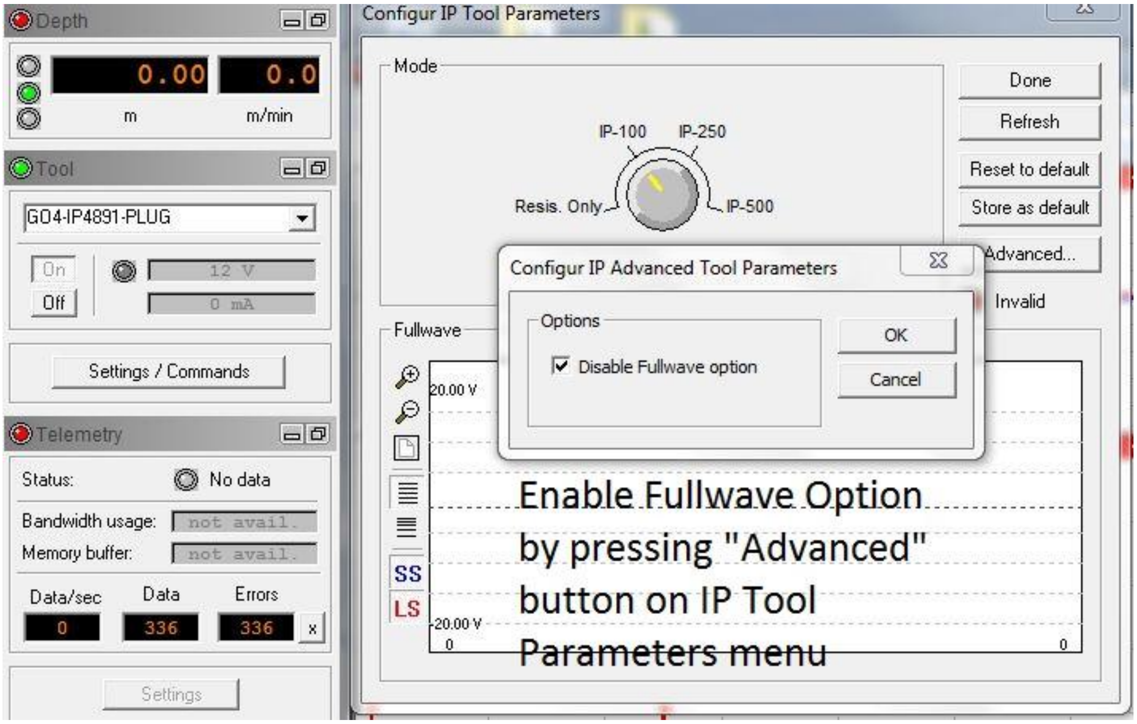


Figure 10

IP Browsers

The IP mode of operation produces three display browsers, which present the log curves (MchCurve), the log data (MchNum), and the IP Full Waveform (IPWave). The MchCurve data includes normal resistivities, SP, SPR, and 10X channels of IP release data for both the 16" and 64" electrode spacings. The user can select the curves to be presented by clicking on the EDIT, Show Logs button on the MchCurve menu bar, and remove or add curves:

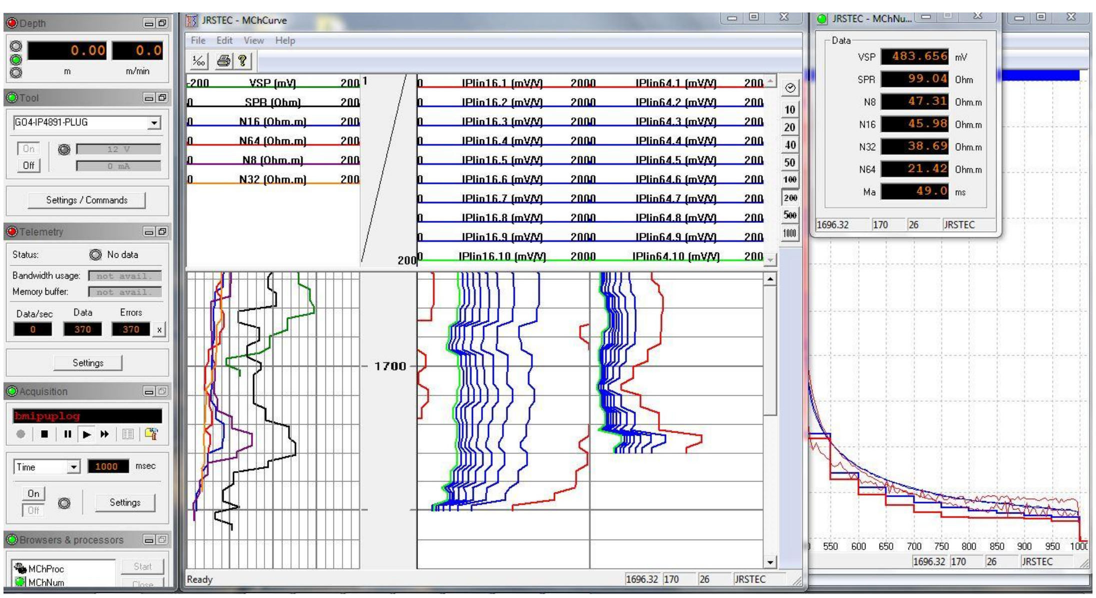


Figure 11

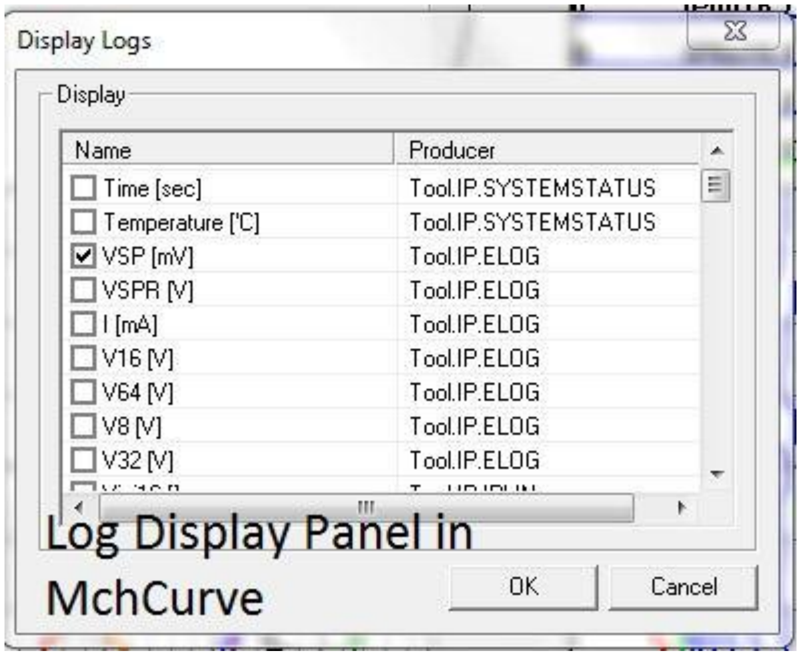


Figure 12

Similarly, the user can select which numerical data values to display in the MchNum browser using the same method:

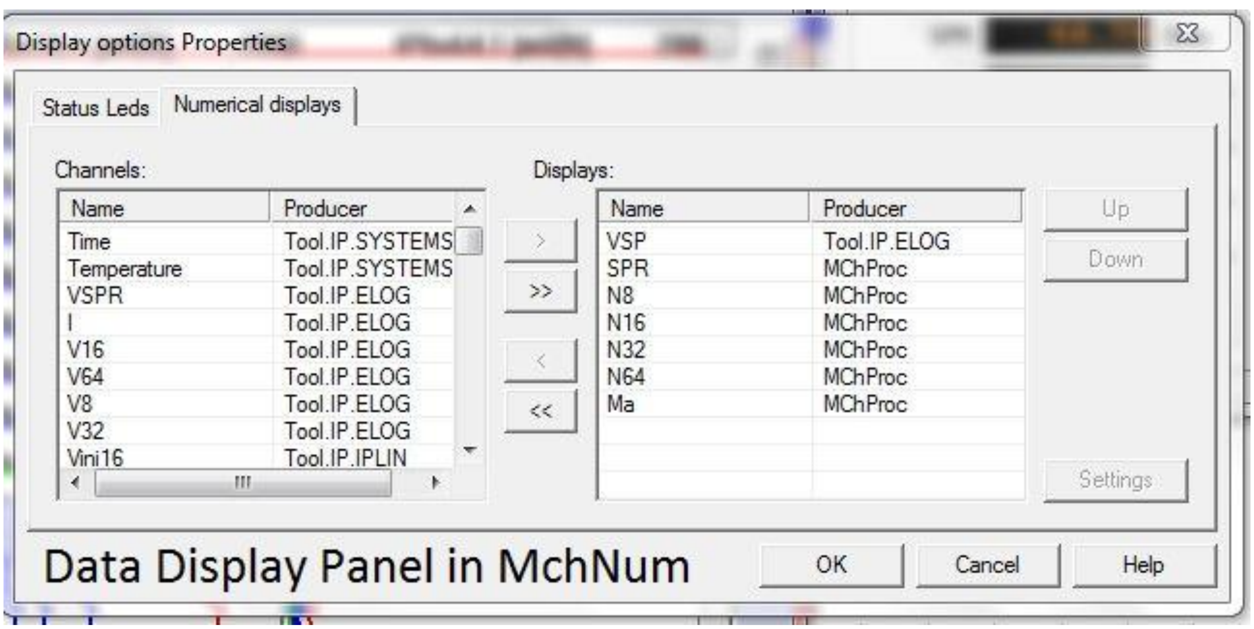


Figure 13

The Full Wave Browser has 3 display windows. The top left is the raw data, which is digitized downhole by the probe, and sent to the surface. The VSP (Spontaneous Potential) is also displayed in this window, since it must be subtracted from the injection and release voltage values to produce a correct chargeability. All windows in this browser can be "zoomed" by left-clicking on the magnifying glass icon in the top menu bar. To "un-zoom, right click with this icon positioned over the window of interest. The SS and LS buttons on the top menu are used to select which spacings are displayed. SS is the 16" spacing, and LS is the 64" spacing.

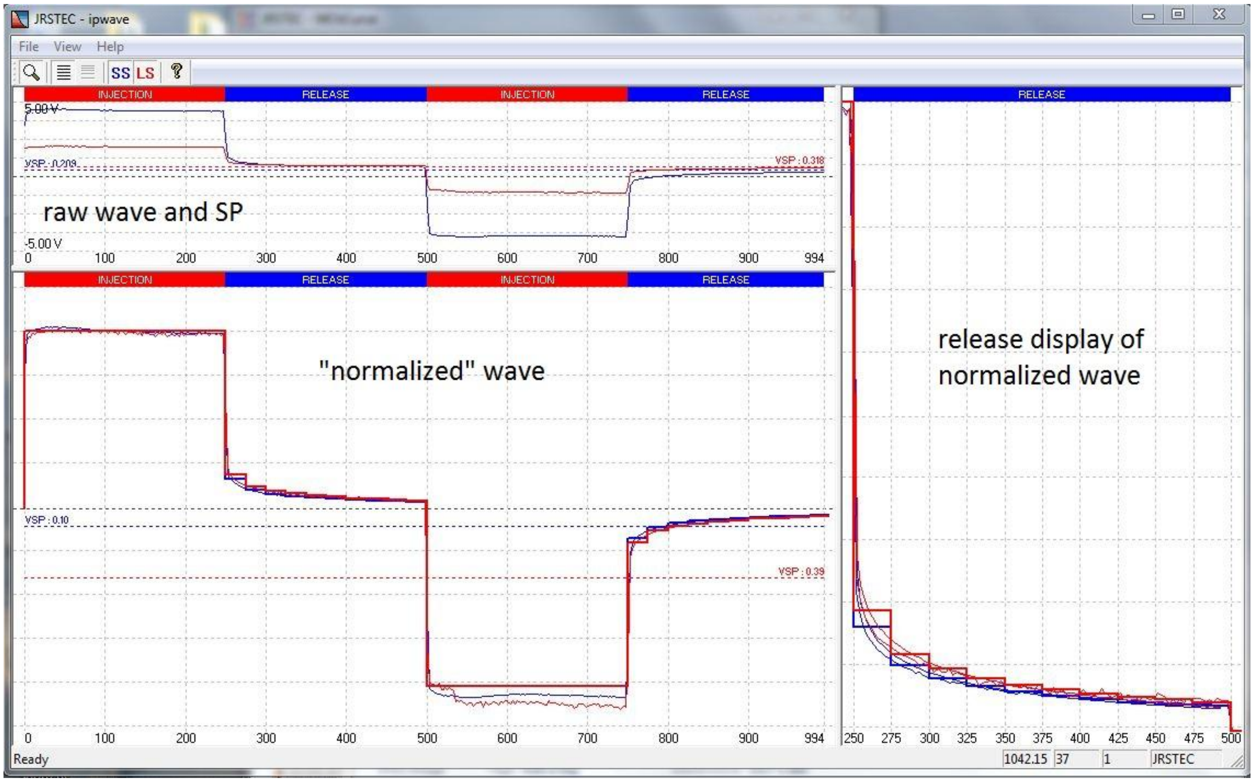


Figure 14

Calculation of IP Chargeability Response

The chargeability, labeled Ma, is calculated by integrating the 10 average voltages in the release cycle (units are V-ms) and then dividing by the injection voltage. For a 250 msec inj/rel time, this means that the average release voltage, beginning with the first 25 msec window after injection is removed is added to the next average release voltage from 25-50 msec, and so on, for those 10 cycles. The output Ma is presented for the SS (16") spacing. The IPWave browser shows the same information for the LS (64") channel.

The lower left portion of the display shows the "normalized raw waveform" with the SP subtracted, and the result divided by the injection voltage. 10 channels of "average" normalized window gates divided by the injection voltage are also displayed. The SP value, also normalized by the injection voltage, is displayed.

The right hand display on this browser is the release portion of the lower left display.

Calculation of Ma, Chargeability

The chargeability for the SS channel is calculated using the following relationship:

```
Formula=0.001*{ch12}*({ch49}+{ch50}+{ch51}+{ch52}+{ch53}+{ch54}+{ch55}
+{ch56}+{ch57}+{ch58}),
```

where ch12 is the release gate time (e.g. 25 ms for a 250 ms inj/rel setting,

and ch49..ch58 are the normalized values for each gate, which is the gate average voltage, divided by the injection voltage.

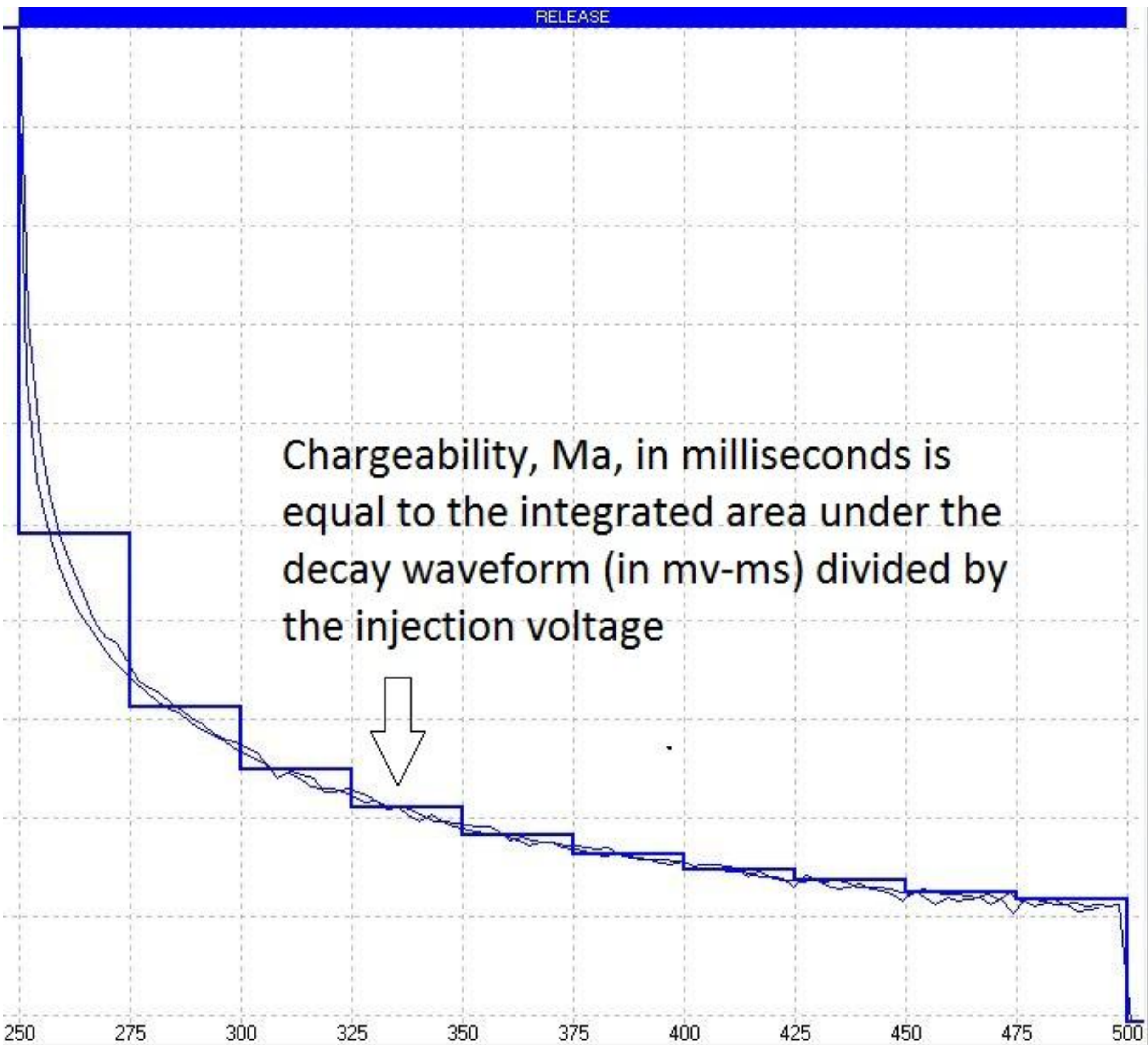


Figure 15

Performance Checks and Calibrations

Calibrations are performed at the factory. Each QL40-ELOG will be delivered with a calibrated “sub” file that should be used for that specific tool. It is also possible to calibrate the tool in the field, using a suitable resistor box with SP reference voltage. The Mount Sopris 4RSP-1000 resistivity/SP calibrator is ideal for this purpose. It includes electrode clamps, cables, and a detailed manual that explains how the electrode clamps should be attached, and how to connect the reference and armor returns. A simple diagram of this set up is shown in figure 9 below. The IP functions are factory calibrated.

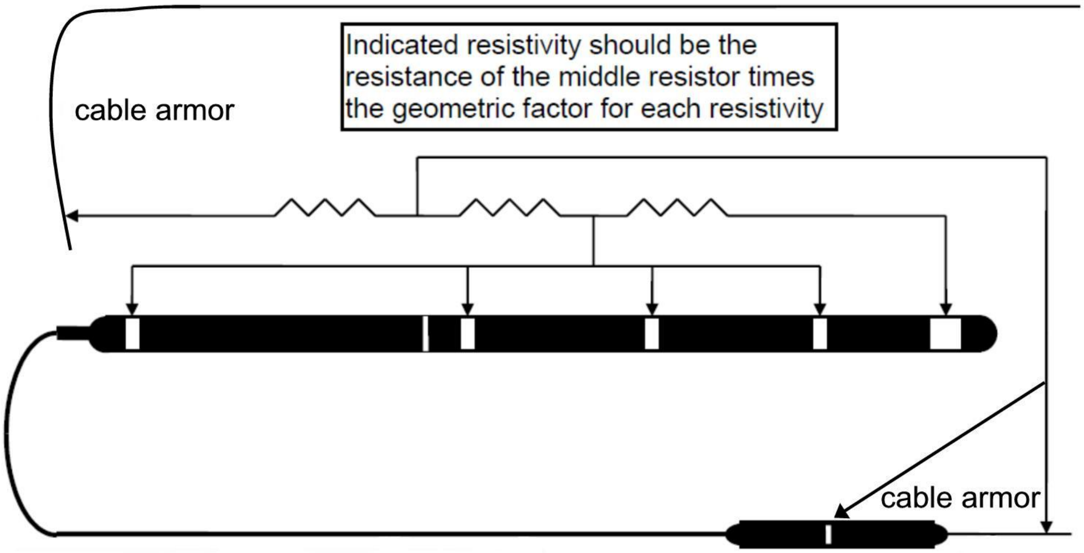


Figure 16

Be sure to consult the operation manual for the calibrator to cross-check the set-up. Once the calibration fixtures are attached, the user should power up the probe and establish good telemetry. Using the time mode for data acquisition, the calibration for each channel are made with the MchNum calibration function, described in detail in the Matrix Operating Manual. A sample screen from a QL-ELOG calibration is shown in Figure 10

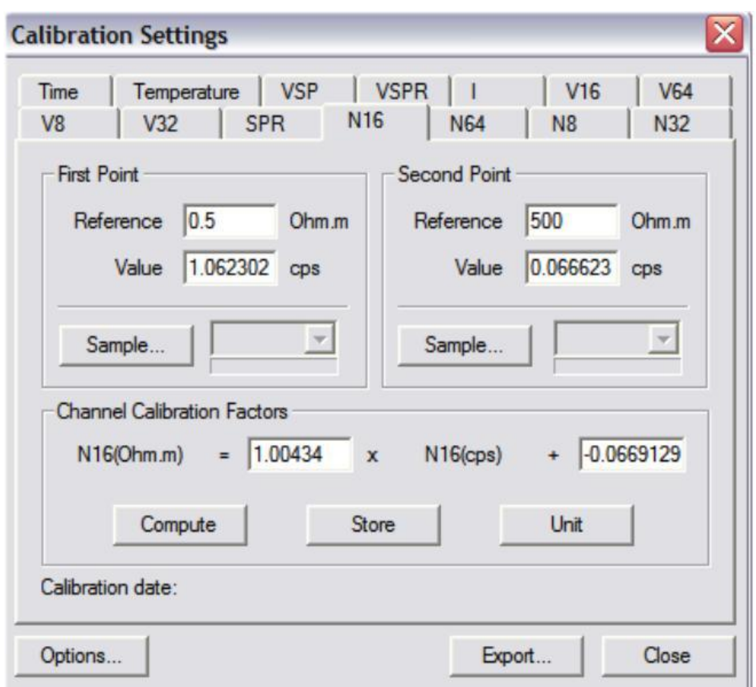


Figure 17

Preventative Maintenance

The QL40 series tools require periodic maintenance. Make sure the threads on the brass nut on the sub bottom are free of sand mud or other dirt. A thin layer of anti-seize is recommended. When disassembling the sub string dry the joint as it is separated to prevent fluid from entering the sub top and getting into the Lemo electrical connector inside.
After replacing top and bottom protectors it is good to wash the probe off after each use. ***Never take the probe apart. This probe is very difficult to disassemble and requires special steps to be taken in order to gain access to the inside of the probe without damaging the electronics. If you have read this after attempting to disassemble the probe chances are the probe has experienced damage and will need to be sent to the factory to be repaired.*** Inspect o-rings occasionally and keep the threads on both ends of the probe clean, to minimize problems in the future.
The heart of the gamma section is the photo multiplier tube and the sodium iodide crystal. Both units are very fragile and can be damaged if the probe is dropped or experiences a very abrupt temperature or mechanical shock. Take great care while handling or packing the probe for transportation.

Locking Ring assembly Maintenance

Tools required:

1.5mm Allen wrench
2 ea 40-42mm spanner wrench
Paper towels or clean rags

Replacement Parts:

ALT26005, Large Threaded Ring, Qty 2
28-174-995 M2x8 SHCS, Qty 2

Disassembly:

Unscrew and remove the two M2x8 socket head cap screws and separate the two halves.
Four guide pins align the two ring halves and tend to hold them together the after the screws are removed. To pry the halves apart you can use a pair of spanner wrenches inserted into the wrench holes on opposite sides of the ring mating surfaces to pull them apart slightly.

Do this carefully to prevent bending the guide pins.

Figure 18

Place something small in the opening and move the spanners to the other side and pry it open slightly. This should be enough to release the two rings as below.

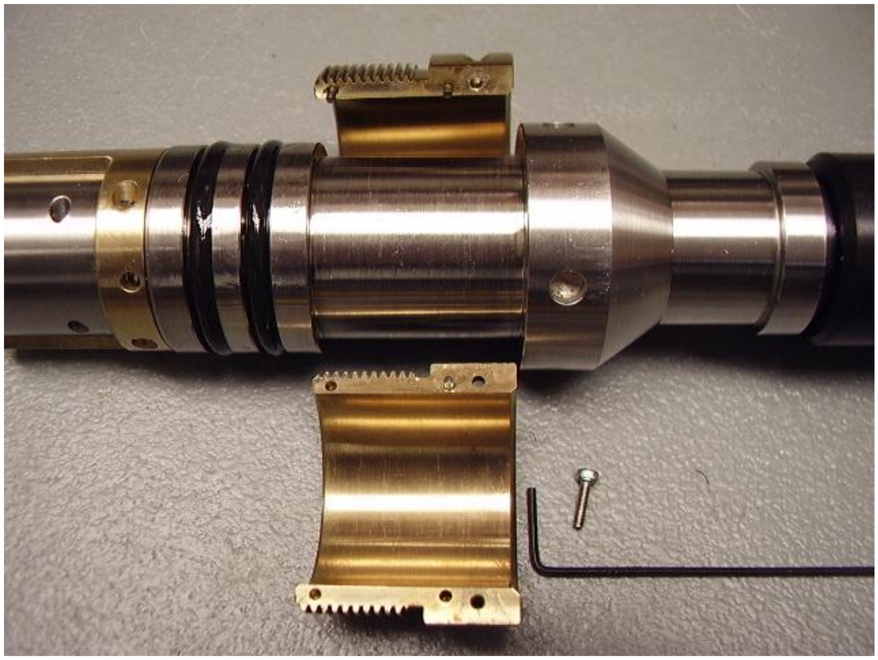


Figure 19

Clean inside surfaces thoroughly and reassemble, coating the inside with a very light film of anti-seize compound. Nickel based compounds are best, to prevent any sticking between the brass and steel surfaces

Troubleshooting

Problems with the Tool

The QL40ELOG and QL40IP probes require a proper current return to armor, and a proper isolation for approximately 7 meters above the probe for correct operation. The downhole tool current (I) must be a reasonable value to insure correct measurements are being made. This value will fluctuate from 10 mA in very high resistivity rock, to as much as 500 mA in very conductive rock. If such values are not obtained during logging, their may be a problem with the cable armor connections at the winch or logger.

NEVER DIS-ASSEMBLE THE PROBE WITHOUT CONSULTING THE FACTORY FIRST

Disassembly Instructions

The QL40-ELOG/IP Probe should **never be disassembled** unless service is necessary. This is a very difficult probe to disassemble, and is highly recommended that any service be performed by Mount Sopris, ALT or a qualified technician.

Suggested QA Procedure

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris family of Acquire programs records the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

HFP-2293
HEAT PULSE FLOW METER

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
October 10, 2002

Table of Contents

General Information

Overview

The Heat Pulse Flowmeter Model HFP-2293 is a tool designed to measure low flow rates in the borehole environment. In conjunction with a low flow rate reading the HFP-2293 will also give the direction of the flow of fluid, up or down in the borehole. Operating on a MGX or MGX II with single conductor wireline and supplied software, the tool is a very useful instrument in determining low flow rates.

As mentioned above the tool is supplied with PC based software, centralizers and a range of diverters for 4 inch through 8 inch holes. Diverters are devises that divert flow in the borehole through a column where the measurement is taken by the tool. The tool can also be run in a 2 inch undeviated hole without a diverter assembly to allow for a safety factor to determine the direction of flow in the borehole. Although running the tool in a 2 inch hole without a diverter will give you a flow rate, it is an uncalibrated reading and cannot be held to the specifications mentioned in this document. Any attempt to use this tool without a diverter or a diverter of improper size with respect to the borehole may result in erroneous data.

The HFP-2293 is also supplied with a trigger assembly. The trigger is a device that communicates to the probe through the cable line, to start a heat pulse measurement cycle. The trigger can be tied into the system via. the banana jacks on the MGX or MGX II.

This document describes the hardware of the HFP-2293 Heat Pulse Flowmeter, installation procedures, tool maintenance and logging procedures. There are separate documents for the operation of the different types of software depending on logger type and or firmware versions, and there will be references made in this document that will relate to the software document regarding certain logging procedures.

Controls, Connectors, and Layout

Controls for the HFP-2293 consist of a trigger assembly that allows the user a means to communicate to the tool to begin a heat pulse measurement cycle. This trigger assembly can be thought of as a simple switch, that when pressed, instructs the tool to fire the heat grid. This trigger assembly connects to the cable line at the surface. The connection can be made on the MGX at the banana jacks or through an area in the surface equipment where access to the cable lines can be made. The trigger assembly is shipped from the factory with banana plugs as a means of termination. For the connection described above, any connector may be used that is compatible with the surface equipment.

Connectors for the tool are as follows. The probe top described below is a Mount Sopris standard single conductor probe top. Other variations of probe tops and wiring can be accommodated at the factory but will not be discussed in this document.

PROBE TOP CONNECTOR:

Pin	Signal	Origin
Probe top housing	Tool power ground	Armor
Center pin in probe top	Tool power positive	Center conductor

Connectors on the tool that are exposed to the borehole environment are located on the bulkhead assemblies. These connectors allow a pressure sealed electrical connection to be made from the inside of the tool to the outside of the tool. These connectors are used for the sensors that measure the heat pulse, and the heater grid, which heats the borehole fluid. On the bulkheads, located under or covered by the filter screens, numbers are stamped by the corresponding connectors and labeled 1, 2 and 3. The connector labels must line up with one another from the top bulkhead to the bottom bulkhead.

Their connections are as follows.

TOP BULKHEAD:

Pin	Signal	Origin
1	Signal from sensors	Top thermistor
2	Connection to heat grid	High voltage capacitors
3	For future use	

BOTTOM BULKHEAD:

Pin	Signal	Origin
1	Signal from sensors	Bottom thermistor
2	GND for sensors and grid	Armor
3	N.C.	

Layout for the tool in general is as follows starting at the bottom of the tool. The lower section consists of the measurement column, diverter, heat grid and sensors. Above the lower section is the main housing of the probe where the electronic circuits reside. Above the housing is the probe top, which is the connection to the cable head tied to the winch assembly.

Theory of Operation

The Heat Pulse Flowmeter operation is as follows. The tool is lowered into the borehole via a cable attached to a winch. When the tool is in position to take a flow measurement the trigger assembly button is pressed. This sends a pulse down the center conductor which when detected by circuitry in the probe, fires the heat grid and signals the surface monitoring equipment and software to begin a flow measurement cycle. The grid heats a sheet of water that moves with the flow of the borehole to the upper or lower sensor. The difference in temperature between the sensors is detected by an amplifier. The output of this amplifier is then converted to a frequency. This frequency is then driven up the cable line and monitored by the surface equipment. When the tool is pulsed by the surface, the tool immediately begins to charge the capacitors that produce the voltage for the heat grid in preparation for the next measurement cycle. A complete flow measurement is made when the time has been accurately measured from when the heat grid was fired to when a peak temperature change, carried by the flow was detected by either the sensor located above or below the heat grid.

The P.C. based software supplied with the tool is very versatile in determining the flow of the borehole. There are two types of software available for use with the HFP-2293. Depending upon the type of data acquisition software used by the MGX II system, either Mslog or Logshell, the programs MSHeat for Windows is distributed or SBCFlow for Logshell users. The MSHeat program operates under the Windows environment. The software, SBCFLOW, is ACQSBC based and users of Mount Sopris MGX LOGSHELL software will be somewhat familiar with the look of the software once they are in the data acquisition portion. A document thoroughly describing the use of the software is also supplied with the tool. This document will again depend upon the type of data acquisition the MGX II system utilizes.

Specifications

The tool, in order to utilize the supplied software must operate with the Mount Sopris MGX hardware and software system. This system is comprised of an MGX logger or MGX II Console connected to a logging system and operating software.

Power Requirements

D.C. voltage at probe top.   MIN. 30 VDC   MAX. 68 VDC @ 200mA
Cable Armor GND Center conductor POWER

Tool Output

Pulse type, positive going, 1.25uS wide from 4.5 KHz to 37000 KHz.

Measuring Range

0.03 gpm to 1.0 gpm	0.113 lpm to 3.785 lpm
0.15 ft/min. to 13 ft/min.	0.046 m/min. to 3.962 m/min.

Resolution

5%

Accuracy

5% (Mid-Range) to 15% (Extremes)

Pressure Rating

2000 PSI or 13789 Pascal

Dimensions

Length	48 inches	122 cm
Diameter	1.63 inches	4.1 cm
Weight	12 lbs	5.5 kg

Installation

Installing the HFP-2293 and support equipment

Refer to documentation on the Data Acquisition software for proper installation onto PC.

Before operating the Heat Pulse Flowmeter, a few simple steps must be performed to ensure that the equipment will function properly.

Installing the Trigger assembly

The trigger assembly provided with the HFP-2293 is a small hand held device with a push button switch in the top, a cable, about 6 ft. in length, and color-coded banana plugs on the end of this cable. The color-coded plugs or wires from these plugs must be tied into the cable lines at the surface. The MGX logging systems have these color coded banana jacks ensuring an easy installation of the trigger assembly. Remember to disconnect the trigger assembly from the logger after the use of the HFP-2293 or during the use of other types of probes. The black plug or wire connects to the banana jack labeled **ARMOR**. The red plug or wire connects to the banana jack labeled **CONDUCTOR**.

CONNECTIONS FOR TRIGGER ON MGX

BANNANA JACKS
ON MGX-200 and 305 units

GREEN
SURFACE ELECTRODE
BLACK
ARMOR
RED
CONDUCTOR

BANNANA JACKS
ON MGX-200 and 305 units

CONDUCTOR
SURFACE ELECTRODE
ARMOR

BANNANA JACKS
ON MGX II Consoles

CONDUCTOR
SURFACE ELECTRODE
ARMOR

Operating Procedure

Operation

Operation of the heat-pulse Flowmeter will begin by determining the size of the borehole to be logged. This is important in that the proper diverter size can be assembled on the probe to give the maximum sealing while in the borehole. Several different diverter sizes are supplied with the HFP-2293, for different sizes of hole diameters. The smallest set of diverter petals is 5 inches that are used in 3 to 4 inch borehole. The next set of diverter pedals are 7 inches and are used in 5 to 6 inch boreholes. The largest set is 9 inches and is used in 7 to 8 inch boreholes.

To install a set of diverters first remove the rings that capture the bottom centralizer using an Allen wrench set. Then remove the bottom screen by loosening the setscrews and sliding the screen off. Choose the desired size of diverter petals to be used. Next slide the stack of diverter petals over the bottom of the probe all the way to the top screen, and then reinstall the bottom screen, centralizer and centralizer rings. Tighten all setscrews. Next install the top centralizer by loosening the setscrews on the centralizer ring and slide it off the probe. If the hole is 6 inches or larger use the larger centralizer; if the hole is 5 inches down to 3 inches use the smaller top centralizer. Slide the centralizer over the top of the probe, reinstall the centralizer ring and tighten setscrews in the ring.

Install the trigger assembly into the logger, connect the probe to the cable line and prepare to log the hole. **For MGX users:** Turn the MGX PROBE SELECT switch to the Pulse 2 position; turn the PROBE POWER switch to the ON position. Bring up SBCFLOW on the P.C., and verify that the tool is sending pulses to the surface on counter CS32. If any other sequence is used besides the one previously discussed SBCFLOW will assume that it has received a fire pulse and system will be out of synchronization. **For MGX II users:** Choose the proper tool file for the M2FLOW program for Logshell or run the MSHeat program for Windows and verify that the calibrations are correct for the probe. Power the probe with the proper menu item or Windows button. The probe will take approximately 30 seconds to charge the high voltage capacitors and approximately a minute to stabilize internal circuitry. Lower the probe down the hole to the desired depth that a flow measurement will be taken. A caliper log run prior to the HFP-2293 may help indicate areas that contain washouts or fractures that will affect the sealing of the diverters. Refer to the operations manual for SBCFLOW, M2FLOW or MSHeat for more in-depth information and instructions. Make sure the software is ARMED and that the data on the screen is in a stable state. Now press the trigger button and observe the PC screen for the heat pulse peak as it passes by a sensor. For SBCFLOW and M2FLOW the waveform will go to the left of center for down flow and to the right of center for up flow. For MSHeat the data trace runs horizontal on the screen so an Up flow is indicated by the waveform moving upward form center and a Down flow moves downward from center. If no pulse is present check to see that there is an adequate pick window. If the pick window is long enough and no flow is present, move to another location and repeat the above steps.

When flow direction has been detected it has been determined through factory flow chambers and calibrations that an increase in the sealing capabilities of the diverters is achieved by positioning the diverter petals to bend into the flow. If the flow is down the borehole, then the correct positioning of the pedals would be up and this would be achieved by moving the probe down the hole. If the flow is up the borehole, the correct positioning of the petals would be down and this would be achieved by bringing the tool up the hole. It may be necessary to move the tool suddenly up or down to get the petals to reverse their direction to properly position them.

Recording of data and output plots are discussed in the all the HFP-2293 data acquisition documentation. One note that should be remembered is that the tool takes approximately 30 seconds to recharge after it has been pulsed. All acquisition software's indicate this charge time by flashing TEMPORARILY DISARMED or DISARMED at the top of the screen until the probe has had sufficient time to recharge the high voltage capacitors. This may not be as noticeable at slower flows as this amount of time is usually taken to determine and record the flow, but will be noticeable at faster flows. You may need to wait a few seconds for the probe to fully recharge.

Performance Checks and Calibrations

Calibrations are performed at the factory and require an elaborate setup. In the event the user feels the tool needs to be calibrated it is advisable to speak with a representative of Mount Sopris. Performance checks can be made in and out of the borehole. When the tool is in fluid, it is good practice to verify a frequency coming from the probe and that the firing or pulse circuit is functioning correctly before continuing down the borehole. The sensors can also be checked for operation near the surface by firing the heat grid while the tool is in fluid and moving the tool up the hole simulating down flow. Repeat the firing sequence, but move the tool down the hole simulating up flow. Note that to move the tool up or down for this test, do not use the winch. Move the tool by hand to simulate flow in the borehole.

Preventative Maintenance

The HFP-2293 requires little maintenance other than washing the probe off after each use. Keeping the screens and the heat grid free from debris will insure smooth operation in the field. If a high-pressure washer is used to clean the tool take care not to spray directly at or on the heat grid, as this is a delicate area. If the tool is to be stored in a horizontal position it is advisable to remove the centralizers and diverter petals so as not to deform them.

Troubleshooting

Problems with the Tool

In the event the tool develops a problem, follow the troubleshooting procedure listed below.

No pulses from the probe.
1. Are the MGX switches set correctly? **PULSE 2** and **ON** positions
2. Are the PROBE CURRENT and PROBE POWER LED's on?
3. Check the cable for conductive leakage across the center conductor to ARMOR.
4. If an oscilloscope is available verify if the probe is sending pulses, if not consult Mount Sopris.
5. If using M2FLOW or MSHeat, did you power the probe up with the software?

The probe will not fire for a measurement cycle.
1. Check that the trigger assembly is connected properly.
2. If step 1 is OK, connect a voltmeter on the banana plugs while they are still plugged into the MGX and the MGX is still on as if it were powering the probe. With the probe powered on, press the trigger button and observe that the voltage on the meter: approx. 60 volts, decreases to about 10 volts or less momentarily. Not all meters will react the same to this short period, but you should see a change on any meter regardless of its reading. This is a reasonable indication the trigger assembly is operating correctly.

3. If step 2 is OK consult Mount Sopris.

The probe appears to fire or be pulsed but no flow is detected.
1. This problem may indicate a failure in the high voltage section or it may indicate that the electronics is functioning correctly, but the heat grid may be broken or open. It is important to note that a no flow detected may also occur if the tool is in a no flow zone, or if the flow is to fast. So verification of this problem is more complete if the tool is in a zone with known flow. If a zone with flow is not known or available the tool can be fired and then moved by hand either up or down to
simulate flow and see that the sensor or sensors are working. If the problem cannot be determined consult Mount Sopris.

Disassembly Instructions

The HFP-2293 probe should never be disassembled unless service is necessary. In the event service is necessary it should be performed by Mount Sopris or a qualified technician.

Schematics

HFP-2293

Available upon request

Drawing Number	50002015A.S01 - S02	Title: Firing Cir. Signal Amp, V/F and H.V. Reg. Trig., Pulse driver and Power supplies
Drawing Number	50002029A.S01	Title: Trigger HFP-2293

Appendix

Suggested QA Procedure

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris acquisition software provides records of the calibration constants. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

MatrixHeat v.3.3

Operator Manual

Advanced Logic Technology s.à,

Mount Sopris Instrument Co., Inc.

License Information

March 21, 2013

Table of Contents

1. System Overview

I. Introduction

MatrixHeat software was developed to allow operation of the Mount Sopris heat-pulse flowmeter probe using the MATRIX Logger. Please refer to the Logger Software Operator Manual for details on the Matrix logger and its associated software.

The software takes advantage of the Microsoft Windows ™ family of operating systems. These multi-tasking software platforms can accommodate all the tasks necessary for maximum data security and ease of operation.

New features have been added to the MatrixHeat logging software:

- New binary data format with .MH file extension
- Probe firing via on-screen button; replaces thumb controlled hardware button
- Ability to scroll through data samples and re-pick heat pulse events
- Simplified user controls for calibrations and picking parameters
- On screen tabulation of each tool firing, with interactive viewing capability
- Export pick times and flow values
- Export traces
- Time stamped data
- No maximum time limit in the acquisition window

II. Required Components

To operate the heat-pulse flowmeter with the Matrix logger, the following items are required:

- Mount Sopris HFP-2293 or 4293 heat pulse flowmeter probe
- Calibration data for the heat pulse flowmeter probe
- Current **.tol** for the heat-pulse probe
- Matrix Logger with firmware numbers equal to or greater than:
    - System controller 112
    - Modem controller 115
    - PSU controller 100
- LoggerSuite operating software installed to provide USB drivers

III. Installation

Run the MatrixHeat setup program provided.

The default location for the installation is C:\MatrixHeat, you can accept this location or change it but make note of any changed location.

A desktop icon and Start Menu folder are created for MatrixHeat.

2. Software Architecture

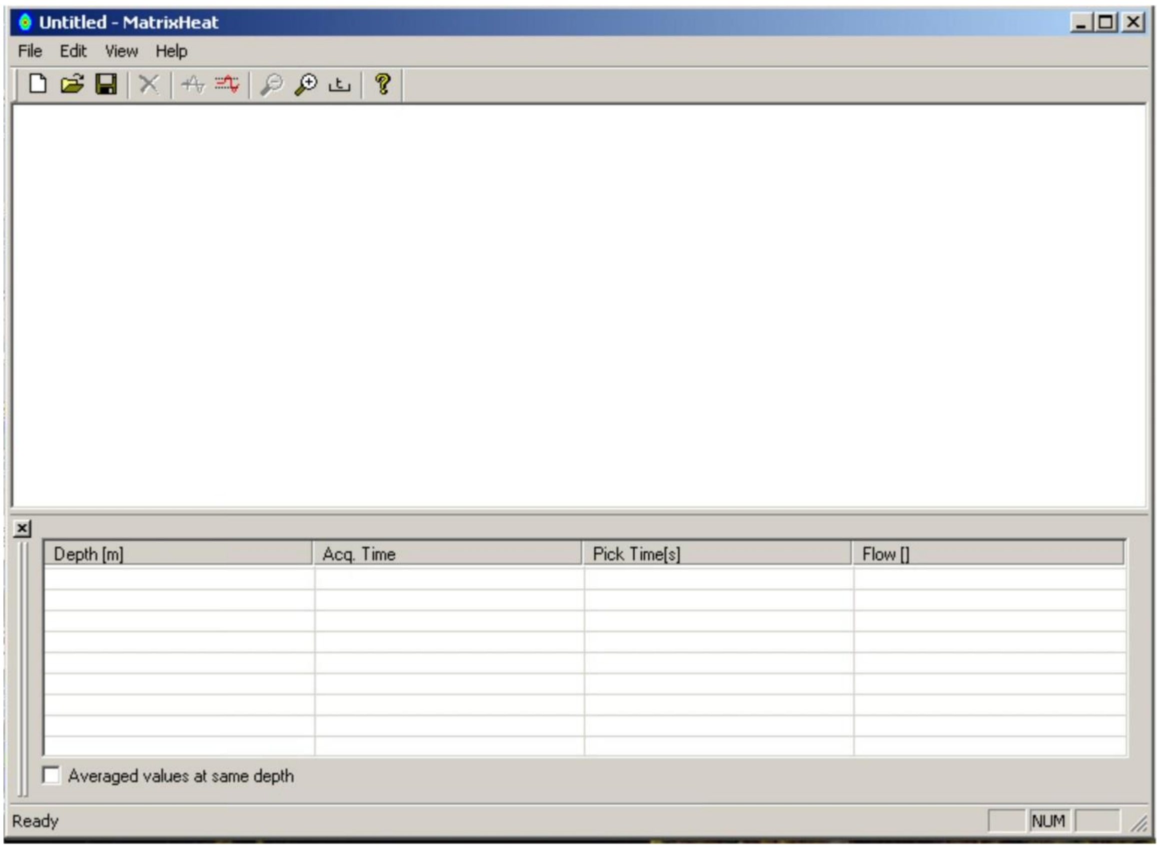
I. Introduction

The MatrixHeat software is a stand-alone product. It is required when operating the Mount Sopris Heat Pulse flowmeter on the Matrix logger.

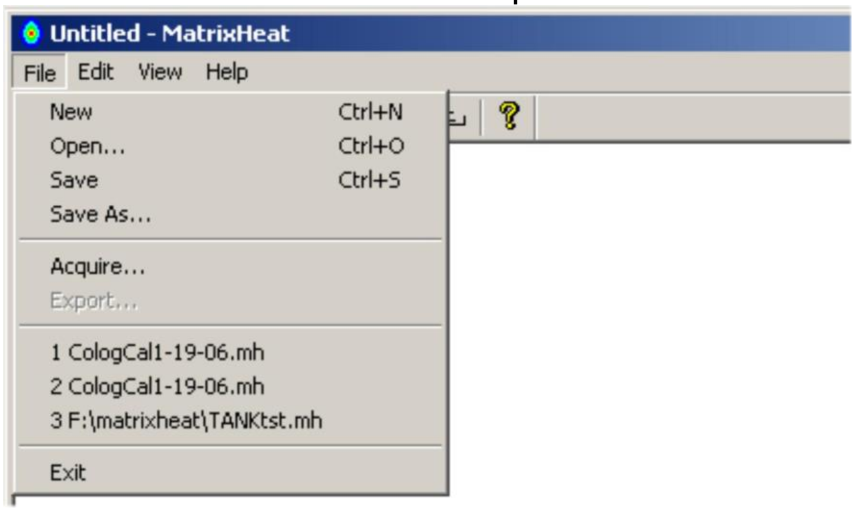
MatrixHeat version 3.2.67 or later is required for operation on Windows 7 and Windows 8.

The Matrix Operating Software, Logger, is not used for this purpose. Clicking on the MatrixHeat shortcut  or executable file in the MatrixHeat directory starts the software.

The program opens a screen like the one below:

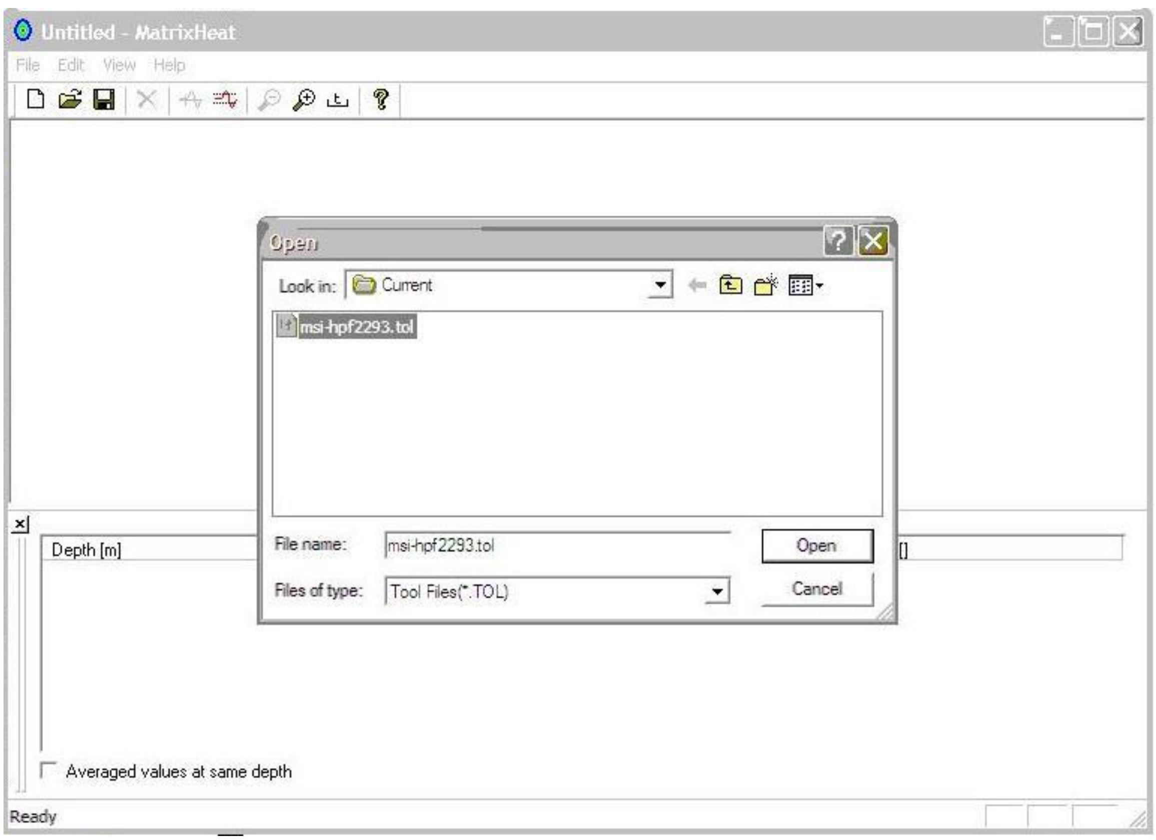


To begin, click on File on the top menu bar:



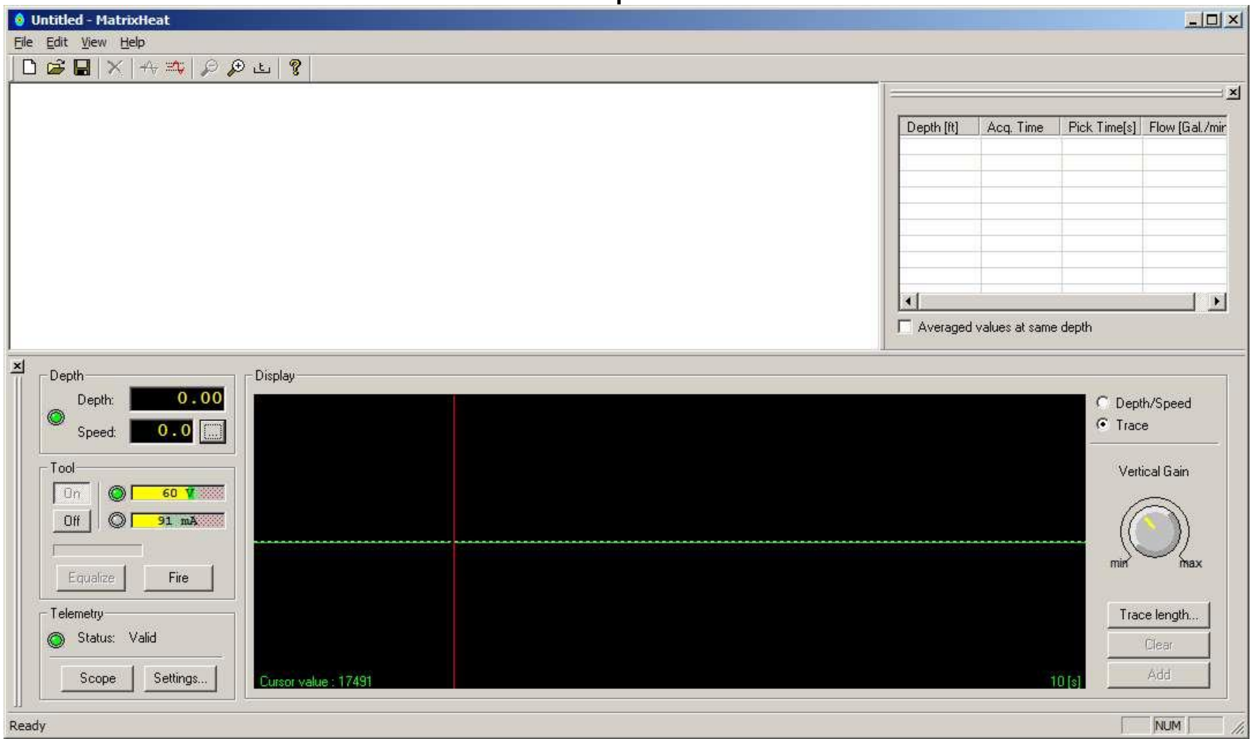
To connect with the Matrix logger, select **Acquire**.

You will be asked to provide a tol file; you should see the HFP2293_mtx.tol TOL file listed. If not you will need to navigate to /MatrixHeat/Tol/Current. This tol file is specific to MatrixHeat software, and should only be installed in the /MatrixHeat/Tol/Current directory. Do not install any other non Heat Pulse tol files in this directory. It is possible to have more than one Heat Pulse tol file in the directory, if you have more than one probe, with more than one calibration. If the Matrix logger is detected by the USB routine on the PC, the tol file will be loaded, and the current depth value in the Matrix logger will be loaded.



NOTE: If the logger has been used with a different winch model, it may be necessary to exit the program and verify (with LoggerSettings.exe) that the proper depth encoder settings are programmed into the logger. Refer to the Logger Operating software manual for more details.

After the tol file has been selected, a screen like the one below will appear:



II. Powering the Probe

Once all winch settings have been confirmed, the probe may be powered up using the Tool On/Off button on the left side of the screen. The correct power settings are read from the Tol file, and are automatically adjusted depending on the wireline type and length. In general, the probe operates on 60 VDC and 180 mA of current. Operating current is lower than charging current. Charging current is applied when the probe is first powered up, or immediately after the probe is fired. New in version 3 are current and Voltage displays. New in version 3.3.22.8 is an option to change the Display to Depth/Speed mode which is useful when operating the winch.

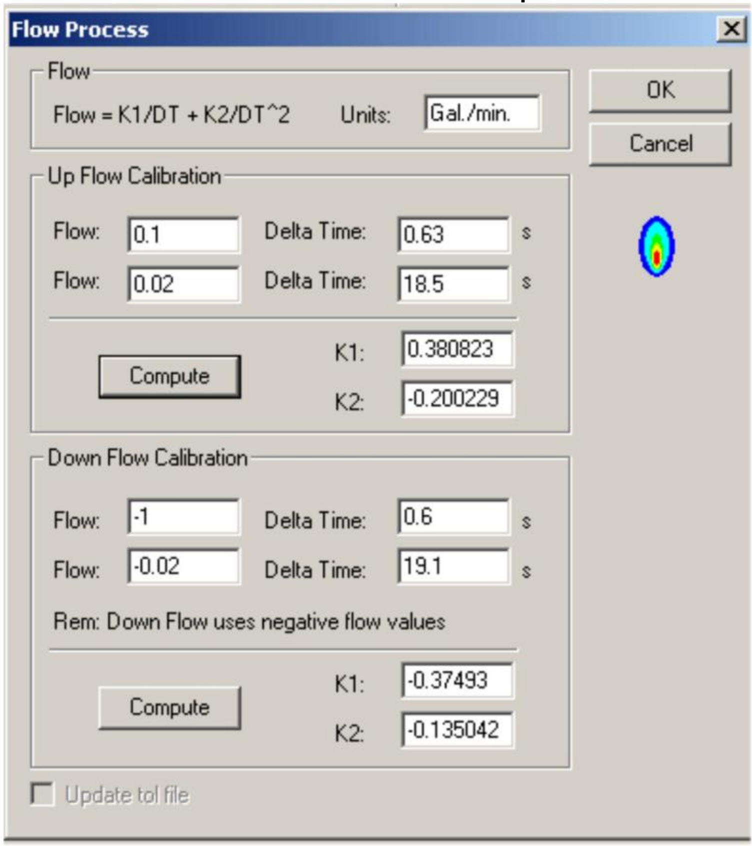
a) Checking calibrations

After the probe is powered up, it will take several minutes for the probe measuring array to stabilize and for the firing capacitors to charge up. This is a good time to confirm that the proper calibrations for the probe have been entered in the Tol file and saved.

ai Note: Calibration Settings

<u>For the Flow Calibration button to be active the probe must be fired at least one time and the data added</u> (click the **Add** button in the lower right side of the Acquisition screen). To access the calibrations screen, select Edit on the top task bar, and then select Flow Calibration as seen below:

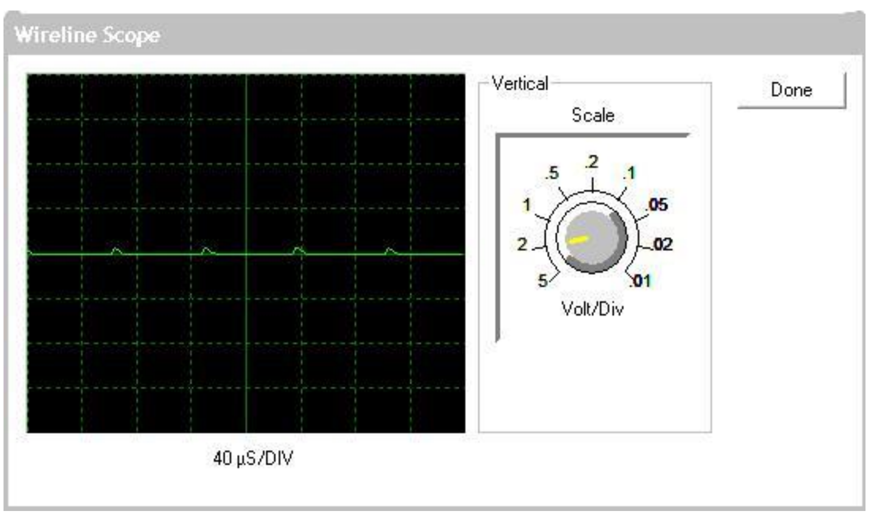
Check the calibration values for the probe being used against the values on the calibration screen. An example follows:



Please note that **Down Flow** values are considered to be ***Negative*** numbers.

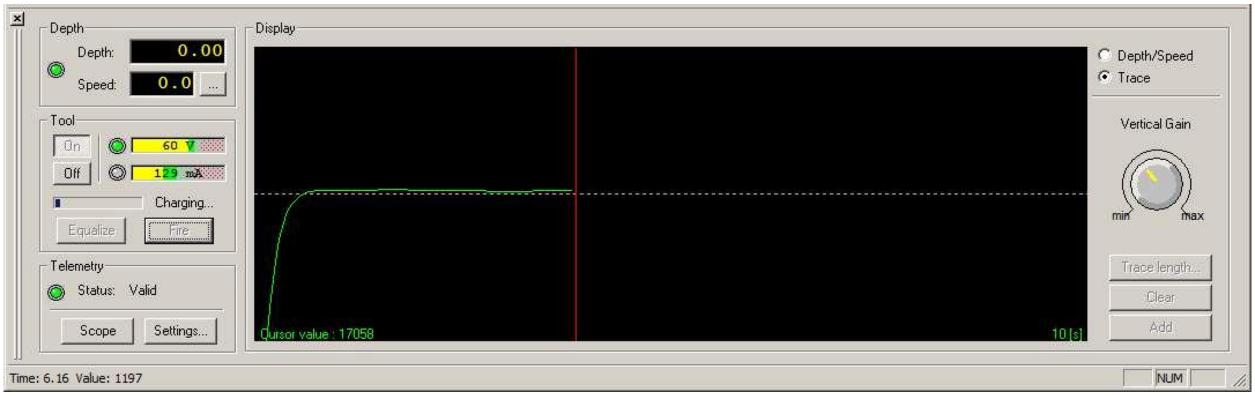
b) Checking proper probe operation

After entering the calibration numbers, it is recommended that the user check the probe data to confirm that it is operating properly, and is ready to begin a logging operation. The best way to see if the probe is sending data is by clicking on the Scope button. A screen like the one below will appear:



Probe data consists of a ~20 kHz positive pulse stream on the wireline, which will vary with the response of the sensor pairs to presence of a heat pulse moving past. If you don't see this kind of data on the wireline scope screen, the probe is not sending data.

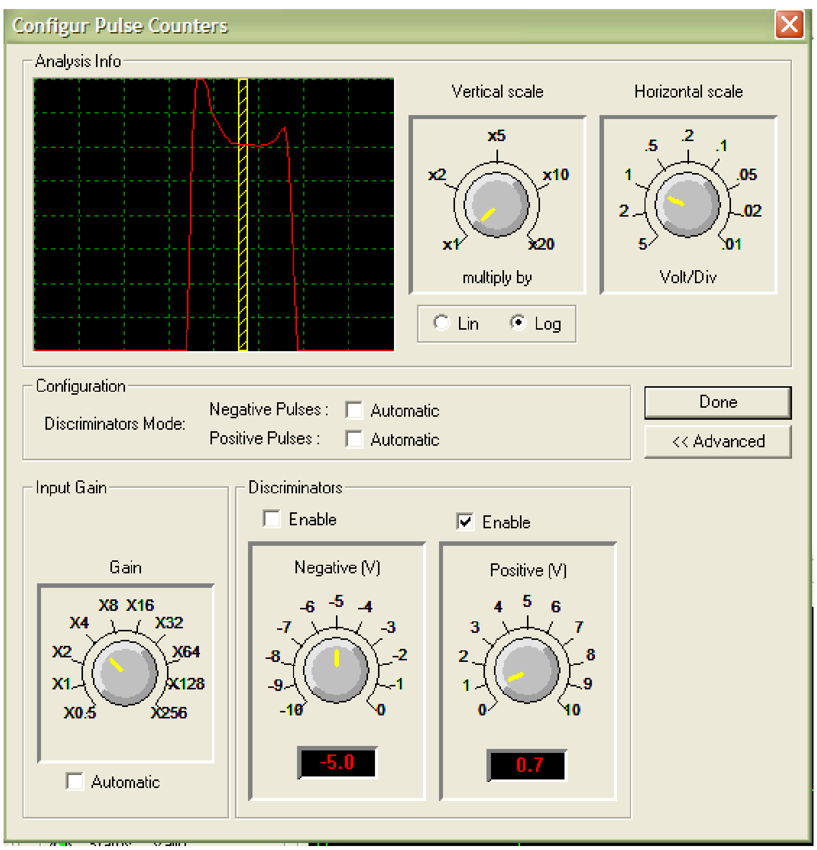
After confirming that the probe is sending data, the user should check the main data display screen to verify that the pulse detection modem is in fact detecting the ~20 kHz signals. The following screen shows a properly functioning probe and modem, with a baseline frequency of around ~19 kHz. If a zero value is indicated on the lower portion of this screen, the modem needs to be adjusted. This might be the case for a long wireline.



c) Adjusting the modem

If a normal (18-20 kHz) value is not indicated on the heat-pulse real time acquisition screen (shown above), modem adjustment may be required. To access the modem controls, click on the Settings... button, and then on "Advanced" to show the modem settings:

The advanced modem settings are embedded in the tol file, depending on the wireline type and



length. In general, the gain of the modem should be left in **manual** mode, and the positive discriminator should also be left in **manual** mode, such that it is centered in the middle of the modem display screen. The screen pictured above shows proper position and settings for the heat-pulse flowmeter operating on a 500 meter winch with 1/8" single conductor cable.

Moving the discriminator slightly closer to the center peak and away from the center of the signal valley may reduce spikey noise on the data trace particularly on coax wireline.

d) Zeroing the depth

Using the winch controls, lower the probe to the zero point. The probe zero point is the junction between the probe top and the cable head. Once the probe is placed at this point, referenced to the zero depth location, click on the "**…**" button on the depth window and a dialog box like the one below will appear:

Depth and Speed can be shown in the Display panel by selecting the **Depth/Speed** menu item located on the right side of the Display panel (v3.3.22.8 and later only). Select the **Trace** menu item to return to data display mode. Units for depth and speed will be those set in the Matrix Logger using LoggerSettings.

Select Zero Tool, and the depth should automatically be set to 0.97 meters (or 3.18 feet), which is the mid-point of the sensor array. Keep in mind that the probe is actually 1.22 meters (4 feet) long.

Once the probe has been zeroed, it can be lowered to the first firing depth. In general, the first depth depends on user preference. It is sometimes preferred to begin measurements at the top of the borehole, so as not to disturb the fluid flow patterns in the lower sections. Movement of the probe (and the close fitting flow diverters) can temporarily influence the borehole flow regime.

To avoid interference from eddy currents that might be induced by lowering or raising the probe, the operator should wait a few minutes at each shot depth before firing the probe. This will provide the most accurate data, and avoid erroneous readings.

Note that the Depth/Speed colors are controlled within the Matrix.ini file located in the C:/MatrixHeat folder. The default color is red characters on black background.

III. Firing the probe

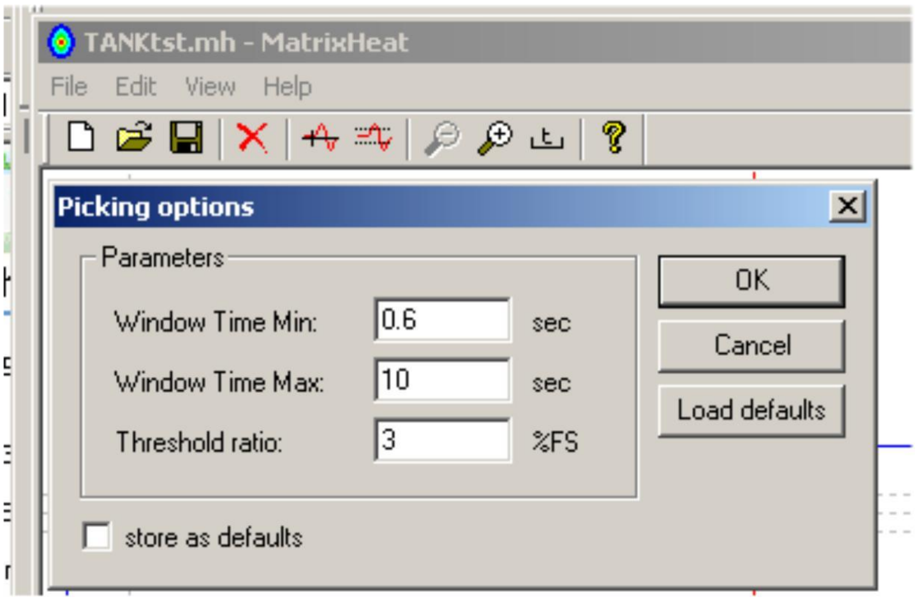
a) Picking Options

Before firing the probe, the operator should set the picking options to match the estimated heat pulse arrival time. In a new well, with no information, it is best to set the parameters so that a long time interval is available. Two Time Sample settings are required. One is in the Flow Pick window, and the other is in the Shot Window display. The Time Sampling for the Shot Window controls the actual length of the record. The Time Setting in the Flow Pick Window only controls the display of the saved flow trace. As the logging proceeds, the operator can "fine tune" these parameters to make the best use of time available. For faster flow rates, the time window can be decreased to save time. However, even for faster flows, the probe must recharge between shots, and this time is fixed.

To set picking options, click on the Pick Options icon on the top selection bar. The various selections on this are shown below:

Picking options can also be accessed by clicking on Edit, Picking Options.

The picking options window is shown below:

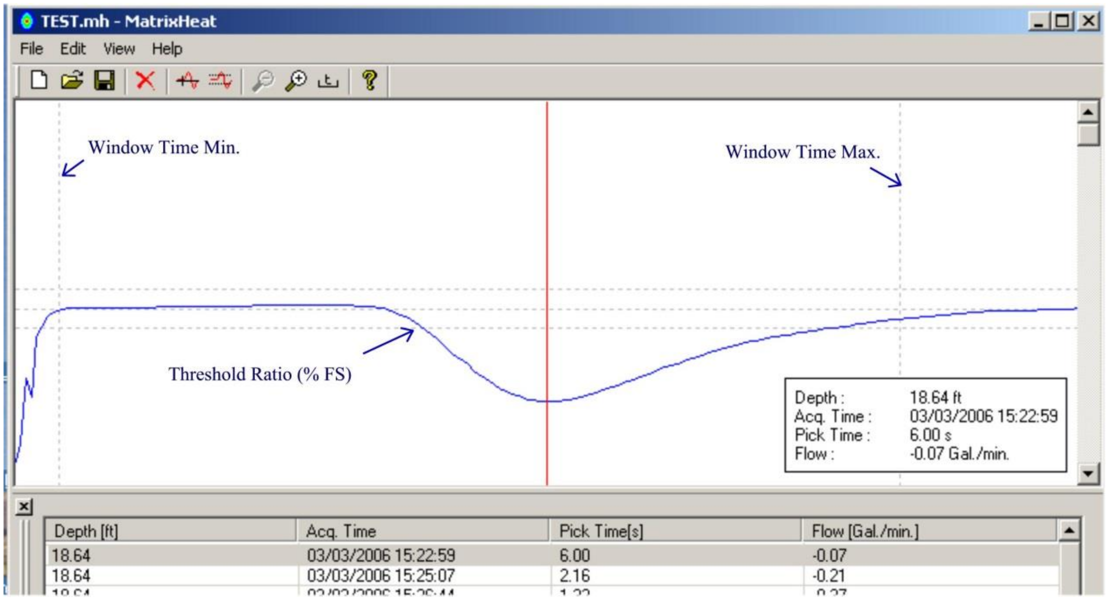


The **Window Time Min** value should be kept low, in general. It is the minimum time after which a pick will be allowed. Normally, there is no measurable flow before 0.6 seconds, as the flow is so fast that the sensors cannot see the heat pulse.

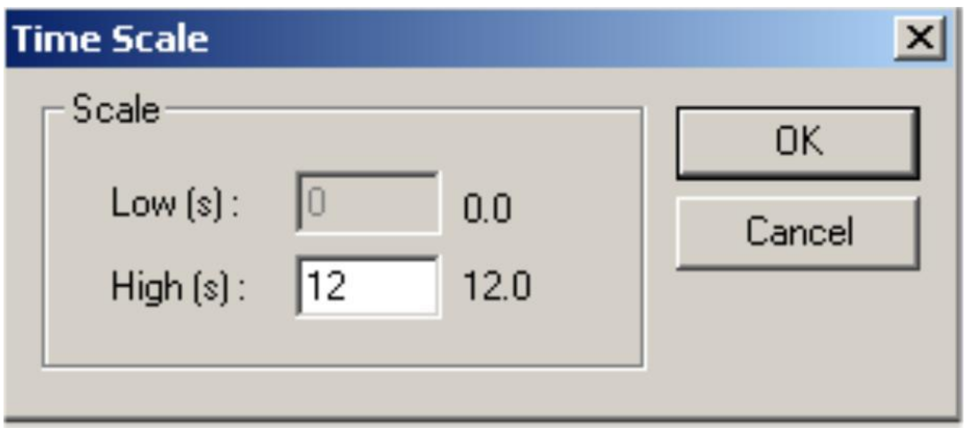
The **Window Time Max** value is the maximum time in which a pick can be allowed. Once this value is reached, the program will stop recording, and automatically make a pick on the maximum or minimum peak produced by the heater grid within these times.

The **Threshold ratio** is the “detection level” above which the software is allowed to make a pick. For low heat pulse peaks, the level may need to be decreased, and for very high peaks, the level can be raised.

These three parameters are represented on the plot record by dashed lines. The Time windows are vertical, and the Threshold ratio is indicated by a pair of dashed horizontal lines equidistant from the zero baseline. An example is shown below:



The **Time Scale** parameter is set by clicking on the time scale icon on the menu bar. It brings up a window like the one below:

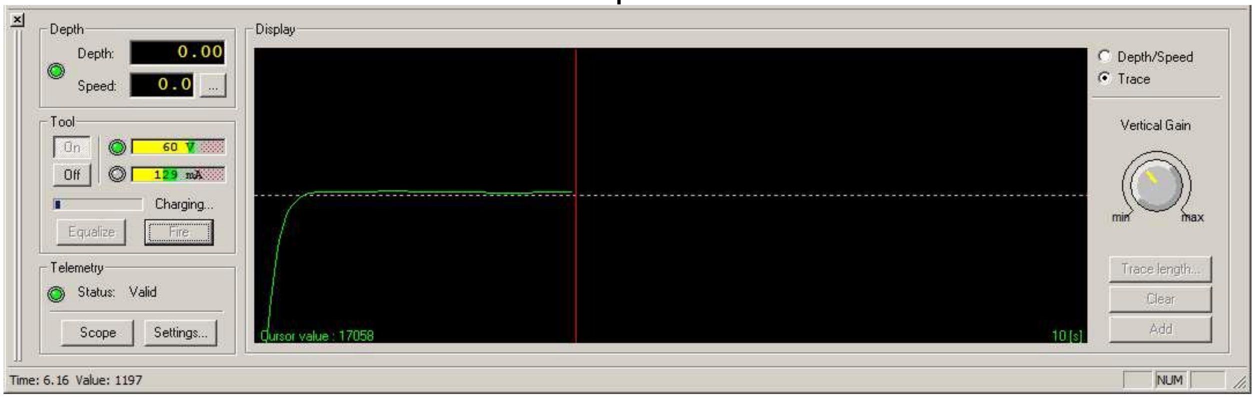


This time scale is the maximum time scale that will be displayed on the Flow Picking screen. This Time Scale is not the same time scale that is presented on the Shot Window, which is described in the following section

A third icon on the main menu is the **AutoPick** selection. It is used to re-pick a heat pulse event in the data records, if the operator does not believe that the first pick was correct. It is used after picking parameters are adjusted, and when pressed, will automatically select a new pick, based on the new parameters.

b) Firing

Once all parameters are set, the probe can be fired. The fire button should only be pressed if a smooth baseline, with a frequency of around 20 kHz, +/- 2 kHz, is present in the shot window. If the baseline is wavy or changing with time, this is usually caused by probe induced flows. The operator should wait until this background “noise” is gone before firing. An example of a smooth baseline is shown on the next page:



Note that the **Time Scale** on the Shot Window is set by clicking **Trace length..** button:

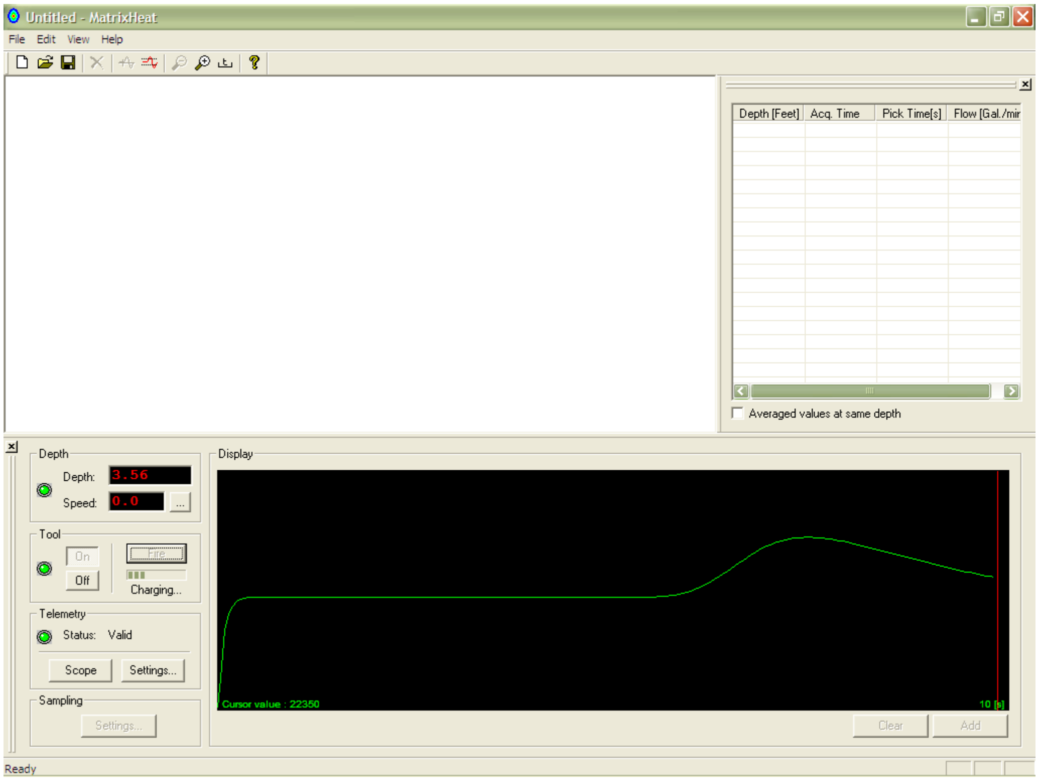
The length of the time scale on the Shot Window must be long enough to capture the heat pulse. If it is not, the operator should increase the time to make sure the pulse is detected, if one exists. Normally, there is no usable data past a time of 25 seconds. When the end of the time scale is reached, the system stops, and the probe begins its recharge cycle.

If the trace goes off the top or bottom edge as it draws across the screen turn the Vertical gain dial counter clockwise towards **min** to shrink the trace size. To increase the trace size, turn the dial clockwise towards **max**.

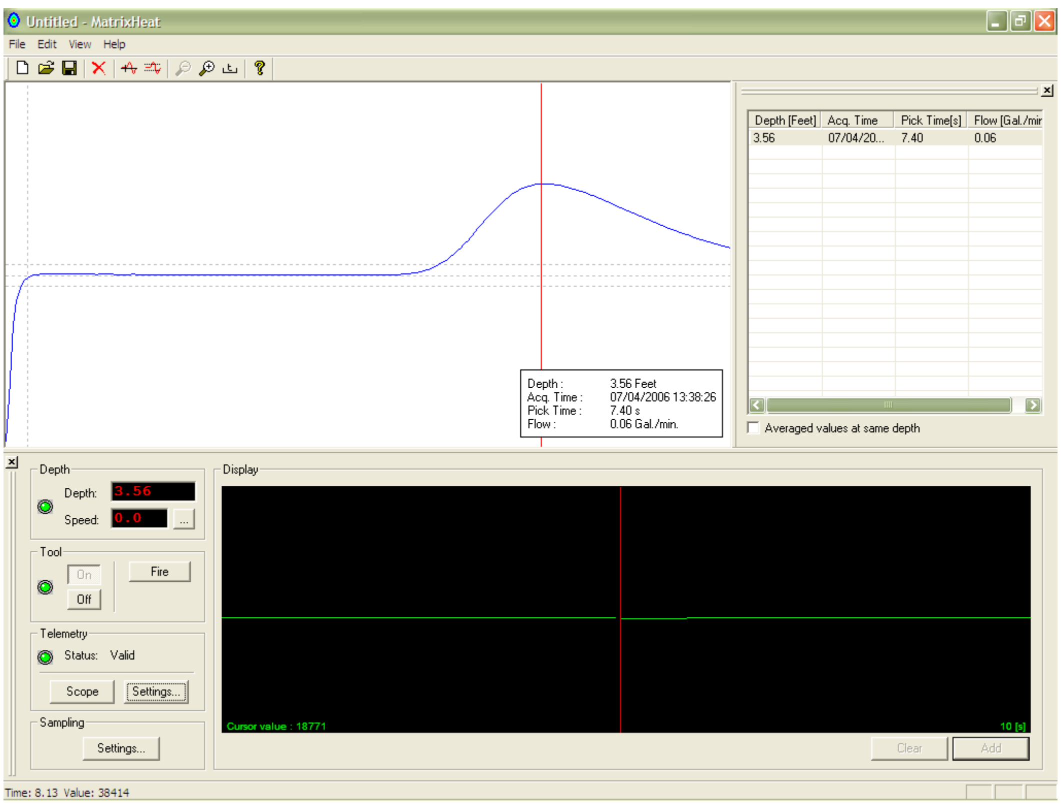
Once the probe fire button is pushed, a real time plot of frequency vs. elapsed time will appear in the shot window. This green line indicates the differential temperature being sensed between the two thermistors, which are located equidistant from the heater grid in the center of the probe. The direction of the flow is based on the net frequency response. If the frequency goes down, the flow is down. This is shown graphically on the shot window until the elapsed time passes the Time Scale setting chosen for the shot. After the firing event, the probe begins an automatic "charging cycle", in preparation for the next shot.

If the shot record appears to indicate a successful flow event, the operator should press the **Add** button at the lower right hand corner of the shot window. If the record is questionable, it can be deleted from the display with the **Clear** button.

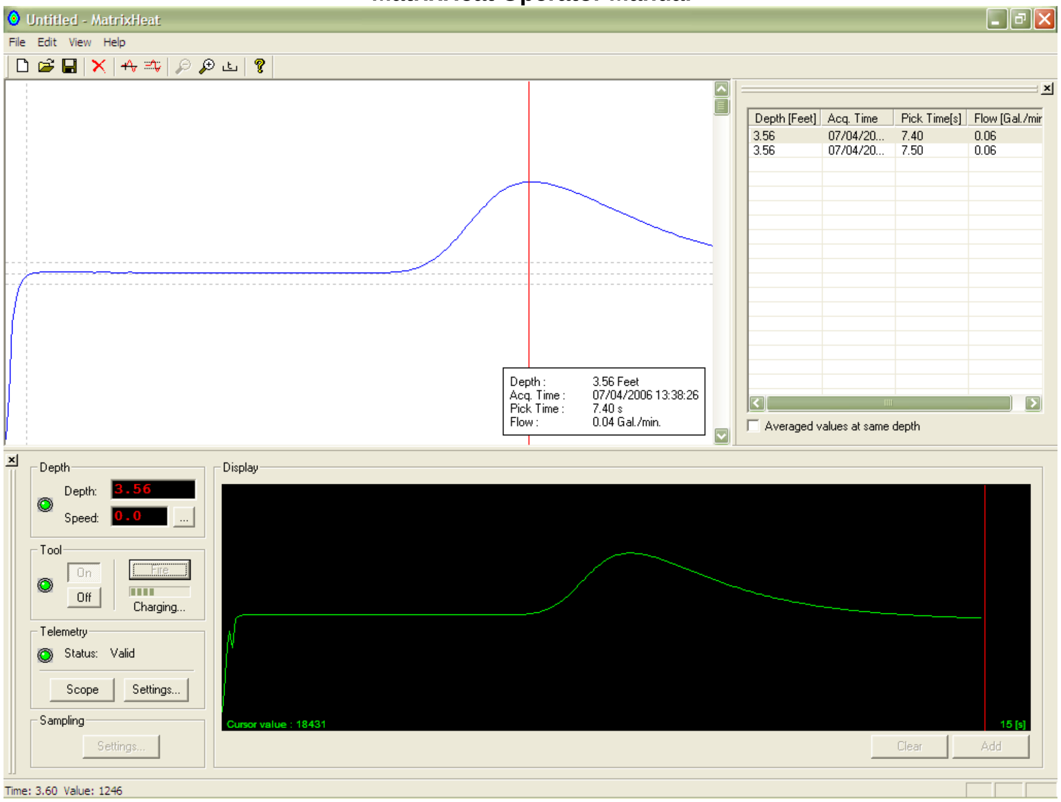
An example of a real time shot record is shown on the following page.



This sample record appears to be valid, so it is added to the Pick Window register by clicking the Add button. The record is then moved into the Pick register table, which shows the pick information and calculated flow rate for the current shot.



To fire the probe again, the user must wait until the probe capacitors are fully charged. This process is indicated in the window with the bar graph meter, right under the Fire button. It is a good idea to make at least two firings per station, to confirm the accuracy of the measurement. A second firing, in the same interval is shown below:



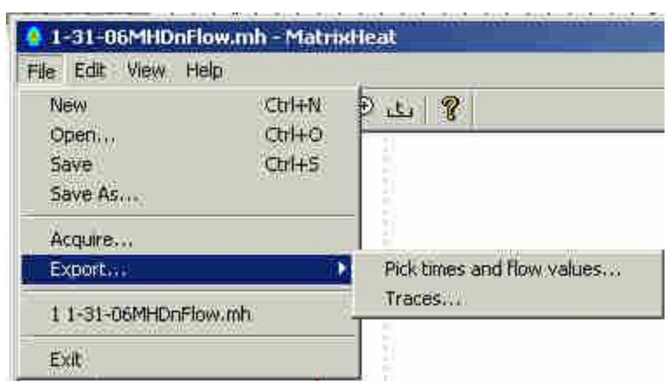
c) Re-picking

In the event that the automatic peak picking did not actually pick on the correct pulse, it is possible to adjust the Min and Max time windows to “bracket” the correct pulse, and/or change the Threshold ratio and then press the autopick button again. It will re-pick a new time within the new parameters. In general, this should only be necessary when a large change in flow magnitude occurs.

Re-picking can be done at any time, simply by highlighting the shot on the list of data in the Pick Flow table. It is even possible to “re-process” picks later, using the program without the logger connected. Simply start the program, open the data file, and proceed as above.

IV. Exporting Data

After a data file has been created, it should be saved as an ***.mh** file, by clicking on the main task bar File selection, and then on Save or Save As. This saves the data in a binary file that can then be displayed or re-processed using MatrixHeat.



To obtain a text version of the data results, for use in other programs such as WellCAD, or Excel, select File, Export…Pick times and flow values, as shown in the image below:

Example of exported ***.txt** flle

testexp.txt - Notepad

File Edit Format Help

```
Depth,Acq. Time,Pick Time,Flow
ft,,s,Gal./min.
18.6418,03/03/2006 15:46:33,0.909091,0.727696
18.6418,03/03/2006 15:47:35,1,0.630327
18.6418,03/03/2006 15:48:36,0.8,0.885455
18.6418,03/03/2006 15:49:44,1,0.630327
18.6418,03/03/2006 15:50:37,1,0.630327
18.6418,03/03/2006 15:51:37,1.05,0.586155
18.6418,03/03/2006 15:53:05,0.95,0.680796
18.6418,03/03/2006 15:56:14,1,0.630327
```

Figure 1 Export Pick times and flow values .txt file

TracesExport.txt - Notepad

File Edit Format View Help

```
Depth,Acq.
Time,0,0.06,0.12,0.18,0.24,0.3,0.36,0.42,0.48,0.54,0.6,0.66,0.72,0.78,0.84,0.9,0.96,1.02,1.08
,1.14,1.2,1.26,1.32,1.38,1.44,1.5,1.56,1.62,1.68,1.74,1.8,1.86,1.92,1.98,2.04,2.1,2.16,2.22,2
.28,2.34,2.4,2.46,2.52,2.58,2.64,2.7,2.76,2.82,2.88,2.94,3,3.06,3.12,3.18,3.24,3.3,3.36,3.42,
3.48,3.54,3.6,3.66,3.72,3.78,3.84,3.9,3.96,4.02,4.08,4.14,4.2,4.26,4.32,4.38,4.44,4.5,4.56,4.
62,4.68,4.74,4.8,4.86,4.92,4.98,5.04,5.1,5.16,5.22,5.28,5.34,5.4,5.46,5.52,5.58,5.64,5.7,5.76
,5.82,5.88,5.94,6,6.06,6.12,6.18,6.24,6.3,6.36,6.42,6.48,6.54,6.6,6.66,6.72,6.78,6.84,6.9,6.9
6,7.02,7.08,7.14,7.2,7.26,7.32,7.38,7.44,7.5,7.56,7.62,7.68,7.74,7.8,7.86,7.92,7.98,8.04,8.1,
8.16,8.22,8.28,8.34,8.4,8.46,8.52,8.58,8.64,8.7,8.76,8.82,8.88,8.94,9,9.06,9.12,9.18,9.24,9.3
,9.36,9.42,9.48,9.54,9.6,9.66,9.72,9.78,9.84,9.9,9.96,10.02,10.08,10.14,10.2,10.26,10.32,10.3
8,10.44,10.5,10.56,10.62,10.68,10.74,10.8,10.86,10.92,10.98,11.04,11.1,11.16,11.22,11.28,11.3
4,11.4,11.46,11.52,11.58,11.64,11.7,11.76,11.82,11.88,11.94,12
ft,
0,31/01/2006
12:53:10,500.042,5211.92,9139.89,15759,19457.4,21747.1,22485.2,22441.2,22250.6,22011.4,21689.
6,21509.5,21443.9,21405,21380.4,21346.5,21340.5,21334.9,21332.8,21331.7,21320.8,21330.1,21329
.6,21329.6,21328.5,21316.8,21324.8,21322.9,21322.4,21320.9,21308.2,21314.4,21311,21308.2,2130
4.7,21289,21292.2,21286.8,21282.8,21278.6,21260.9,21263.3,21257.1,21251.5,21246.2,21227.7,212
29.4,21224.2,21218.7,21212.1,21191.3,21191.9,21185.3,21179.2,21174,21154.9,21157.6,21152.9,21
147.1,21140.7,21122.2,21122.8,21117.2,21111.2,21104.3,21085.2,21085.9,21079.5,21073.2,21065.2
,21045.2,21045.8,21039,21033.1,21027.3,21007.2,21006.7,21000.9,20995.7,20989.2,20968.8,20968.
7,20963,20957.6,20951.9,20933.3,20936,20931.3,20925.5,20918.4,20898.3,20896.9,20889.1,20880.6
,20872.7,20850.8,20849.3,20841.2,20834.2,20826.6,20804.5,20803.2,20795.8,20788.6,20782.1,2076
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0660.4,20656.1,20650.3,20631.8,20633.1,20628.3,20623.8,20620.3,20603,20605.4,20600.7,20596.6,
20593,20577.1,20580.2,20575.1,20570.4,20562.2,20550.2,20559.6,20558.6,20550.3,20559.3,20528.2
,20528.3,20522,20515.9,20507.7,20487.2,20488.1,20482,20475.8,20467.9,20445.7,20445,20436.2,20
428.4,20419.8,20397.1,20395.6,20387.9,20380.1,20372.4,20353,20354.4,20348.3,20343.7,20339,203
22.2,20326.8,20324.7,20323.5,20321.3,20307.3,20313.8,20310.9,20308.2,20305.7,20292.8,20299.4,
20297.6,20295.3,20293,20279.8,20285.1,20280.9,20277.3,20274.2,20259.2,20264.6,20261.8,20258.5
,20255.2,20240,20244,20239.8,20236.4,20232.6,20217.8,20223.2,20219.1,20215.4,20211.8,20194.9
1,31/01/2006
12:54:36,326.087,5104.04,9147.48,18517.5,21645.5,23146.3,23734.6,23660.3,23256.5,22941.9,2270
4.1,22554.7,22429.4,22378.2,22357,22338.5,22328.6,22319.4,22322.3,22323.6,22323.1,22324.1,223
15.2,22325.9,22325.8,22324.7,22323,22311.3,22319.6,22316.9,22314.7,22314.7,22300.2,22307.4,22
305.8,22302.4,22299.7,22284.6,22289.2,22285.2,22281.3,22276.8,22261.9,22265.6,22261.8,22257.6
,22253.4,22237.8,22243.8,22241.2,22238.9,22235.6,22218.9,22221.1,22214.4,22207.8,22201.1,2218
```

Figure 2 Export Traces .txt file

In the traces export file above, the first and second line Depth,Acq.Time is a label followed by the acquisition time digitization sequence which beginning with 0 and ends with 12(seconds) on line 12. Note the trace amplitude values are sampled every 0.06 seconds with trace length time equal to the longest used during the acquisition.

Line 13 is ft. label, which depends on the Software Depth/Speed Units; see MatrixSettings.

Line 14 begins: 0,31/01/2006; which is depth, date

Line 15 begins: 12:53:10, 500.042; which is time stamp, first amplitude data point additional amplitude data points per time slice follow.

The next amplitude trace record is at line 32 the sequence of Line 14 and 15 is repeated on this and subsequent records. Traces may vary in length depending on the trace length used.

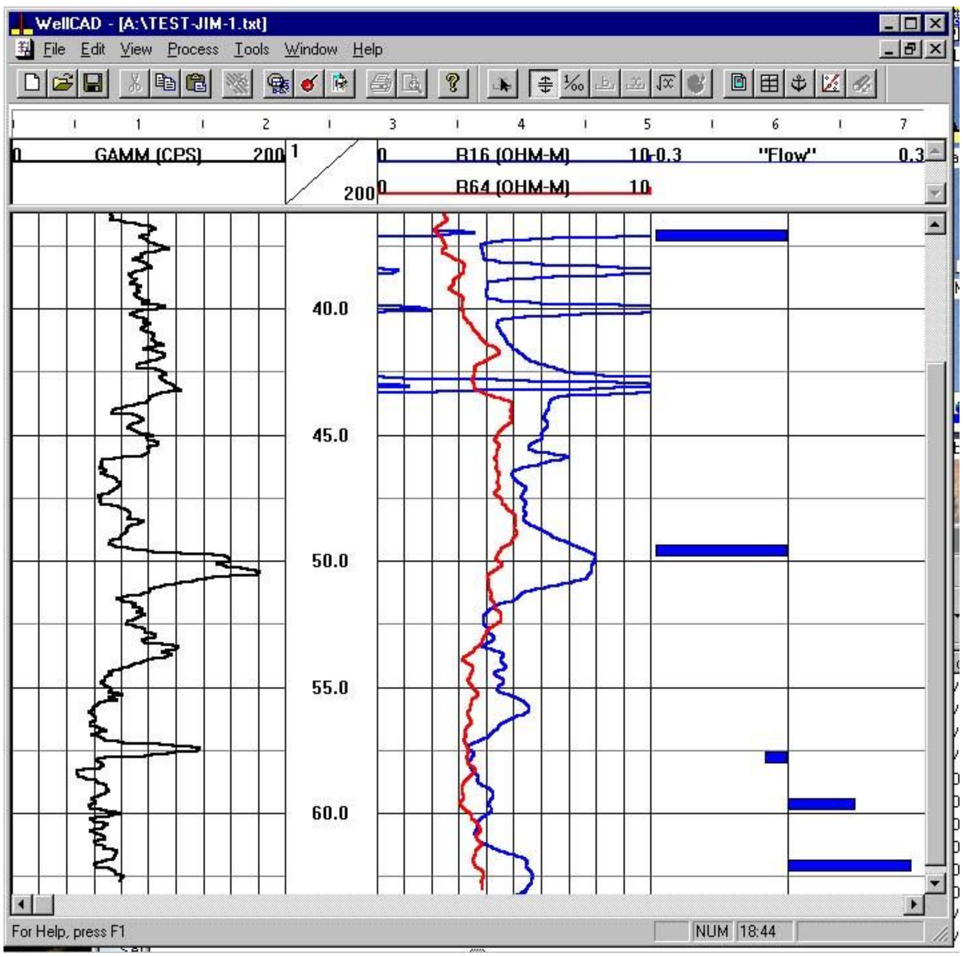
V. Appendix

a) Import to WellCad

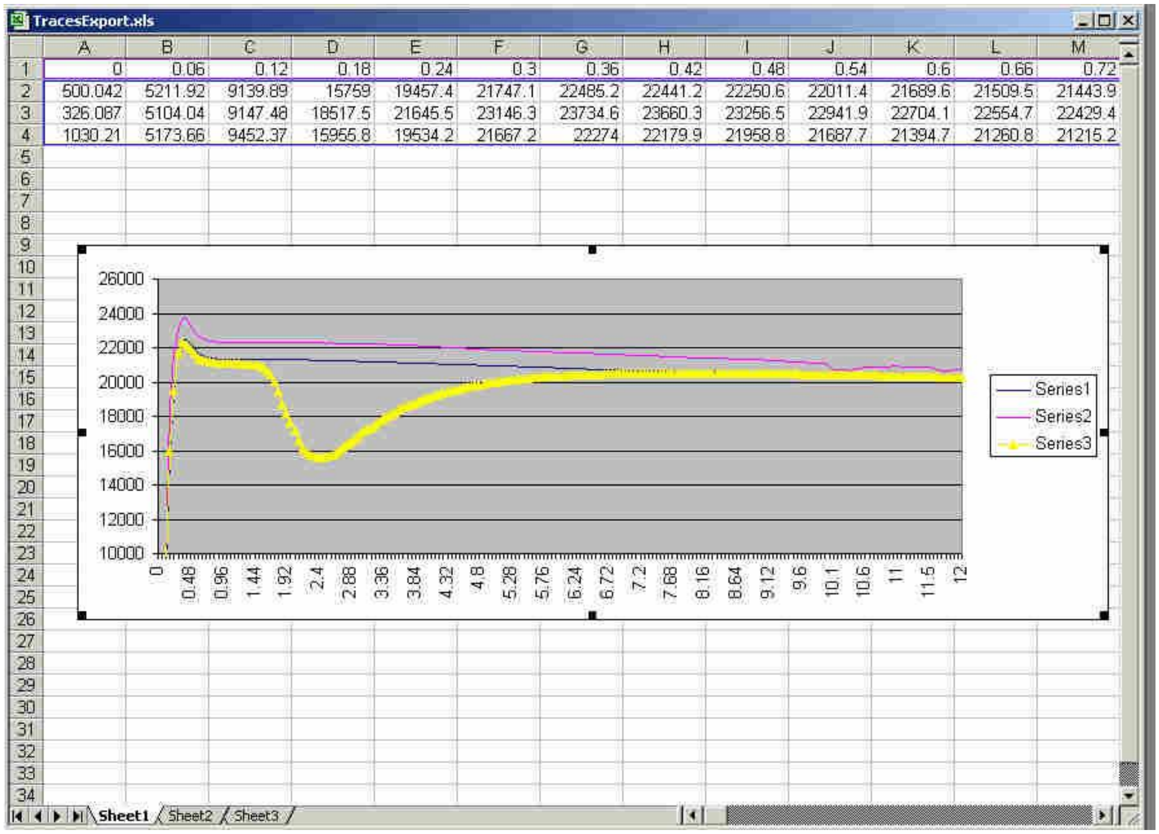
1. Locate the Pick-times **.txt** file that was exported from MatrixHeat and rename it with **.waf** extension instead of .txt.
2. Start WellCad and select the 'Import' command from the 'File' menu. Next select 'Single File'.
3. Answer the import wizard questions when prompted. Note that the first line contains titles and the second line contains units. Make sure that these boxes are checked in the import wizard. When the wizard asks what type of log to import select **Mud-log**.
4. After importing the text file, double click the scale header of the time or flow log. Under style, chose **'fixed w/ polarity**". Also, change the plotting scale the necessary negative to positive range.

Delete the unnecessary logs (time, speed) if desired. Set the depth scale and track positions as usual. Save the resultant **.wcl** file and plot as usual.

b) Example of WellCAD presentation of Heat Pulse Flow data as mud log



c) Example of Excel presentation of exported traces



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	0	0.06	0.12	0.18	0.24	0.3	0.36	0.42	0.48	0.54	0.6	0.66	0.72
2	500.042	5211.92	9139.89	15759	19457.4	21747.1	22485.2	22441.2	22250.6	22011.4	21689.6	21509.5	21443.9
3	326.087	5104.04	9147.48	18517.5	21645.5	23146.3	23734.6	23660.3	23256.5	22941.9	22704.1	22554.7	22429.4
4	1030.21	5173.66	9452.37	15955.8	19534.2	21667.2	22274	22179.9	21958.8	21687.7	21394.7	21260.8	21215.2

Figure 3 Excel plot of exported traces

To start this spreadsheet the time data from the exported traces, line two was copied into the spreadsheet at line one. After using the Data, Text to Columns tool to format the first line, three data sets from the exported traces file were copied and pasted into the following lines two through four.
A graph was created from the data with the x-axis representing the time axis.

Note that depth and time stamp were not included although they could have been.

d) MatrixHeat ".ini" files

Two ".ini" configuration files are used with MatrixHeat, matrixheat.ini and matrix.ini. These files are in the same folder as MatrixHeat.ini. There can be some crossover in their functionality but the following examples are normal.

Matrixheat.ini

[Tol Files]

RootDir=C:\MatrixHeat\TOL\Current

[FirstArrival]

; The following values are managed by the MatrixHeat dialogs

Threshold=3

TimeMin=0.6

TimeMax=10

[Recent File List]

Matrix.ini

[Dashboard Panels]

; The following values are described below

LedDisplayBkgColor=0

LedDisplayFontColor=ffff

e) Font and background color of numerical displays

The color of the background and characters in the Depth display can be controlled in the Matrix.ini file, which can be found in \MatrixHeat installation folder. Yellow characters on a black background seem to give the best contrast the settings for which are shown below.

Use the following keys in matrix.ini

[Dashboard Panels]
LedDisplayBkgColor=0
LedDisplayFontColor=ffff

The table below shows some common color codes:

Color	Color HEX	Color
	#000000	Black
	#0000FF	Red
	#00FF00	Green
	#FF0000	Blue
	#00FFFF	Yellow
	#FFFF00	Bright Blue
	#FF00FF	Violet
	#C0C0C0	Grey
	#FFFFFF	White

There are many other hues of colors available by adjusting the Hex numbers. If you use another resource that describes standard HTML font colors for browsers note that *the order of the HEX numbers shown above are reversed* from those standards.

f) Robertson Geologging Heat Pulse tool operation notes

MatrixHeat supports the operation of the Robertson Geologging Heat Pulse Flowmeter on a Matrix in which the associated, optional modem has been enabled. Contact Mount Sopris Instruments for further information.

The tol file for the RG HFP tool is in the \MatrixHeat\tol\ folder; copy it to the \MatrixHeat\Tol\Current folder.

Warning: Do not turn the HFP-2293 on with the RG HPF tol file selected for acquisition as damage to the HFP-2293 tool will result due to the higher operating voltages for the RG HPF.

As the RG HPF tool isn't as stable as the Mount Sopris HFP-2293 it takes a little practice to figure out when the best time to fire it is depending on the values from the tool.

It is a two-step process; first the Stabilize button is pressed then perhaps pressed again about 5 seconds before firing the tool.

It should probably be stabilized and fired a couple more times to verify the flow signature.

User Guide

QL40 OBI-2G Optical Borehole Imager

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v14.12.17

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Table of Contents

1 General Information

The QL40 OBI-2G is the new generation of slimhole Optical Borehole Imager. The new system consists of a completely redesigned optical assembly and electronics. It implements a high resolution CMOS digital image sensor combined with a fisheye lens. The tool produces an extraordinarily clear, sharp, 360° continuous - unwrapped digital picture of the borehole wall, either in air or clear water. Resolutions up to 1800 pixels over the borehole circumference can be achieved making it ideal for lithological, mineralogical and structural analyses.

A built in high precision orientation sensor incorporating a 3-axis fluxgate magnetometer and 3 accelerometers allows orientation of the images to a global reference and determination of the borehole's azimuth and inclination.

The QL40 OBI-2G is supplied as a bottom sub of the Quick Link (QL) product line and it can either be combined with other QL40 tools to form a tool string or be run as a standalone tool.

Applications:

- *Detailed and oriented structural information*
- *Reference for core orientation*
- *Fracture detection and evaluation*
- *Breakout analysis*
- *Detection of thin beds*
- *Determination of bedding dip*
- *Lithology and mineralogical characterization*
- *Casing inspection*

Measurement features:

- *360° RGB true colors oriented image*
- *Borehole azimuth and tilt*
- *Relative bearing*
- *3 accelerometer calibrated components*
- *3 magnetometer calibrated components*
- *Temperature of CMOS image sensor*

Operating conditions:

- *Dry or clear water filled borehole*
- *Centralizers required*
- *Borehole diameter range: 2 ½" to 21"*
- *Logging speed:* function of image resolution and wireline electrical properties
  i.e: 6 m/min with 900 pixels azimuthal resolution, 2 mm vertical sampling rate @ 100 Kbps

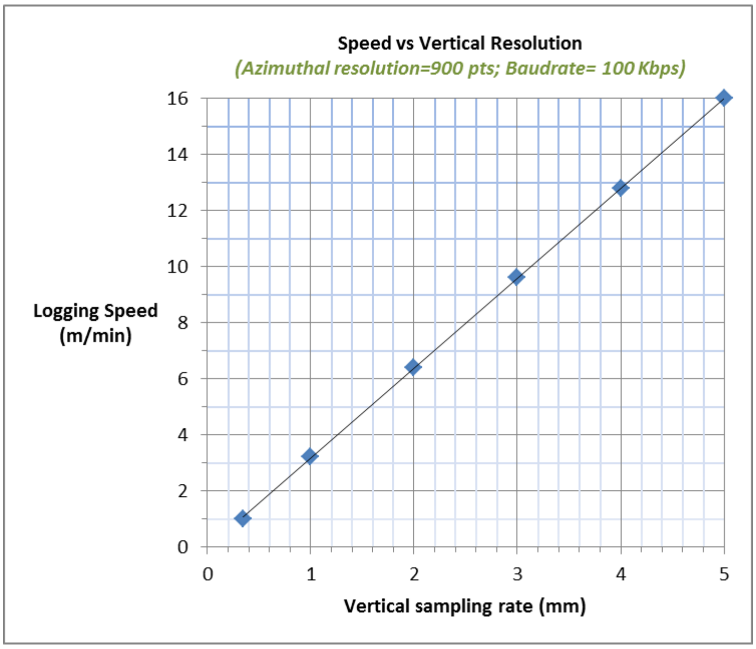


Figure 1-1-1 *Logging Speed vs Vertical Sampling Rate (900 pxls-100 Kbps)*

1.1 Dimensions

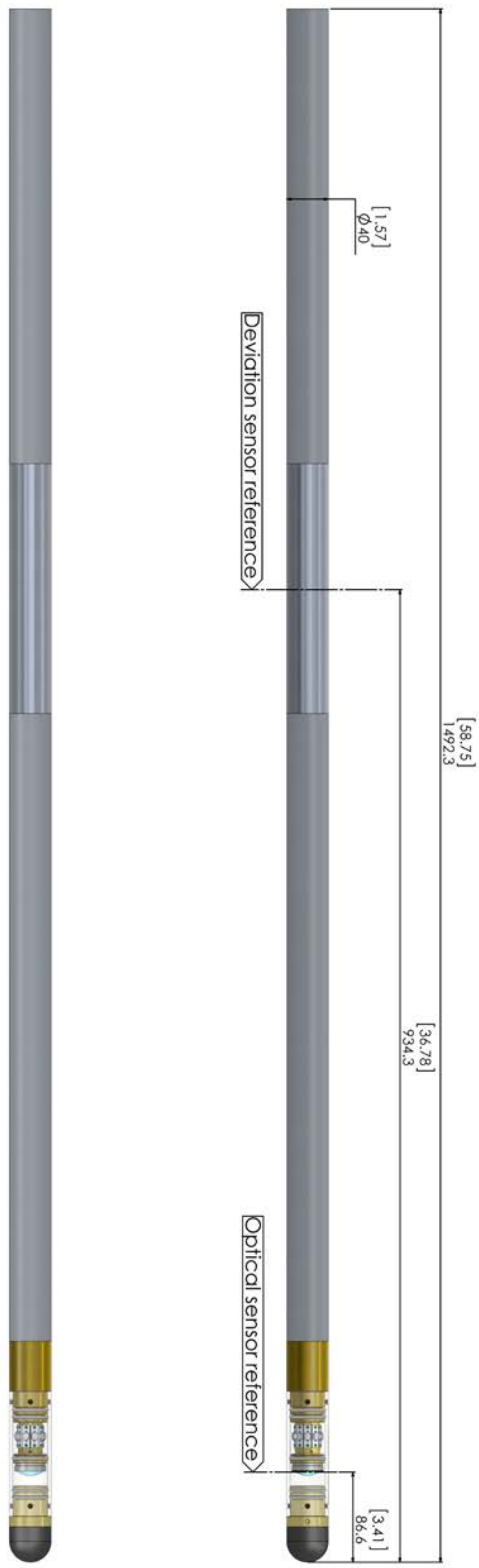


Figure 1-1 *QL40 OBI-2G overview*

1.2 Technical Specifications

Diameter:	40 mm (1.6”)
Length:	1.49 m (58.7”)
Weight:	5.3 kg (11.7 lbs)
Max. Temperature:	70°C (158°F)
Max. pressure:	200 bar (2900 PSI)

Optical system

Sensor:	1/3” high sensitivity CMOS digital image sensor
Color resolution :	24 bits RGB true colors
Responsivity :	5.48v/lux-sec
Azimuthal resolutions :	120, 180, 360, 600,900, 1800 points
Vertical resolution :	User defined. Function of depth encoder resolution

Light source

Light source:	High efficiency LEDs
Color temperature:	5600 K
Light intensity:	750 lm
Color rendering index:	80 %
Power max.:	5.60 W

Compatibility

Wirelines:	Multi conductor, mono or coaxial
Acquisition systems:	ALTLogger, BBOX and Matrix
Min. software configuration:	LoggerSuite 11.2 – WellCad 5.0 build 1103

Orientation sensor

Sensor:	APS544 – 3 axis magnetometer and 3 accelerometers
Azimuth accuracy:	+/- 1.2 deg
Tilt accuracy:	+/- 0.5 deg

2 Measurement Principle

The tool incorporates a 1/3-inch CMOS digital image sensor with an active pixel array of 1.2 Mp and fisheye matching optics. The digital image sensor captures the reflection of the borehole wall through the fisheye lens. The light source is provided by 10 high efficiency LEDs.
The displayed log image is derived from a single annulus extracted from the active pixel array. Azimuthal resolutions available are 120, 180, 360, 600, 900 and 1800 pixels per recorded circle. By using processed digital images in combination with deviation sensor data, the tool can generate an unwrapped 360° oriented image.

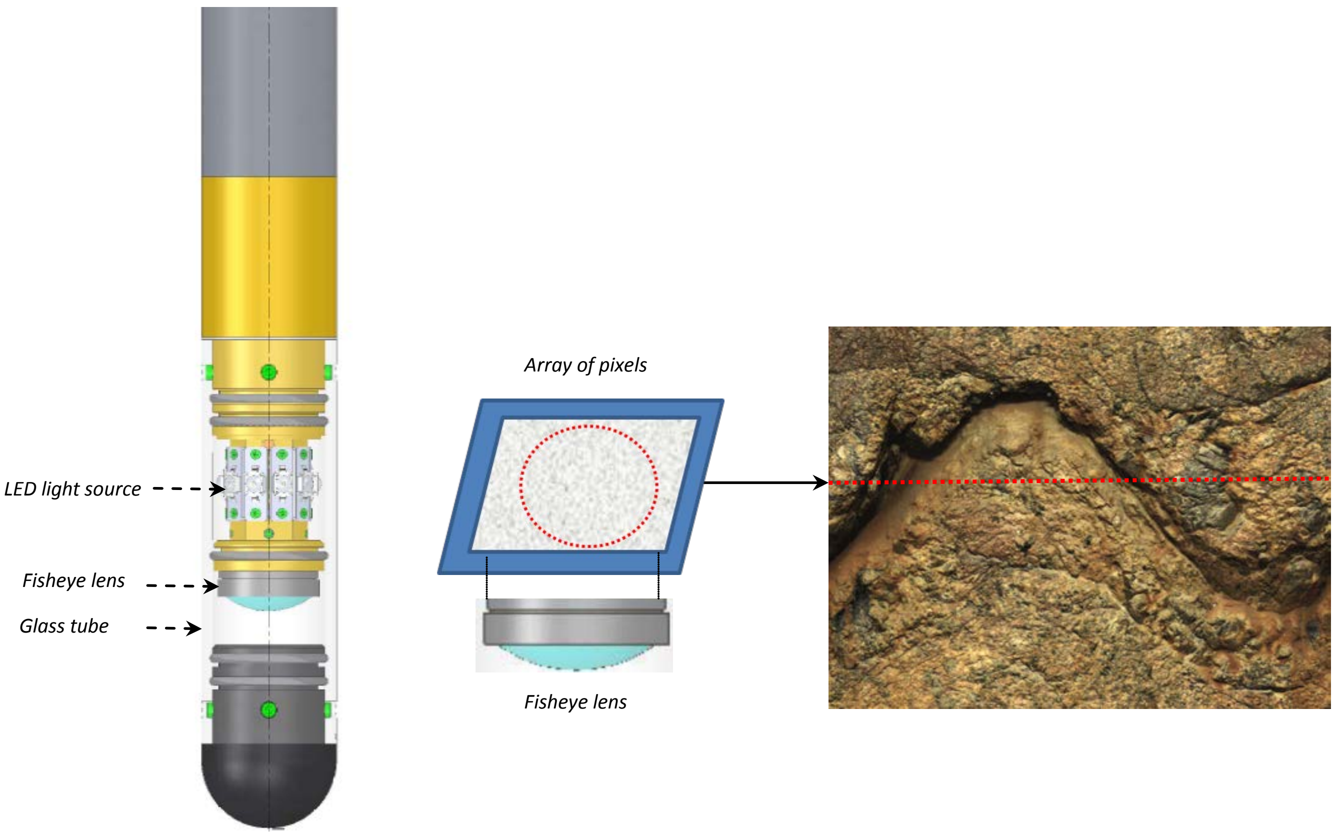


Figure 2-1 *Optical assembly and principle of measurement*

3 Notes on QL tool assembly

The following explanations are only valid for the QL40 OBI tool. OBI40 users can skip this chapter.

QL stands for **Q**uick **L**ink and describes an innovative connection between logging tools (subs) allowing to build custom tool stacks. QL40 describes a specific family of logging tools. Each sub is equipped with its own Telemetry board, Power supply element and A/D converter allowing an operation as stand-alone tool or as a stack in combination with other subs of the QL product family.
The QL40 probe line deals with two types of subs - Bottom Subs and Mid Subs.

Bottom Sub
A bottom sub is a tool that must have one or more sensors located at the bottom. It can be operated in combination with other QL subs connected to the top but it is not possible to connect another sub below. When used in stand-alone mode the bottom sub only needs a QL40 tool top adaptor, which fits the cable head.

Mid Sub
A mid sub is a tool that can be integrated anywhere within a stack of tools. When used at the bottom of a tool string a QL40 bottom plug must be used to terminate the string. If the mid sub is used as a stand-alone tool it needs a QL40 bottom plug at the lower end and a QL40 tool top adaptor at the top.

3.1 QL40 stack assembly

QL40 tool stacks are terminated by either a QL40 bottom sub or a QL40 bottom plug. At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available, special ones can be made on request.

To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.

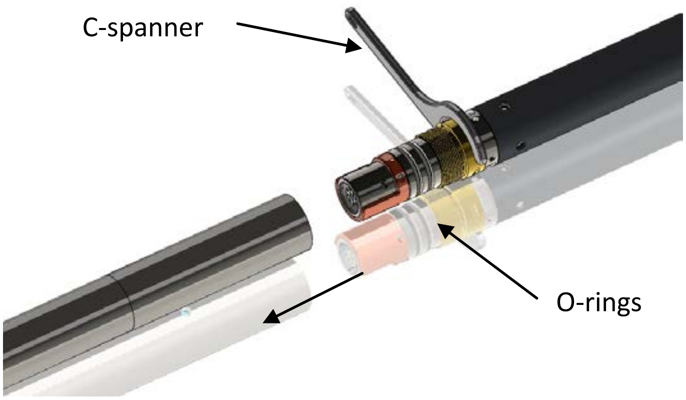


Figure 3-1 *C-spanner and O-rings of QL connection*

The following example of a QL40-ABI, QL40-GR and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GR sub stand-alone.

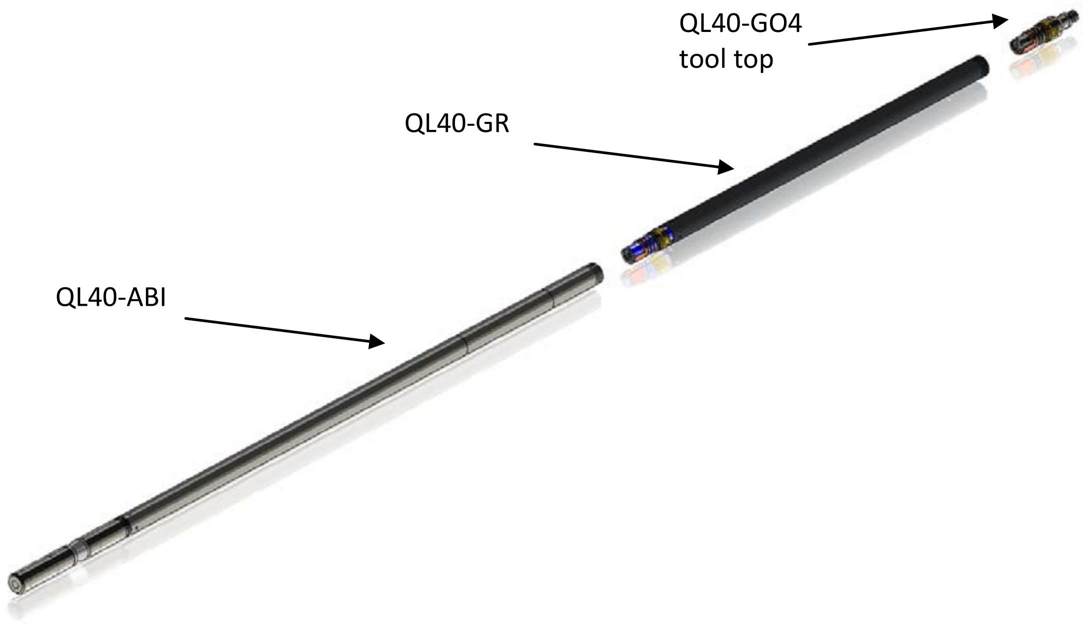


Figure 3-2 *Tool stack example*

To remove the QL40-ABI bottom sub attach the C-spanner to the thread ring as shown in Figure 3-3, unscrew the thread ring and remove the QL40-ABI bottom sub.

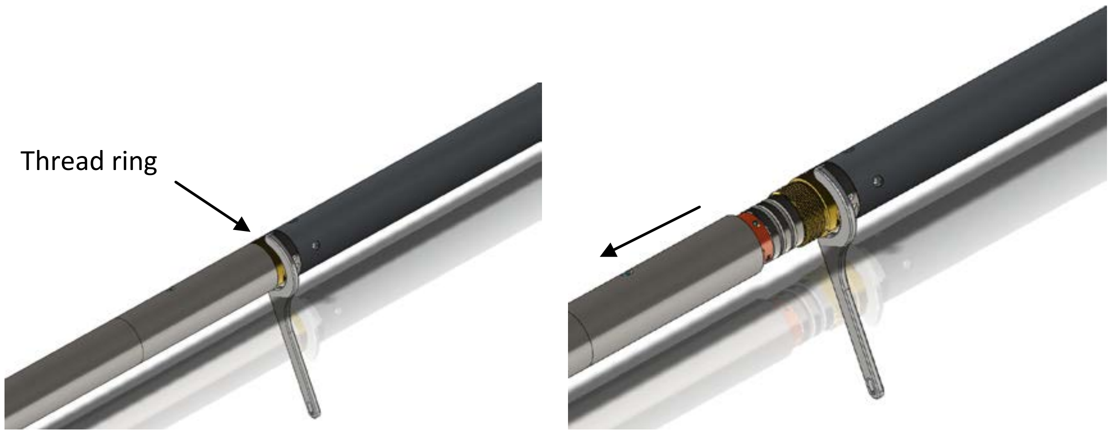


Figure 3-3 *Unscrewing the thread ring and removing the bottom sub*

After checking the O-ring integrity slip the QL40-Plug over the exposed QL connector (Figure 3-4) attach the C-spanner and screw the thread ring until the plug fits tight.

Figure 3-4 *Attaching the QL40-Plug*

The QL40-GR can now be run stand-alone (Figure 3-5).

Figure 3-5 *QL40-GR mid sub with tool top and bottom plug*

4 Operating Procedure

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the data acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

4.1 Quick Start

1. Connect the tool to your wireline and start the data acquisition software.

2. Select the relevant OBI tool from the drop down list (Figure 4-1) in the software's **Tool** panel (if your tool is not listed check that your tool configurations file is stored in the designated folder on your computer).

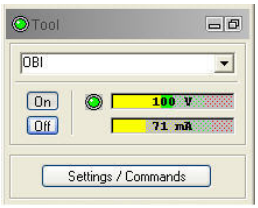


Figure 4-1 *Tool panel*

3. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure. (Setup the tool communication as explained in section **4.2** if an error message is displayed.)

4. On the **Tool** panel (Figure 4-1) click the **Settings / Commands** button to configure your tool (see chapter **4.5** for details).

5. In the **Acquisition** panel (Figure 4-2) select the sampling mode (depth or time). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button).

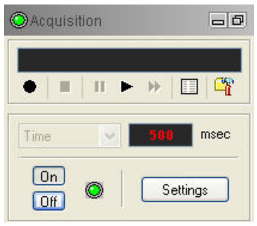


Figure 4-2 *Acquisition panel*

6. Press the **Record** button in the **Acquisition** panel (Figure 4-2), specify a file name and start the logging.

7. **<u>During logging</u>** observe the controls in the **Telemetry** panel (Figure 4-3):
   - Status must be valid (green light);
   - Bandwidth usage in green range;
   - Memory buffer should be 0%;
   - Number of **Data** increases and number of **Errors** negligible.

   <u>In the OBI40Img browser the processor "workload" and camera "frame rate" must stay below 100%</u>

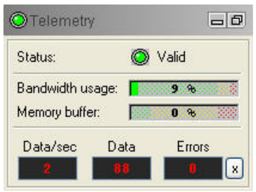


Figure 4-3 *Telemetry panel*

8. To end the logging procedure press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

9. In the **Tool** panel power off the tool.

4.2 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on **Settings** to display the **Configure Tool Telemetry** dialog box (Figure 4-4). A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate**, check the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialisation sequence the next time it is turned on.

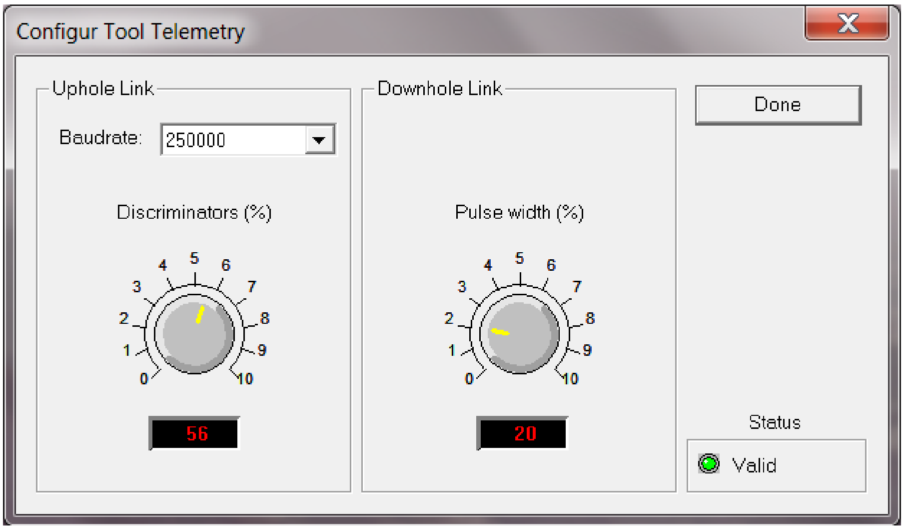


Figure 4-4 *Tool communication settings*

4.3 Tool Communication with MATRIX

The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (Figure 4-5) providing various controls to adjust the telemetry settings and monitor its current status.
The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.
The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal

is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.
The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.
For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see Figure 4-5) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.

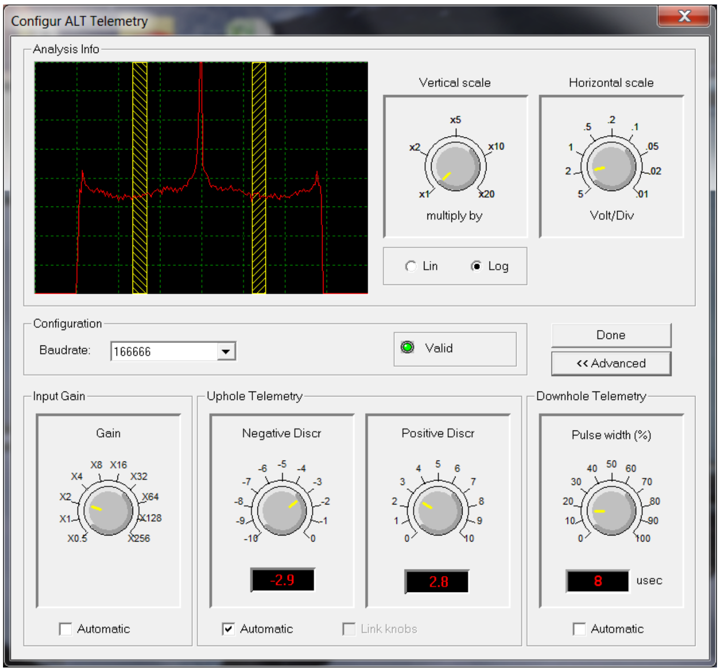


Figure 4-5 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in “Valid” status the next time the power is turned on.

4.4 Use of centralizers

Optical televiewer image quality is highly dependent upon tool centralization.
One set of centralizers is supplied with the OBI that is suitable for all tools with an external diameter of 40mm. The standard assembly comprises upper and lower mounting rings with sets of bow springs. Two C spanners are provided for tightening the locking ring. Bowsprings for other borehole diameters are available on request.
The following points relating to the use of centralizers should be considered:
The centralizers should be fitted before mating the tool with the wireline cable head and should always be fitted from the cable head end to avoid damaging the optical window. In case magnetic centralizers are used (the ALT centralizers are non magnetic) avoid mounting a centralizer over the deviation sensing point which is located in the middle of the roughened area on the pressure housing.

The “compression” ring of the centralizer, i.e. the one that is screwed tight, should always be fixed toward the **top** end of the probe. This is to avoid catching on a downhole obstruction when winching up.
Use the C spanner to fasten the fixing rings but take care not to cross thread or over tighten them as this could damage the pressure housing
(The weak point of the bowsprings is the welded bearing pin. Take care during assembly as the weld can be broken by reverse bending.)

4.5 Configuring Tool Parameters

The **Tool Parameters** dialog box for the QL40 OBI-2G is shown below (Figure 4-6). It can be accessed by clicking the **Settings / Commands** button from the **Tool Panel**. Changes and the effect of new settings on the image are displayed in real time in the **OBI image** browser.

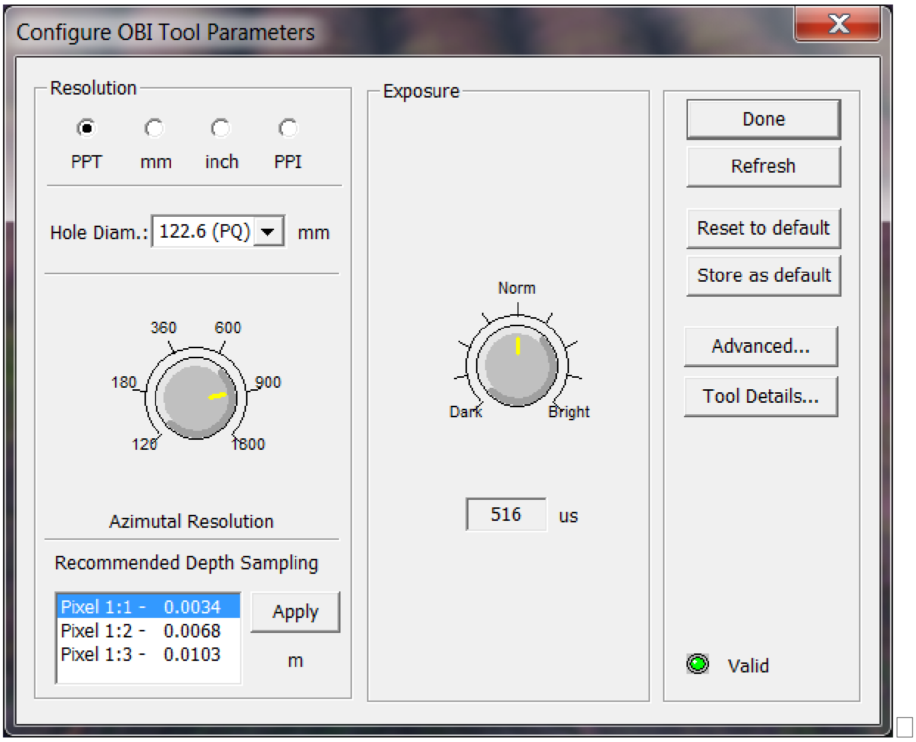


Figure 4-6 *Tool parameters dialog box*

4.5.1 Image resolution

The azimuthal resolution of the image can be defined by the operator. The choice of azimuthal resolutions is now extended to 1800 pixels over the borehole circumference.

Multiple options are possible for displaying the azimuthal resolution: points per turn (PPT), millimetres (mm), inches (inch) or points per inch (PPI).
By editing or selecting a nominal borehole diameter in the *caliper window*, the system computes automatically the azimuthal resolution values for each display options.

The system suggests in addition a *recommended vertical depth sampling rate for the selected azimuthal resolution* and offers a choice of different image ratios (ratio between horizontal and vertical resolutions). A link can be activated to apply automatically the recommended vertical sampling rate in the "*acquisition*" panel of the dashboard. Note that User is always free to edit manually the vertical depth sampling rate from the "settings" option in the "acquisition" panel of the dashboard.

Important remark:

The digital images recorded by the QL40 OBI-2G are compressed in real time to increase the transfer rate of the images to the surface acquisition system. To optimize the compression process, the tool records eight optical data frames per vertical sample. ***For this reason, the vertical sampling value to edit must be multiplied by a factor of eight. I.e. in practice, if the User wants to record an image with an effective 1mm vertical depth sampling rate, a value of 8mm (8x1mm) must be manually entered in the "acquisition" window of the dashboard.***

4.5.2 Exposure

The "Exposure" control knob allows optimization of the exposure time set for the image sensor when capturing an image of the borehole wall under a given light level. (By default the lighting intensity is set at 100%, see Section 4.5.4). The exposure value is displayed below the knob in µsec.
Practically speaking, the exposure must be adjusted adequately for the borehole conditions: diameter, dry or water filled, rock colors.
By experience a lower exposure value is required in small diameter borehole, whitish formations and dry conditions. The reverse is applicable.

A good way to set the exposure time is to check the luminance distribution in the histogram view available with the "ObiHisto" browser (refer to chapter 4.6.3). The spectrum of the luminance should normally be centered on the luminance scale axis (Figure 4-7). A situation where the luminance spectrum is too far to the right on the luminance scale corresponds to an image saturated with light.

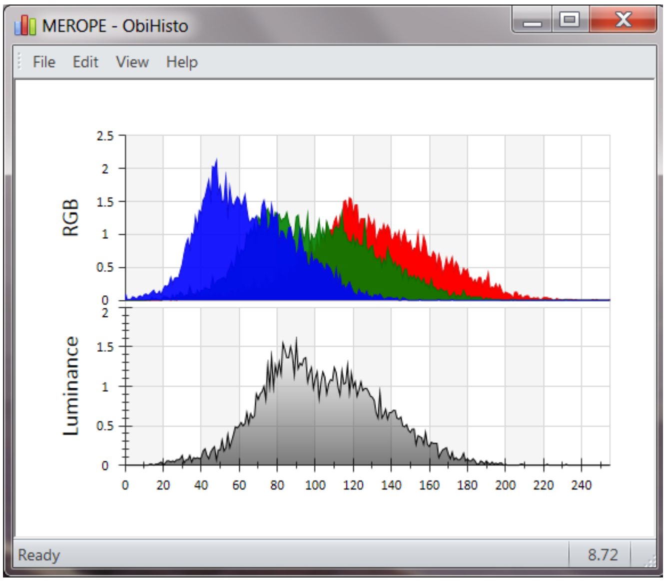


Figure 4-7 *Example of a correct luminance distribution and exposure level*

4.5.3 Tool parameters buttons

- **Refresh**: Click to refresh the settings of the dialog box.
- **Store as default**: Selected settings can be saved as defaults in the tool's default settings memory. The default settings are the tool settings loaded during the tool initialization sequence after the tool has been powered on.
- **Restore to default**: Load the default values from the tool's default settings memory.

4.5.4 Advanced settings

By default the light level is always set to 100%. It is the recommended light level for most borehole conditions.
In a situation where the image is overexposed to light, first, the exposure control knob must be adjusted. If, when the lower exposure value is used the image is still too bright, the light level can be decreased.

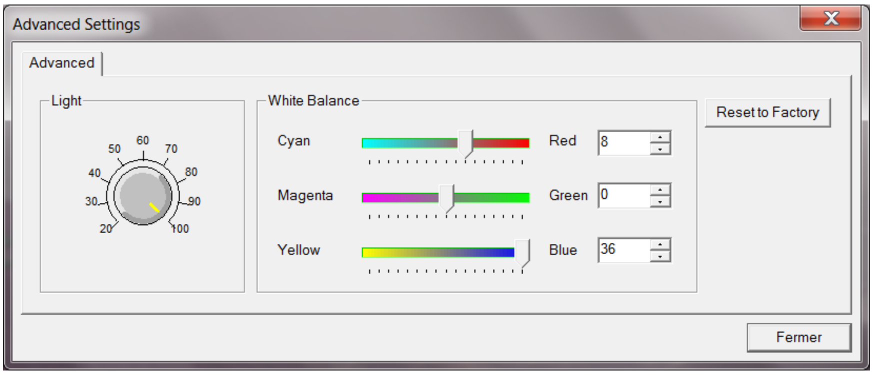


Figure 4-8 *Advanced settings dialog box*

The white balance controls the ratio between the three main colors (red, green, blue). In other words, the white balance calibrates the white color of an object or image.

The calibration of the white balance requires specific equipment and is performed at manufacturing time. No change should be applied to the white balance settings when the tool is operated under normal conditions.

- **Reset to factory:** Load the original image sensor settings stored in the tool's memory during factory calibration.

4.5.5 Tool details

The **Tool Details** window lists the tool parts serial number, firmware and hardware versions.

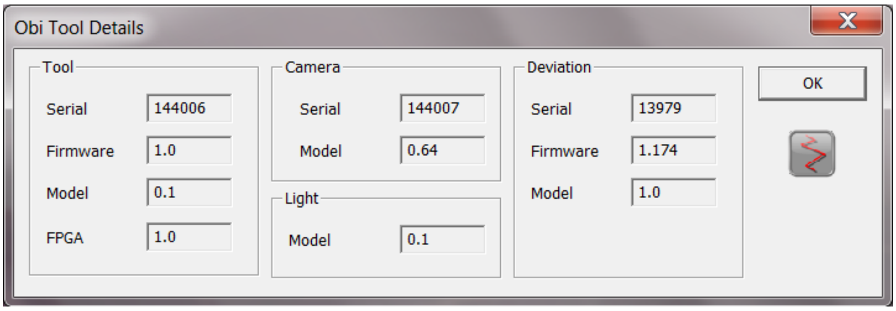


Figure 4-9 *Advanced settings*

4.6 Recorded Parameters, Processors and Browsers

4.6.1 Recorded parameters

Besides the image, the following data channels are recorded by the tool.

TCam[1]	Temperature of the image sensor - °C
FRate	Image sensor frame rate per second - fps
Workload	Percentage of the processor workload used for the image compression – %
Azimuth	Azimuth from Magnetic North – deg
Tilt	Inclination from verticality – deg
Roll	Tool relative bearing calculated from accelerometers - deg
MRoll	Tool relative bearing calculated from magnetometers - deg
MagnField	Magnetic field surrounding the borehole - µT
Gravity	Absolute value of the Earth gravity – g
TAPS	Temperature inside the deviation sensor - °C

[1] *The light source of the QL40 OBI-2G is switched off automatically when TCam reaches 105°C which is the maximum operation temperature of the image sensor.*

4.6.2 “Obi40Img” Browser

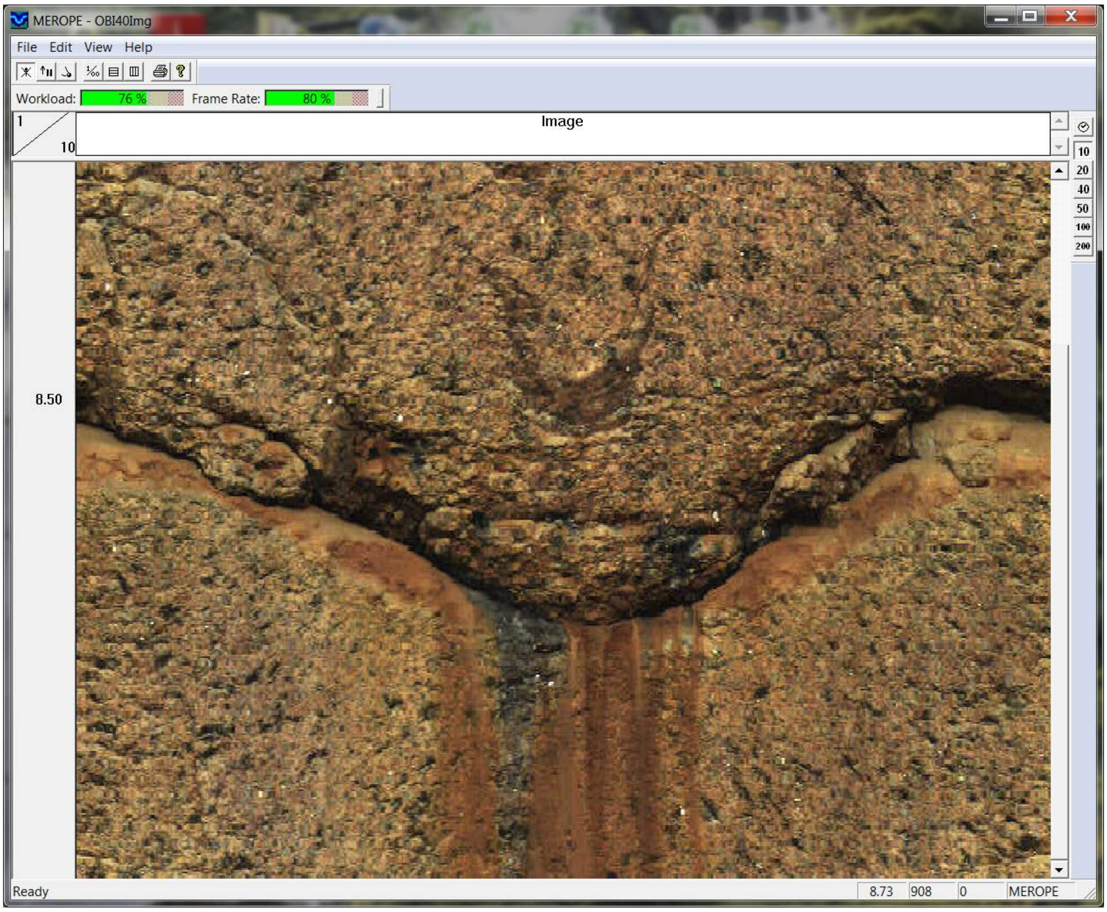
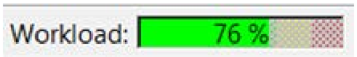
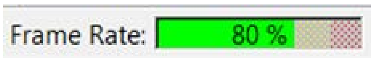


Figure 4-10 *OBI40 image browser*

A real-time 360° unwrapped image is displayed in the OBI40 image browser window (Figure 4-10). This browser has control buttons for choosing the system of orientation, time or depth mode, depth scale, grids and printing.

At the top of the browser, two bar meters monitor in real time the camera processor workload and frame rate in percent.





The bar meters must be used to control the logging speed during a record. To avoid bad records it is recommended to keep the percentage values in the green range.

Image orientation:

 Image is non-oriented

 Orient image to magnetic North

 Orient image to High Side of the tool

There are two modes of tool data orientation: Orientation to High Side and orientation to North (Figure 4-14). Orientation to High Side is used in inclined boreholes when magnetic data is unavailable (for example in a cased hole).

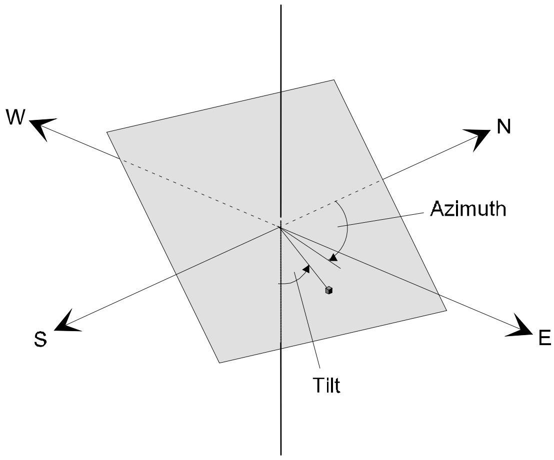
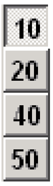


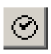
Figure 4-11 *Orientation to Magnetic North*

Vertical scales and grids:



Depth mode display and pre-defined depth scales


Operator defined depth scales, interval spacing and settings


Time mode display

4.6.2 “MChNum” Browser

Figure 4-12 shows a typical example of the numerical values displayed in the MChNum browser.

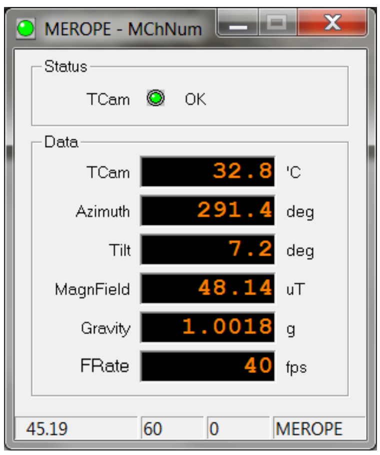


Figure 4-12 *MChNum browser*

TCam:	Temperature of image sensor - °C
Azimuth:	Azimuth from Magnetic North - deg
Tilt:	Inclination from verticality - deg
Magn.Field:	Magnetic field surrounding the borehole - µT
Gravity:	Absolute value of the earth gravity - G
FRate	Image sensor frame rate per second - fps

Right click on the MChNum browser title and select **Display Options to** add / remove channels.

4.6.3 “ObiHisto” browser

An histogram view is available to visualize the luminance and RGB colors distribution during the acquisition. The histogram view helps the user to set the adequate exposure level for the borehole conditions. Refer to chapter 4.5.2 to set adequately the exposure and luminance parameters.

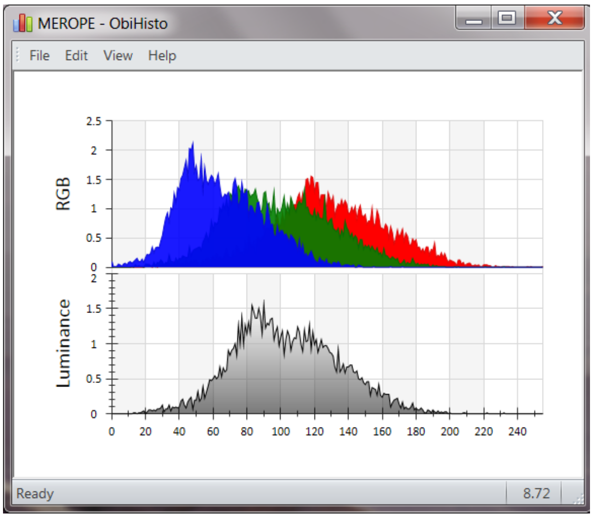


Figure 4-13 *Histogram view of the luminance and RGB colors*

The ObiHisto browser offers the option to zoom a defined area on the histogram view. To proceed left click on the histogram view and drag the mouse to highlight the area to zoom.

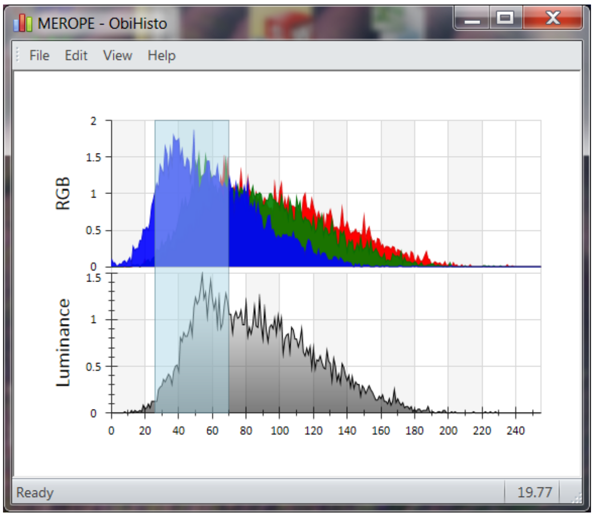


Figure 4-14 *Left click and drag the mouse to select a zoom window*

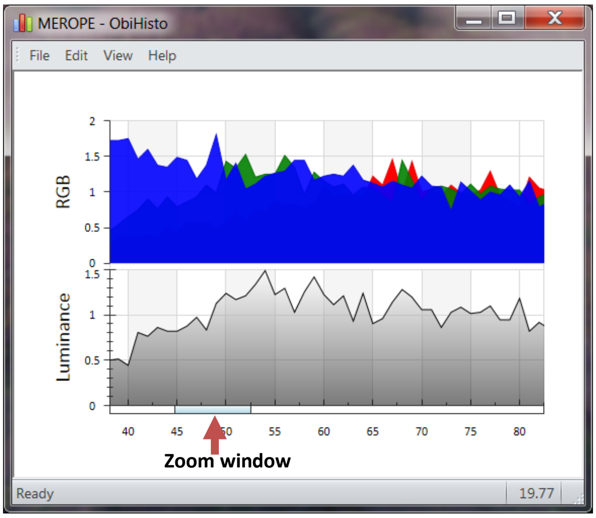


Figure 4-15 *Zoomed area in the histogram view*

The “zoom window” visible as a light blue rectangle (Figure 4-15) can be dragged on the horizontal axis to display the luminance and RGB colors distribution at the zoom scale.

To come back to the original histogram view right click on the ObiHisto browser.

Some additional options are available in the “File” and “Edit” menu to export (.bmp format) or copy the histogram view in a separate document.

5 Performance Check & Calibration

5.1 Testing the Deviation System

The QL40 OBI-2G deviation system is factory calibrated and does not require further calibration.

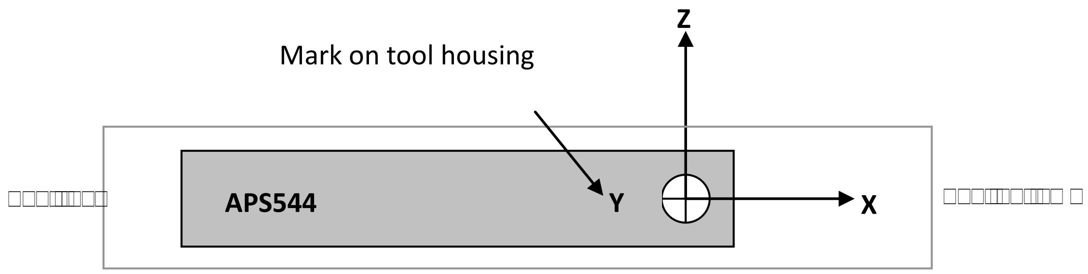


Figure 5-1 *Deviation sensor reference axis system*

The functionality test described hereafter should be executed to check that the tool is giving the correct deviation outputs:
To check Roll and Tilt outputs, place the probe on a flat surface with the Y mark engraved on the tool housing pointing up (Y axis of the coordinate system is pointing down, Figure 5-1).
Verify that the Roll and Tilt outputs are as follows:
Roll = 90° ± 0.5°
Tilt = 90° ± 0.5°
Next, roll the probe counterclockwise (looking towards the tool bottom) about its X axis in increments of 90° and verify that for each position the roll angle increments in succession to 0°, 270° and 180° while the tilt remains 90° ± 0.5°.
To verify inclination at 0° and 90°, position the probe so that the X axis is pointed down (0° inclination) and then horizontal (90°).
To verify azimuth accuracy, a good compass and an area free from magnetic materials should be used. Use a compass to orient the probe horizontal and North and verify that the azimuth reading is 0° ± 1°. Repeat the procedure for East, South and West directions.

5.2 Rolling Test – Azimuth And Tilt Check

Azimuth and tilt can be tested by rotating the tool about its long axis while maintaining both a constant inclination to the vertical, say 15°, and a fixed azimuth. The data imported into WellCAD should show a deviation of the azimuth less than the limit of ±2.5° and a deviation of the tilt less than the limit ±0.5°.

6 Maintenance

The QL40 OBI-2G optical televiewer is a delicate instrument and should be treated with care at all times. Excessive shock or temperatures should be avoided and the tool should always be carried in its transport case or a similarly cushioned enclosure. Never support the tool on its optical head that is the weakest part of the tool, and be particularly careful to avoid scratching the optical window.

6.1 Tool Top Adapter

The tool top adapter provides the connection between wireline cable head and chassis electronics and can be provided to suit 7 conductors, 4 conductors, mono or special wireline configurations. The adapter is fixed by the means of a threaded ring screwed in the pressure housing. To remove the tool top adapter, use the correct C spanners provided with the tool - see picture below (Figure 6-2).

Figure 6-1 *Removing the tool top*

The wireline cable head socket and tool top adapter connector pins should be checked for cleanliness before each use of the tool. The pin inserts, whether 4 or 7 pin, have a locating mark indicating WL1 or A that should line up with the slot mating with the cable head.

Check O-Ring seals and apply silicon grease before re-assembly. Silicon grease of a similar type to RS Components Ref 494-124 is suitable for this and other O-Ring seals.
(Rem: O-Ring reference for tool top and for the quick link 40 is AS215 26,57 x 3,53 Viton Shore 75)

6.1.1 Locking Ring assembly Maintenance

Tools required:

1.5mm Allen wrench
2 ea 40-42mm spanner wrench
Clean rags

Replacement Parts:

ALT26005, Large Threaded Ring, Qty 2
28-174-995 M2x8 SHCS, Qty 2

Disassembly:

Unscrew and remove the two M2x8 socket head cap screws and separate the two halves.
Four guide pins align the two ring halves and tend to hold them together after the screws are removed. To pry the halves apart you can use a pair of spanner wrenches inserted into the wrench holes on opposite sides of the ring mating surfaces to pull them apart slightly.
Do this carefully to prevent bending the guide pins.

Figure 6-2 *Disassembly of the locking ring –step 1*

Place something small in the opening and move the spanners to the other side and pry it open slightly. This should be enough to release the two rings as below.

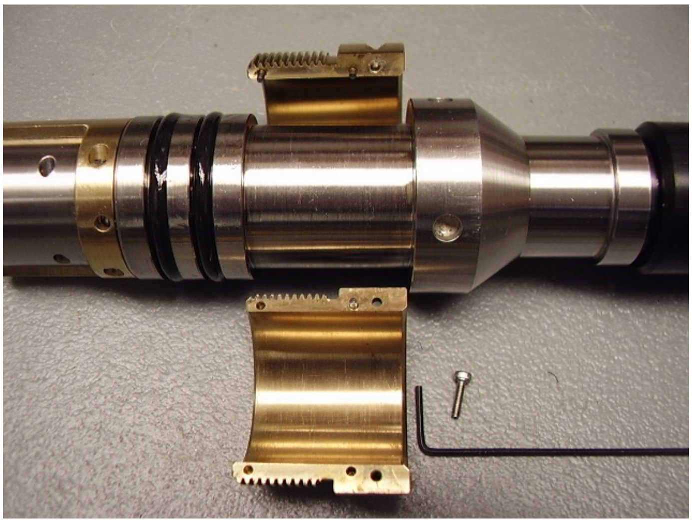


Figure 6-3 *Disassembly of the locking ring –step 2*

Clean inside surfaces thoroughly and reassemble, coating the inside with a very light film of anti-seize compound. Nickel based compounds are best, to prevent any sticking between the brass and steel surfaces

6.2 Pressure housing

<u>Warning:</u> Removing the electronic chassis from pressure housing without prior consultation with ALT will void the tool warranty.
Disassembly of the electronic chassis from the pressure housing should never be attempted in the field.

Should it become necessary to open the tool, the tool parts must be separated in the following sequence:

1. Remove the tool top adapter
2. Unscrew the pressure housing from the optical system brass interface

Before screwing back the pressure housing make sure that the threads on the brass interface are clean and properly greased with anti-seized compound. Once fully screwed on verify the correct alignment between the pressure housing and orientation key of the multi-pin Lemo connector as shown on Figure 6-4.

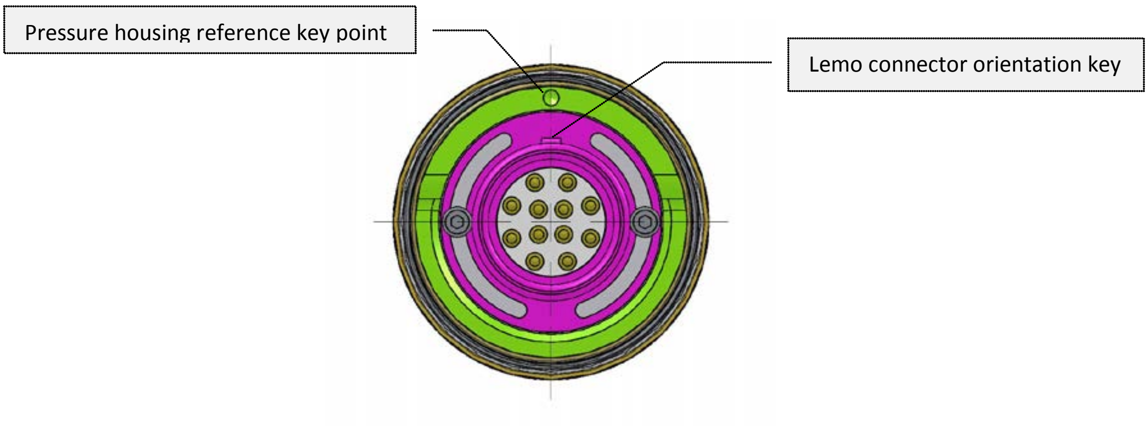


Figure 6-4 *Pressure housing top view – Correct orientation of the pressure housing and Lemo connector*

6.3 Optical system

<u>It is strongly recommended to inspect the integrity of the glass sleeve before each run</u>. **<u>Never immerse the tool in a borehole if any defect or crack is visible in order to avoid irreversible damage to the tool.</u>** Replace the sleeve with a spare one if necessary.

<u>Always use the ALT standard screws DIN912-M2.5x3 to fix the glass sleeve on the tool</u>. The size and shape of the screws are specifically designed for this purpose. Spare screws are usually provided with the tool spare kit.
<u>Note that the use of a different screw model may damage the glass sleeve when exposed to pressure and will void the tool warranty.</u>

7 Troubleshooting

Observation	To Do
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been copied into the …/Tools folder (refer to logger manual about details of the directory structure)?
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 4.5).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** **-**Possible short circuit (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of a shortcut. - If the above shows no issues, use test cable (provided by ALT/MSI as an option) to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3). - If problem cannot be resolved contact [illegible] or [illegible]
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can't receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed, decrease azimuthal resolution and/or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3). - Check bandwidth usage and telemetry error status.

Black image – the light source stopped working.	Verify the temperature of the image sensor in the MCHNUM browser. The light source is automatically switched off when the temperature of the image sensor reaches 105°C. Cool down the tool.

8 Appendix

8.1 Parts list

Detailed part numbers and descriptions are available for tool delivery and spare part kits. Please contact support@alt.lu or tec.support@mountsopris.com for further details.

8.2 Technical drawings

The following technical drawings are available on request:

- Wiring Diagram.

Index

Asiakirjan tiedot

Otsikko: PFL DIFF virtausmittarin ja ohjelmiston käyttöohje
Kohde: Yleinen
Kohteen tarkenne:
Laatija/pvm: Komulainen Jere / 07.02.2020
Tarkastaja/pvm:
Hyväksyjä/pvm:
Viimeinen voimassaolo:
Julkaisupaikka:
Yhteistyötaho:
Vanhentunut tunnus:
Arkisto:
Liitteet:
Jakelu:

Muutosluettelo

Versio	Kohta	Muutokset	Nimimerkki	Pvm
1	Ohje luotu		JERK	7.2.2020

Sisällysluettelo

PFL DIFF virtausmittarin ja ohjelmiston käyttöohje

1 Yleistä

PFL DIFF virtausmittarin pääsovellutus on mitata kairareikää leikkaavissa raoissa virtaavan veden virtausmäärä. Virtauksen lisäksi voidaan mitata veden lämpötila, sähkönjohtavuus, paine ja kairareiän ominaisvastus (Single point resistance). Laitteiston maanpäällisillä osilla, jotka ovat mittauskärryssä, mitataan ilmanpaine, reikäveden pinnan korkeus ja luetaan vinssiltä anturin syvyys reiässä.

PFL DIFF virtausmittaria voidaan käyttää eri tavoin virtausten ja paineiden mittaukseen sellaisenaan tai tulppakalustoon liitettynä maanpäältä lähtevissä rei'issä ja tunnelirei'issä. Tunnelissa on mahdollista mitata jopa yläkätisiä reikiä käyttämällä apuna kairareiän sulkumekanismia. Tässä ohjeessa on esitetty perusasiat liittyen mittauskaluston kasaamiseen ja laitteiston käyttöön. Mittaussuunnitelmissa voidaan tarkemmin eritellä tiettyyn mittaukseen liittyvät poikkeukset tähän ohjeeseen verrattuna. Esitettävät mittaukset ovat:

- Reikäveden sähkönjohtavuuden ja reiän suuntaisen virtauksen mittaus
- Virtausmittaus mittavälistä
- Rakoveden sähkönjohtavuuden mittaus

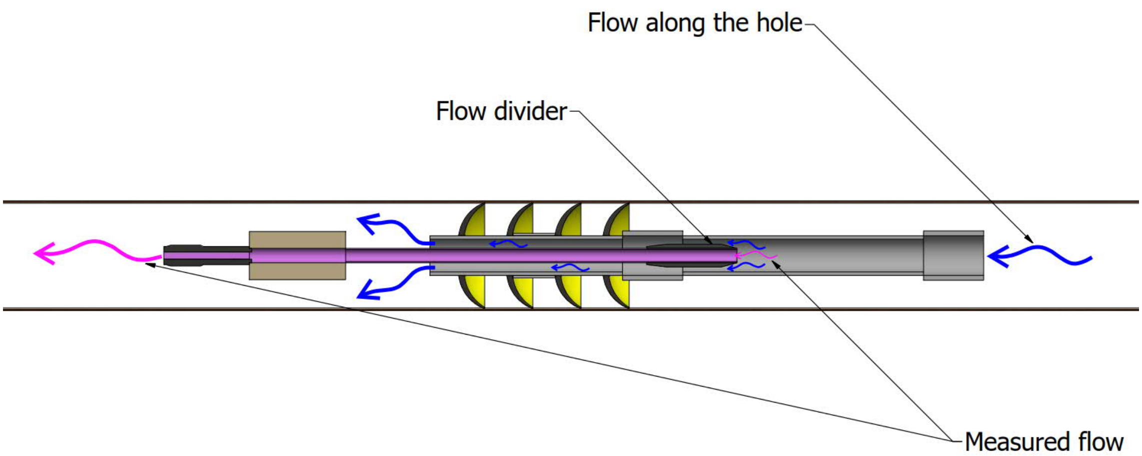
2 Kalusto asennukset

Seuraavassa on esitetty PFL DIFF anturin kasaaminen. Reikäveden ja rakoveden mittauksen vaativat hieman erilaisen anturikokonaisuuden kasaamisen, mutta suurelta osin asennus on sama.

2.1 Anturin kasaaminen reikäveden sähkönjohtavuuden ja reiän suuntaisen virtauksen mittaus

Reikäveden sähkönjohtavuuden (reikä-EC) mittausta varten anturi kasataan siten, että ajettaessa anturia kairareiässä ylös ja alaspäin vesi pääsee mahdollisimman nopeasti sähkönjohtavuus elektrodille. Reiän suuntainen virtaus kairareiässä on usein jopa kymmeniä litroja minuutissa joten mittaus pitää toteuttaa eri tavalla kuin rakovirtauksen mittaus. Käytännössä reiän suuntainen virtaus ohjataan anturille siten, että osa virtauksesta menee virtausanturille ja osa menee ohivirtauskanavaa. Tällöin virtausmittarille menevä virtaus on mittausalueella, mutta koko virtausmäärä voidaan kuitenkin arvioida. Alla olevassa kuvassa (Kuva 2-1) on esitetty anturi reikäveden sähkönjohtavuus mittauksen vaatimassa kokoonpanossa. Virtausputki joka jakaa reiän suuntaisen virtauksen virtausanturille ja ohivirtausputkeen on asetettu anturin viereen kohtaan johon se anturin sisällä tulee. Virtauksen reitti reiän suuntaisen virtauksen mittauksen aikana on esitetty kuvassa (Kuva 2-2).

Kuva 2-1 Virtauseromittari Reikä-EC-mittauskokoonpanossa. Kuvassa pystyvirtauserotin ja virtausputki on otettu Virtauseromittarin viereen esille.



Kuva 2-2. Virtausten reitit reiän suuntaisen virtauksen mittauksessa.

Virtauseromittarin runkona toimii elektroniikkaputki (Kuva 2-3), jonka yläpäässä on yläpäätykappale ja alapäässä alapäätykappale. Yläpäätykappaleeseen on kiinnitetty kaapelipäätteen vastakappale murtosokkineen. Elektroniikkaputken alapäässä puolestaan on alapäätykappale läpivienteineen, mihin on kiinnitetty virtausanturin suojaputki.

Tässä vaiheessa on hyvä tarkastaa, että virtausanturi on tyhjä (siellä ei ole roskia tms.) ja termistorien pinnat ovat kirkkaat. Virtausanturin termistorit näkee katsomalla virtausanturin sisään ja valaisemalla virtausanturia sivulta. Mikäli virtausanturin sisällä näkyy jotain ylimääräistä, pitää se puhdistaa varovasti pienellä piippurassilla. Jos termistorien pinna eivät ole kirkkaat, niitä pitää liottaa tarvittaessa laimennetulla etikkahapolla, jossa on 80% vettä ja 20% etikkahappoa.

Kuva 2-3. Virtauseromittari.

Elektroniikkaputken alapäätykappaleessa (Kuva 2-4) on kaksi Subconn-liitintä. Toinen Subconn-liitin on maadoitusvastuselektrodille ja toinen on EC-elektrodille. Maadoitusvastuselektrodin Subconn-liittimen erottaa parhaiten EC-elektrodin Subconn-liittimestä siitä, että maadoitusvastus-liittimen on oltava samassa linjassa virtausanturin ulkopuolella olevan uran kanssa (Kuva 2-5), joka on tarkoitettu maadoitusvastuselektrodin johtimelle.

Kuva 2-4. Virtausanturin suojaputki, jonka sisällä alapäätykappaleen Subconn-liittimet.

Kuva 2-5. Ominaisvastuselektrodin johdon ura virtausanturin sivulla.

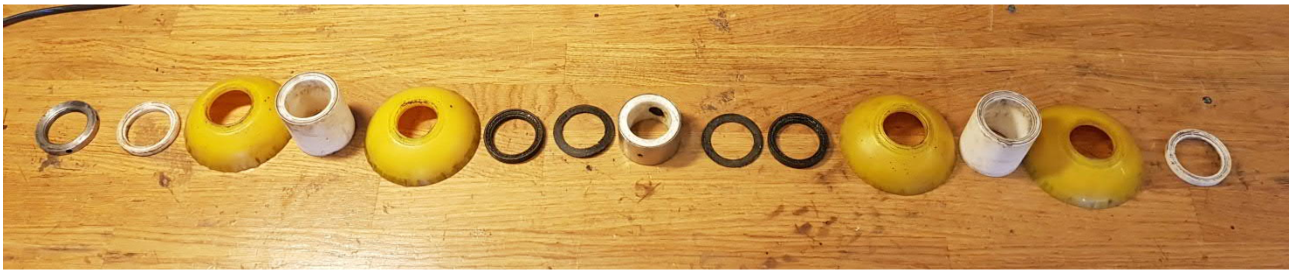
Anturin kasaaminen aloitetaan asettamalla kiila virtausanturin alapuolella. Kiilan jälkeen asennetaan hetulaputki, hetulaholkki ja sovitin (Kuva 2-6). Hetulaputken sovittimessa on sisäkierre, joka sopii hetulaputken ulkokierteeseen. Hetulaputken yläpäässä kierteet ovat pidemmät kuin alapäässä. Ennen hetulaputken kiinnittämistä sovittimeen, pitää hetulaputken yläpään kierteisiin laittaa yksi kiristysrengas. Sovitin kierretään hetulaputken yläpäähän, siten että sovittimessa oleva kuusiokoloruuvin reikä on kohdakkain hetulaputken kuusiokoloruuvin reiän kanssa. Kierrettä ei siis kiristetä loppuun asti. Sovitin lukitaan paikoilleen hetulaputkeen kuusiokoloruuvilla.

Kuva 2-6. Hetulaputki, hetulaholkki ja sovitin.

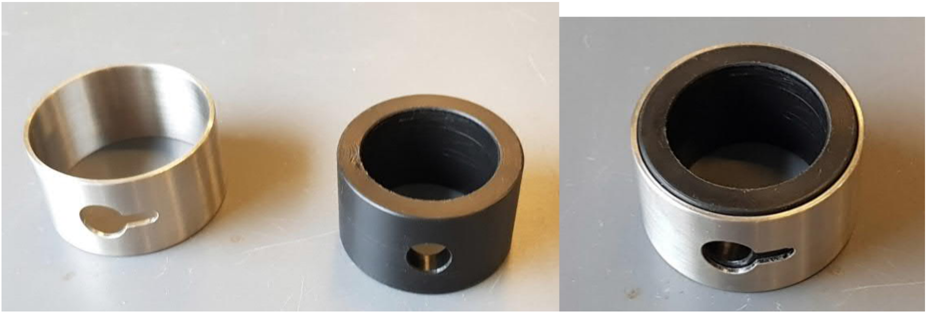
Kuva 2-7. Hetula putki ja sovitin kiinnitettynä virtausanturin suojaputkeen.

Hetulaputken kiinnityksen jälkeen hetulaputkeen laitetaan hetulat hetulaholkkeineen ja maadoitusvastuselektrodin rengas. Tässä vaiheessa pitää tarkistaa hetuloiden kunto. Hetuloiden tulee olla ehjät ja elastiset. Rikkinäiset ja kovettuneet hetulat pitää vaihtaa ehjiin.

Hetulaputkeen tulevat osat, hetulat, hetulaholkit ja maadoitusvastuselektrodi ovat oikeassa järjestyksessä Kuva 2-8, niin että osat asennetaan hetulaputkeen aloittaen oikealta. Maadoitusvastuselektrodissa tulee olla sekä metallinen, että muovinen osa (Kuva 2-9). Hetulaholkeissa epätasainen reuna tulee hetulaa vasten. Hetuloiden väliin laitetaan aina paksumpi (Kuva 2-10) hetulaholkki ja ohuet hetulaholkit tulevat hetuloiden ulkopuolelle.

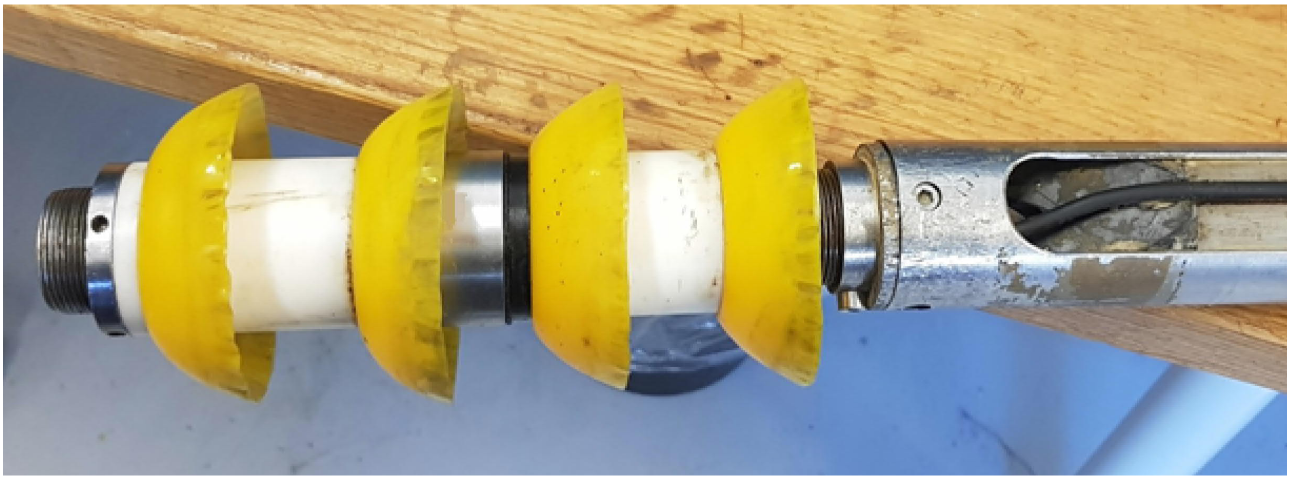


Kuva 2-8. Hetulaputkeen asennettavat osat oikeassa järjestyksessä.



Kuva 2-9. Maadoitusvastuselektrodi.

Hetulaputkeen laitetaan aluksi kaksi hetulaa ja hetulaholkit niiden väliin. Hetuloiden ja hetulaholkkien väliin tulee aina laittaa ohut kerros Molykote 111 Compound -voitelusainetta. Hetulat tulee asettaa kaikki samansuuntaisesti. Seuraavaksi laitetaan maadoitusvastuselektrodi paikoilleen. Maadoitusvastuselektrodin molemmin puolin laitetaan kumirenkaat eristykseksi. Toiset kaksi hetulaa asennetaan maadoitusvastuselektrodin toiselle puolelle. Kun hetulat holkin ja elektrodi on asennettu, kiristetään hetulat molemmista päistä hetuloiden kiristämiseen tarkoitetuilla avaimilla (Kuva 2-11).



Kuva 2-10. Hatulat ja maadoitusvastuselektrodi asennettuna anturiin.

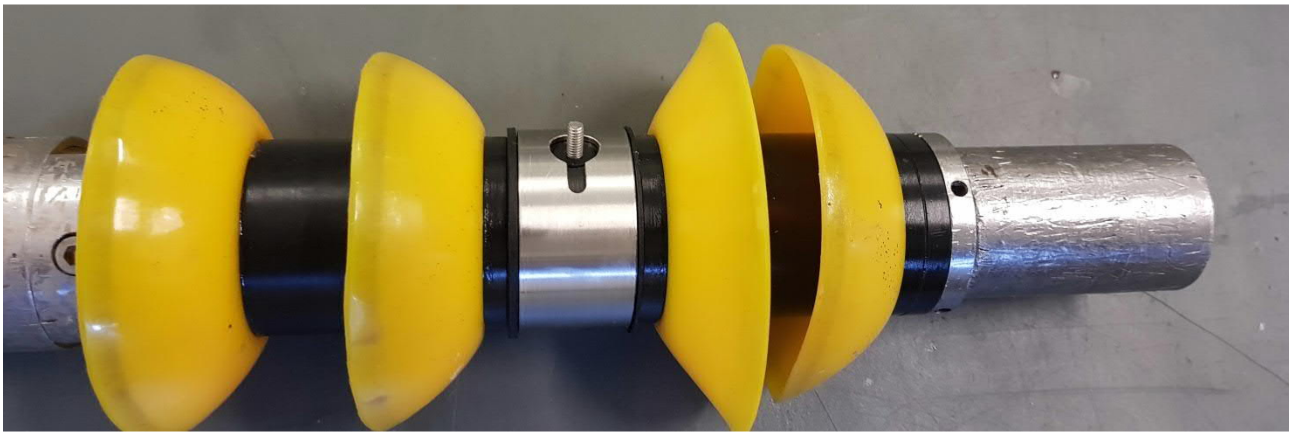
Kuva 2-11. Hetuloiden kiristämiseen tarkoitetut avaimet.

Seuraavaksi asennetaan maadoitusvastuselektrodin johto elektroniikka putkelta elektrodille (Kuva 2-12). Toinen johtimen osa pujotetaan maadoitusvastuselektrodin läpi niin, että se pää, jossa on kierretappi jää hetulaputken ulkopuolelle (Kuva 2-13). Johtimen toinen osa (jossa on Subconn-liitin) liitetään elektroniikkaputken alapäätykappaleessa olevaan Subconn-liittimeen.

Kuva 2-12. Uudenmallisen maadoitusvastuselektrodin kaksiosainen johdin.

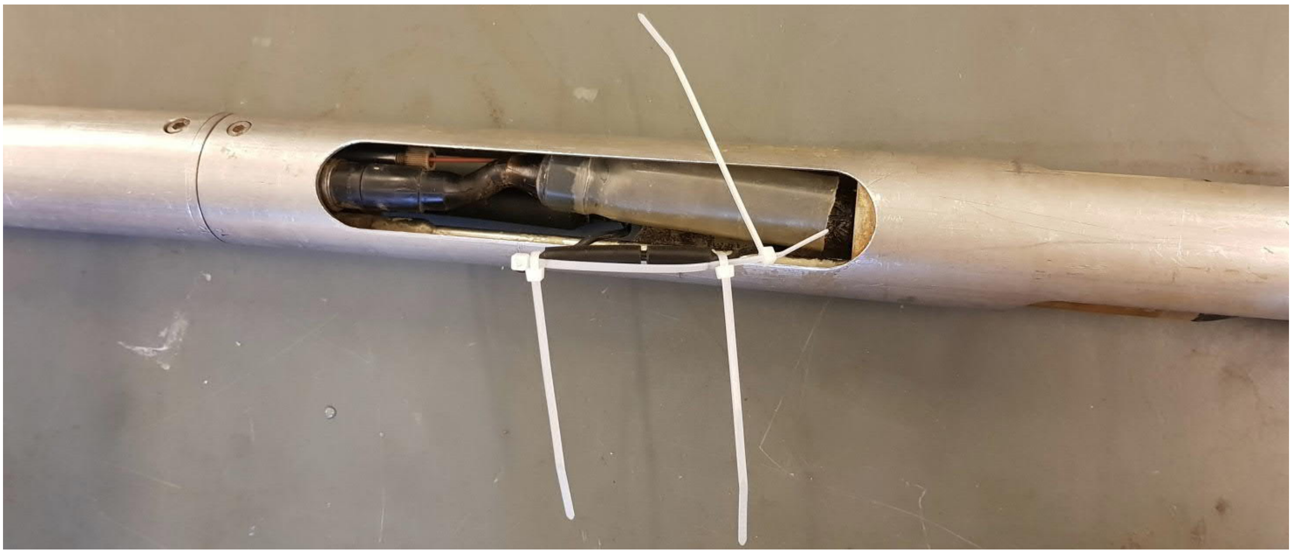
Kuva 2-13. Maadoitusvastuselektrodin johdon pujottaminen.

Johtimen pää, jossa on kierretappi, asennetaan maadoitusvastuselektrodissa olevaan reikään Kuva 2-14 mukaisella tavalla. Maadoitusvastuselektrodia teräsrengasta käännetään niin, että kierretappi menee elektrodin kapeampaan uraan. Kierretappiin laitetaan mutteri, jolla johdin kiristetään paikalleen maadoitusvastuselektrodiin. Mutteri kannattaa asentaa kierretappiin jo ennen kuin johdin asetetaan paikalleen reikään. Tällä estetään johtimen pään pyöriminen mutteria kiristäessä. Mikäli johtimen pää pääsee pyörimään, se aiheuttaa johtimen kiertymisen hetulaputken sisällä ja tällöin johdin saattaa vaurioitua tai katketa. Mutteria kiristäessä kierretapista täytyy pitää kiinni, jotta se ei pyöri.



Kuva 2-14. Johtimen kiinnitys maadoitusvastuselektrodiin

Maadoitusvastuselektrodin johtimen päät liitetään toisiinsa, Kuva 2-15. Liitoksen kiinnipysyminen varmistetaan pienillä nippusiteillä, jotka kiinnitetään johtimen liitoksen rinnalle. Lopuksi nippusiteistä leikataan ylimääräiset osat pois, Kuva 2-16.



Kuva 2-15. Maadoitusvastuselektrodin johtimen liitoksen varmistus.

Kuva 2-16 Maadoitusvastuselektrodin johtimen liitoksen varmistus valmiina.

Nämä vaiheet tulee tehdä anturia kasatessa aina riippumatta siitä mitataanko reikävettä vai mittavälistä tulevaa vettä.

Reikä-EC:n ja reiän suuntaisen virtauksen mittausta varten hetuloiden kiristämisen jälkeen laitetaan pystyvirtausohjain ja virtausputki paikoilleen, Kuva 2-19. Virtausputki ja pystyvirtausohjain (Kuva 2-17) liitetään toisiinsa kierteellä, Kuva 2-18. Ennen virtausputken ja pystyvirtausohjaimen liittämistä toisiinsa, tulee kierteeseen laittaan ohut kerros Molykote 111 compound -voiteluainetta. Sitten virtausputki ja pystyvirtausohjain työnnetään hetulaputken ja kiilassa olevan reiän läpi paikolleen virtausanturin virtauskanavaan.

Kuva 2-17. Pystyvirtausohjain (vasemmalla) ja virtausputki (oikealla).

Kuva 2-18. Pystyvirtausohjain ja virtausputki.

Kuva 2-19. Pystyvirtausohjain ja virtausputki asennettuna paikolleen.

Virtauseromittarissa on elektroniikkaputken sisällä absoluuttipaineanturi. Elektroniikkaputken alapäätykappaleessa on läpivienti absoluuttipaineanturille. Absoluuttipaineanturin läpivientiin liitetään kapillaariputki (Kuva 2-20), jonka avulla paine saadaan mitattua hetuloiden alapuolelta.

Kuva 2-20. Kapillaariputki ja liitinosat.

Ennen kapillaariputken asentamista paikoilleen pitää elektroniikkaputken alapäätykappaleessa olevan kapillaariputken liittimen reikä täyttää akkuvedellä, ettei kapillaariputkeen eikä paineanturin ja sektorin väliin jää ilmaa. Täyttäminen onnistuu parhaiten kääntämällä virtauseromittari ylösalaisin ja tukemalla esim. ruuvipenkkiin. Nyt liittimen reiän saa helposti täytettyä injektioruiskulla, Kuva 2-21.


Kuva 2-21. Absoluuttipaineanturin liittimen reiän täyttö akkuvedellä.

Absoluuttipaineanturin kapillaariputki pujotetaan läpi liitinosista, jonka jälkeen kapillaariputki liitinosineen työnnetään paikoilleen elektroniikkaputken alapäätykappaleessa olevaan reikään (Kuva 2-22). Samalla, kun kapillaariputken liitin työnnetään paikoilleen reikään, niin pitää katsoa että kapillaariputken toisesta päästä tulee vettä (Kuva 2-23). Jos liitin ei mene kunnolla reikään ja vettä ei tule kapillaariputken lävitse, on kapillaariputki tukossa.


Kuva 2-22. Kapillaariputki asennettuna paikoilleen.


Kuva 2-23. Kapillaariputken toinen pää.

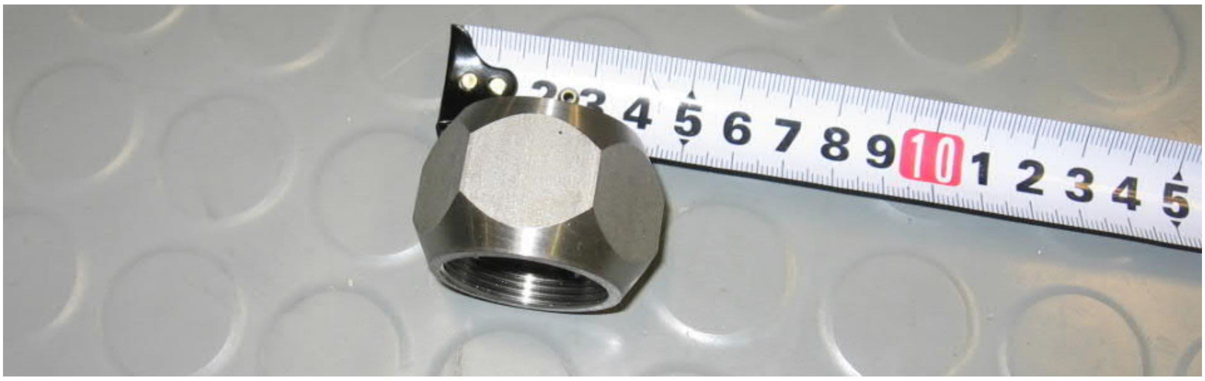
EC-elektrodi (Kuva 2-24) asennetaan paikolleen sen jälkeen, kun absoluuttipaineanturin kapillaariputki on asennettu paikoilleen. EC-elektrodi asennetaan paikoilleen toiseen (vapaana olevaan) Subconn-liittimeen elektroniikkaputken alapäätykappaleessa, Kuva 2-4. Ennen mittauksia EC-elektrodin pinnat tulee aina tarkistaa ja tarvittaessa puhdistaa karstasta. Puhdistaminen tehdään kevyellä vesihionnalla vesihiontapaperilla. Asennuksen jälkeen pitää varmistua siitä, että EC elektrodi ei pääse tulemaan ulos anturin rungon sisältä kiinnittämällä se nippusiteellä tai teipillä.

Kuva 2-24. EC-elektrodi ilman huppua ja holkkia.

Reikä-EC-mittauksissa käytetään 0.406 m jatkoputkea, jossa on keskitin ja avoin painolenkki, Kuva 2-25. Jatkoputki kiinnitetään väliholkin avulla hetulaputkeen, Kuva 2-26. Kaikkiin tässä kappaleessa mainittujen metallikierteiden väliin tulee laittaa ohut kerros Molykote 111 Compound -voitelusainetta.

Kuva 2-25. Painolenkki, 76 mm keskitin ja 0.406 m jatkoputki.

Jatkoputkien, väliholkin (Kuva 2-26), keskittimen ja avoimen painolenkin (Kuva 2-28) asennusjärjestyksellä ei ole merkitystä. Jatkoputken, väliholkin, keskittimen ja painolenkin voi koota aluksi valmiiksi kokonaisuudeksi tai liittää osa kerrallaan hetulaputken jatkoksi.



Kuva 2-26. Jatkoputkien väliholkki.

Reikä-EC-mittauksessa käytetään avointa painolenkkiä, Kuva 2-28. Avoin painolenkki mahdollistaa reiänsuuntaisen virtauksen Virtausero-mittarin läpi.

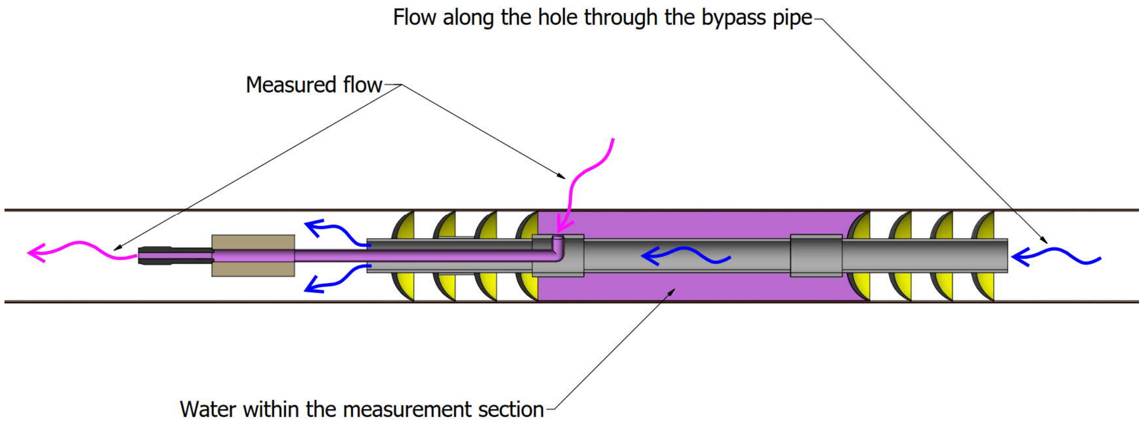
Kuva 2-27. Jatkoputki, keskitin ja painolenkki asennettu paikoilleen.

Kuva 2-28. Avoin painolenkki.

2.2 Anturin kasaaminen rakovirtausmittausta ja rako-EC mittausta varten

Mitattaessa mittavälistä tulevaa virtausta kaluston kasaaminen poikkeaa hieman edellä esitetystä. Tässä kappaleessa on esitetty poikkeavuudet. Alla olevassa kuvassa on esitetty PFL DIFF anturi rakovirtausmittaus kokoonpanossa (Kuva 2-29).

Kuva 2-29. PFL DIFF anturi rakovirtausmittaus kokoonpanossa.

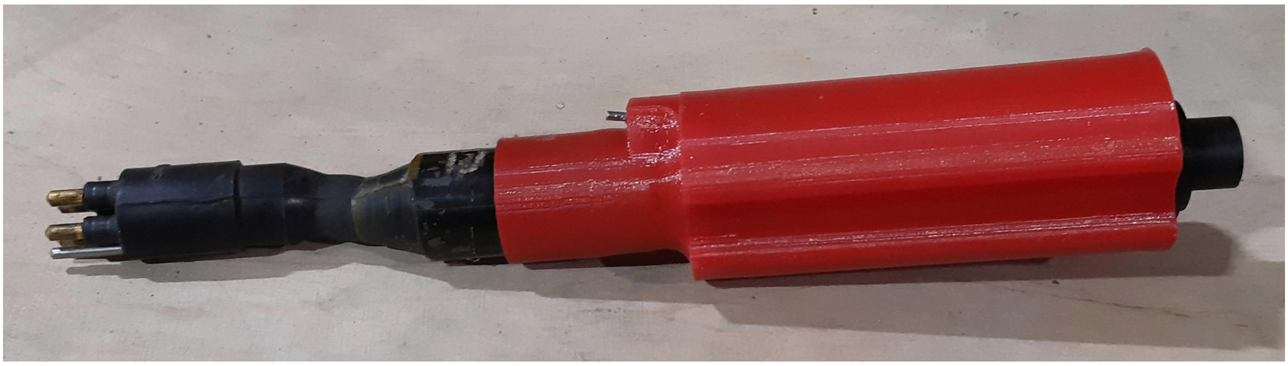


Kuva 2-30. Rakovirtauksen ja reiän suuntaisen virtauksen reitit virtausmittauksen aikana.

Mitattaessa mittavälistä tulevaa virtausta ylähetulaputken alapuolelle kiinnitetään virtausohjain joka ohjaa mittavälistä tulevan virtauksen virtausanturille ja päästää reiän suuntaisen virtauksen menemään virtausanturin ohi.

Painemittaus tehdään mittavälistä joten kapillaari putki pitää kiinnittää virtausohjaimeen. Kapillaariputken pujottaminen tehdään samalla tavalla kuin reikä-EC mittauksen kalustoasennuksessa, mutta nyt kapillaariputki kiinnitetään myös mittavälin puolelta. Kun kapillaariputki on kiinnitetty virtausohjaimeen täytetään paineanturin putki elektroniikkaputkessa vedellä kun edellä ohjeistettu ja katsotaan, että kapillaariputkesta tulee vettä virtausohjaimen puolella.

Rako-EC mittausta suoritettaessa halutaan varmistua, että pienetkin virtaukset kulkevat varmasti EC-elektrodin läpi. EC-eletrodin päälle asetetaan holkki joka yhdistää elektrodin ja virtausanturin näin kaikki vesi virtausanturilta tulee EC elektrodille. Elektrodin ja holkin päälle asennetaan vielä huppu mikä estää reikäveden ja rakoveden sekoittumisen (Kuva 2-31).



Kuva 2-31. EC elektrodin holkki ja huppu asennettuna elektrodin päälle.

Virtausohjaimen alapuolella kiinnitetään mittavälin putki. Putken pituus määrittyy mittaohjelmasta jossa määritetään miten pitkällä mittavälillä mittaus tehdään. Lyhin putkea käytettäessä mittavälin pituudeksi tulee 0.5 m. Suurin pituus voi olla jopa kymmenen metriä ja tällöin mittaväli koostuu useista putkista jotka liitetään yhteen kairareiässä yksitellen. Mittavälin alapuolelle kiinnitetään hetulat ja alakeskitin.

3 Kaapelin kiinnitys anturiin

Virtauseromittari, kuten Dummy-luotainkin kiinnitetään mittausperäkärryn vinssin kaapeliin. Vinssin kaapelissa on Gearhart-Owen -kaapelipääte (Kuva 3-1), joka kiinnitetään Dummy-luotaimessa tai Virtauseromittarissa olevaan vastakappaleeseen (Kuva 3-2). Ennen kaapelipäätteen kiinnittämistä Virtauseromittariin tai dummy-luotaimeen pitää tarkastaa, että kaapelipäätteen O-renkaat ovat kunnossa ja varmistettava etteivät ne leikkaudu asennuksessa. Vesitiiviyden varmistamiseksi laitetaan Molykote rasvaa o-renkaisiin ja neljään sähköliittimeen.

Kuva 3-1. Gearhart-Owen kaapelipääte.

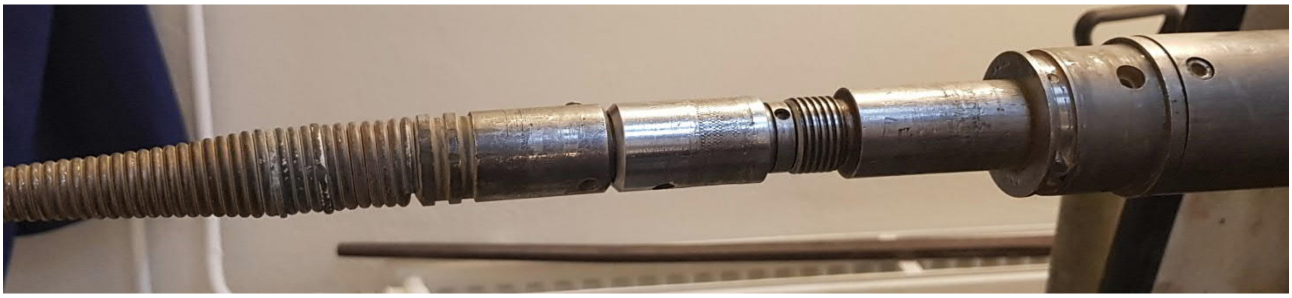
Kaapelipäätteessä on ohjuri, joka menee virtauseromittarin vastakappaleessa olevaan hahloon. Tällä varmistetaan, että kaapelipääte on liitetty virtauseromittariin oikeassa asennossa. Dummy-luotaimen vastakappaleessa ei ole hahloa, koska dummy-luotaimessa ei ole elektroniikkaa eikä näin ollen myöskään johtimia. Kaapelipääte sopii siis dummy-luotaimen vastakappaleeseen joka asennossa (kierto).

Kuva 3-2. Kaapelipäätteen vastakappale virtauseromittarin yläpäässä. Hahlo näkyy sisällä alareunassa.

Ennen kaapelipäätteen kiinnittämistä kaapelipääte tulee pujottaa irrallaan olevan Virtauseromittarin kivikupin läpi niin, että kivikupissa olevat kierteet jäävät yläpäähän, Kuva 3-3.

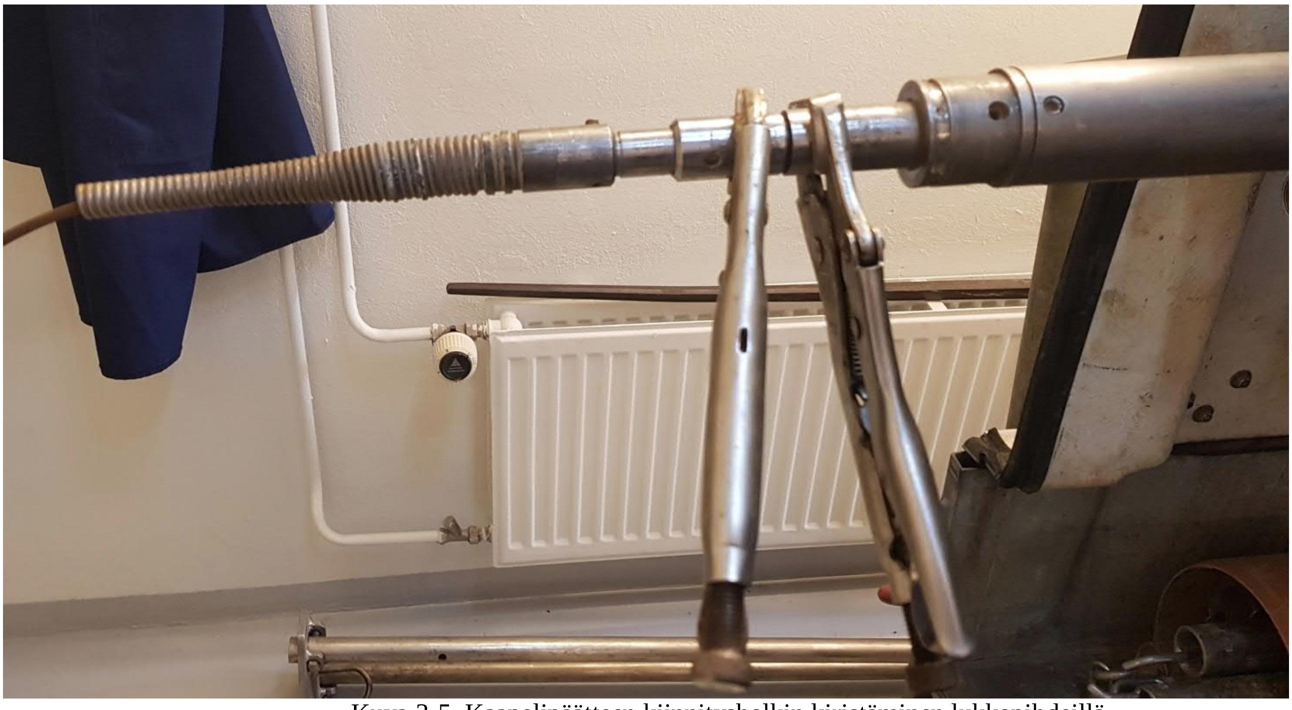
Kuva 3-3. Kaapeli ja kaapelipääte pujotettuna kivikupin läpi.

Kaapelipääte kiinnitetään virtauseromittarin vastakappaleeseen työntämällä kaapelipääte vastakappaleen pohjaan siten, että kaapelipäätteen uloke osuu vastakappaleen hahloon (Kuva 3-4). Sitten kaapelipäätteessä oleva holkki kierretään kiinni vastakappaleessa oleville kierteille.

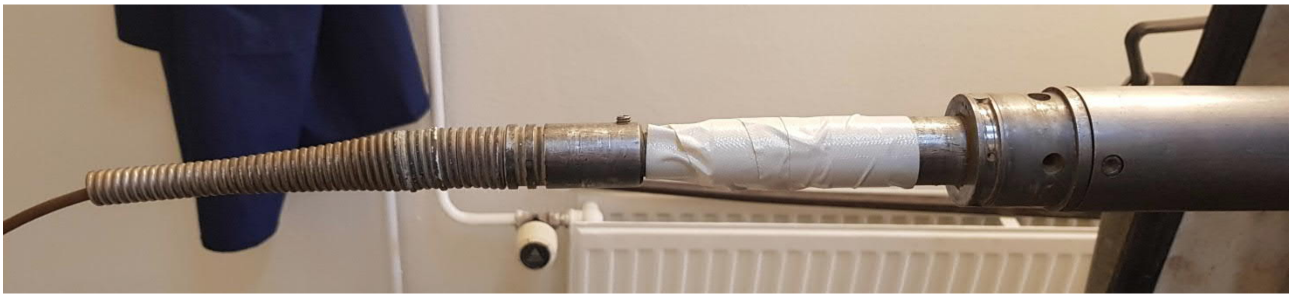


Kuva 3-4. Kaapelipääte asetettuna Virtauseromittarissa olevaan vastakappaleeseen.

Holkki kiristetään lukkopihtien avulla, niin että se ei pääse aukeamaan, Kuva 3-5. Auki kiertyminen estetään vielä laittamalla holkin ja vastakappaleen päälle ilmastointiteippiä (Kuva 3-6). Seuraavaksi laitetaan kivikuppi paikalleen ja kiinnitetään se kahdella kuusiokoloruuvilla (Kuva 3-7).



Kuva 3-5. Kaapelipäätteen kiinnitysholkin kiristäminen lukkopihdeillä.



Kuva 3-6. Kaapelipäätteen kiinnityksen varmistus teipillä.

Kuva 3-7. Kivikuppi asennettuna paikoilleen virtauseromittariin.

4 Anturin asennus kairareikään

Reikä-EC ja korkeintaan 0.5 m pitkällä mittavälillä varustettu anturi voidaan kasata valmiiksi ennen kairareikään asentamista. Jos käytetään pidempää mittaväliä, asennus suoritetaan siten, että painot alapäätykappale ja mittaväli asennetaan reikään ensin ja kiinnitetään anturi reiän suulla. Kiinnitettäessä anturi mittavälin putkiin reiän suulla pitää kiinnittää huomiota, että kaapeliin ei jää kierrettä sen jälkeen kun väliputki on kierretty kiinni. Alla on selostettu kokonaisen anturin asennus kairareikään.

Valmiiksi kasattu ja kaapeliin kiinnitetty virtauseromittari kiinnitetään reiässä olevaan ylimpään painoon. Ylimmässä painossa on sakkeli, joka kiinnitettään virtauseromittarissa kiinni olevaan painolenkkiin. Ennen virtauseromittarin nostoa ketjutaljan varaan tulee yläpään kivikupin kierteisiin kiinnittää pidike (Kuva 4-1), jossa on reiät L-raudalle ja lenkki ketjutaljan koukulle, ottaa vinssiltä ulos riittävästi kaapelia ja kiinnittää elektroniikkaputkenpihdit (Kuva 4-2). Virtauseromittarin laskun ja noston aikana tulee aina käyttää solumuovista tehtyä pehmustetta, joka tarvittaessa vaimentaa iskua, jos virtauseromittari jostain syystä pääsisi tippumaan reikään noston aikana. Pehmuste asetetaan reiän suulle tai virtausanturin suojaputken päälle hetuloiden yläpuolelle, Kuva 4-4.

Kuva 4-1. Pidike Virtauseromittarin kivikuppiin.

Kuva 4-2. Elektroniikkaputkeen asennettavat pihdit.

Elektroniikkaputkenpihdit kiinnitetään elektroniikkaputkeen, Kuva 4-3. Pihtejä ei saa laittaa elektroniikkaputken alaosaan kohtaan, jossa O-renkaat ovat, ettei elektroniikkaputki painu kasaan pihtien puristuksessa tältä kohtaa. Elektroniikkaputkenpihdit pitää kiristää paikoilleen riittävän kireälle, ettei virtauseromittari pääse luiskahtamaan pihdeistä laskun aikana.

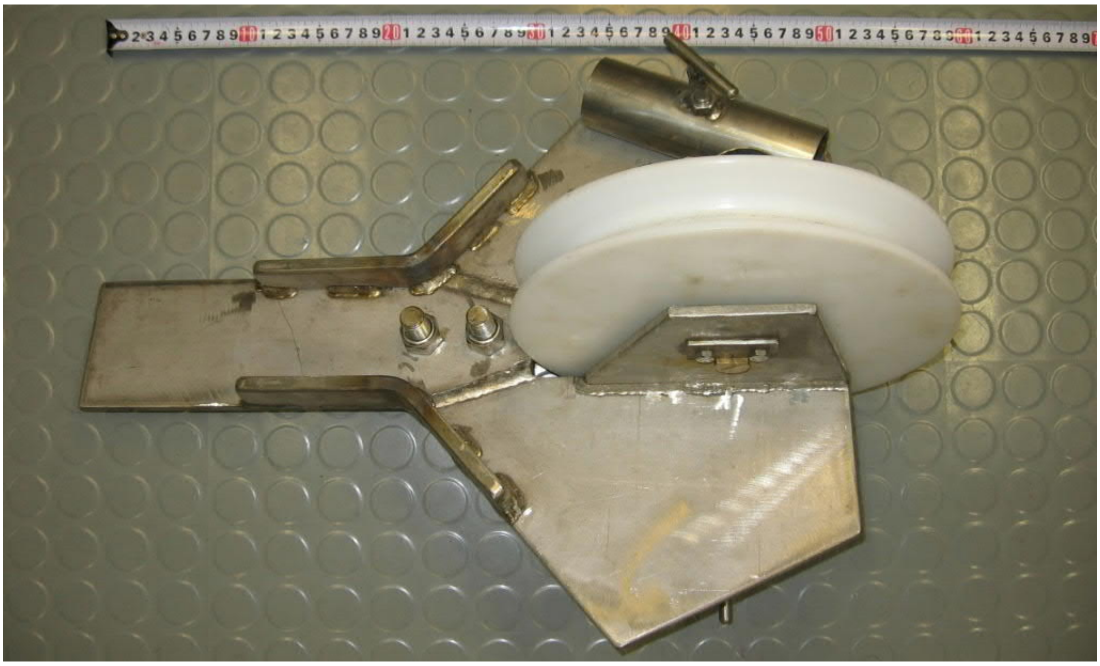
Kuva 4-3. Elektroniikkaputken pihdit paikallaan laskussa.

Virtauseromittari nostetaan roikkumaan ketjutaljan varaan anturiputken pihdeistä, Kuva 4-4. Poistetaan L-rauta reiän suulta painojen yläpuolelta ja lasketaan virtauseromittari reiän suulle elektroniikkaputken pihtien varaan. Seuraavaksi irrotetaan ketjutalja elektroniikkaputken pihdeistä ja kiinnitetään ketjutalja kivikupissa olevaan pidikkeeseen.

Sitten nostetaan virtauseromittaria sen verran, että saadaan anturiputken pihdit irrotettua. Kun elektroniikkaputken pihti on irrotettu, lasketaan virtauseromittari L-raudan varaan, joka on kivikupissa kiinni olevassa pidikkeessä.


Kuva 4-4. Anturin lasku reikään.

Mikäli suojaputken halkaisija on riittävän suuri, asetetaan taittopyörä (Kuva 4-5) suojaputken suulle virtauseromittarin roikkuessa L-raudan varassa reiän suulla. Taittopyörän runko kiinnitetään suojaputkeen kiristysliinalla, ettei taittopyörä pääse liikkumaan väärään asentoon. Sitten kiristetään vaijeri vinssiltä niin, että virtauseromittari jää roikkumaan vaijerin varaan. Nyt voidaan poistaa L-rauta ja laskea anturia reikään sen verran, että saadaan kivikupissa kiinni oleva pidike poistettua. Pidikkeen poistossa tulee varmistukseksi pidikkeen lenkkiin kiinnittää naru tai ketju, jonka toinen pää on kiinnitetty esimerkiksi taittopyörän runkoon, ettei pidike pääse tippumaan reikään.



Kuva 4-5. Taittopyörä.

Mikäli suojaputken halkaisija on niin pieni, ettei taittopyörää voida asentaa reiän suulle, niin että osa kivikupista ja siinä oleva pidike ovat vielä ulkona reiästä, pitää laskussa käyttää apuna jatkoputkien pihtejä, joissa on kaapeliinsovitusosat (Kuva 4-6) kiinni.

Kuva 4-6. Jatkoputkien pihdit ja kaapeliinsovitusosat.

Kaapeliinsovitusosat kiinnitetään jatkoputkien pihtiin kuusiokoloruuveilla. Lisäksi tarvitaan vielä taljaankiinnitysosa (Kuva 4-7). Jatkoputkien pihdit kaapeliinsovitusosineen kiristetään vaijerin ympärille ja pujotetaan taljaankiinnitysosa paikalleen, niin että vaijeri kulkee sen urassa ja pihdit ovat Kuva 4-7 näkyvän lenkin sisällä. Taljaankiinnitysosa kiinnitetään ketjutaljan koukkuun ja nostetaan virtauseromittaria ketjutaljalla (Kuva 4-8), niin että saadaan irrotettua kivikupista pidike ja L-rauta. Sitten ajetaan vinssillä kaapelia sisään sen verran, että saadaan ylimääräinen kaapeli sisään. Tämän jälkeen lasketaan ketjutaljalla virtauseromittaria reikään, niin että anturi jää roikkumaan kaapelin varaan. Kun virtauseromittari on kaapelin varassa, poistetaan taljaankiinnitysosa ja pihdit kaapelista.

Kuva 4-7. Taljaankiinnitysosa jatkoputkien pihteihin.

Kuva 4-8. Virtauseromittarin lasku kaapelista.

Joskus maanpäällinen suojaputki saattaa olla niin lyhyt, että siihen ei saa taittopyörää asennettua. Tällöin taittopyörän runkoon voidaan asentaa jalat, joiden varassa taittopyörää voidaan käyttää. Taittopyörä asennetaan siten että vaijeri menee taittopyörältä kairareikään mahdollisimman keskellä, Kuva 4-9. Taittopyörän runkoon tulee myös kiinnittää kiristysliina tai ketju, joka on toisesta päästä kiinni maassa lähellä reikää tai jossain kiinteässä esineessä trailerista nähden reiän takapuolella. Jos kairareikä lähtee esimerkiksi betonilaatasta, niin betonilaattaan voi porata reiän, johon voi ankkuroida koukun varmistusliinan/-ketjun kiinnitystä varten.

Kun virtauseromittari on saatu kairareikään, niin että kaikki pihdit, L-rauta ja kivikuppiin asennettava pidike on irrotettu, lasketaan virtauseromittari reikään syvyydelle, josta mittaus halutaan aloittaa. Matkalla aloitussyvyyteen tulee ensimmäinen keltainen teippi tai tussilla tehty kaapelin syvyysmerkki kohdistaa vinssin optiselle anturille ja mitata vinssin optisen anturin ja reiän suun välinen etäisyys.

Mittaus pyritään aloittamaan mahdollisimman ylhäältä, mutta kuitenkin siten, että vesipinta-anturi saadaan asennettua reikään paikoilleen ennen Reikä-EC-mittauksen aloittamista. Vesipinta-anturi kannattaa asentaa vähintään noin metrin vedenpinnan alle. Tällöin vesipinta-anturi on vielä vedessä, vaikka vesipinta reiässä hieman laskisi mittauksen aikana.

Kuva 4-9. *Taittopyörä tukijalkojen varassa.*

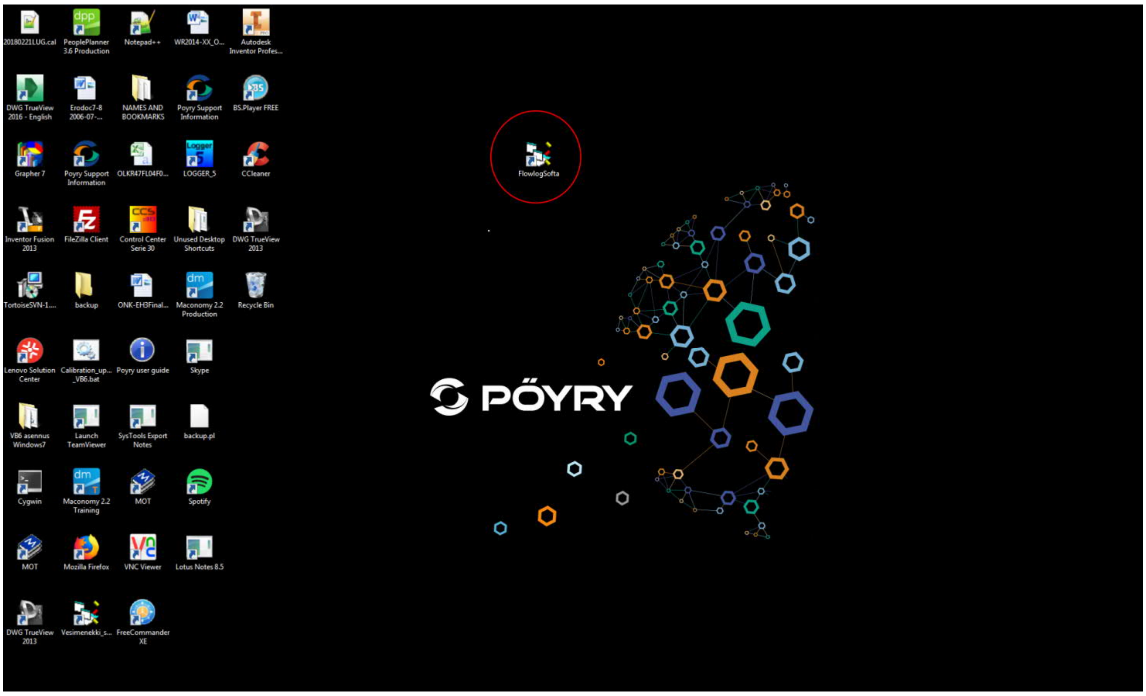
5 Mittauksen alkuvalmistelut

Tässä luvussa esitellään PFL-ohjelmiston ja vinssin käyttö mukaan lukien mittauksen aikana tehtävät tarpeelliset käytännön toimenpiteet. Kappaleessa esitetyt tiedostot ja kansiot ovat nimetty sen mukaan, että mittaukset tehtäisiin Olkiluodossa reiällä OL-KR41. Tällöin on helpompi ymmärtää mistä tiedostojen ja kansioiden nimet muodostuvat.

Reikä-EC-mittaus tehdään yleensä kairarei’issä sekä ylhäältä alas että alhaalta ylös. Mittaus vain toiseen suuntaan (ylhäältä alas) riittäisi, mutta koska se ei hidasta Virtauseromittarin siirtoa takaisin ylös, niin mittaus tehdään myös anturin ylös siirron aikana. Lisäksi pumppauksen aikana alhaalta ylös tehtävän Reikä-EC-mittauksen aikana tehdään pystyvirtausmittaus. Virtausmittaukset tehdään ylöspäin, ellei toisin määrätä mittausohjelmassa. Virtausanturia alas laskiessa voi tehdä reikä-EC mittauksen jos käytössä on pisarahetulat jotka mahdollistavat reikäveden pääsyn EC-elektrodille. Tämä mittaus ei ole täysin edustava, mutta jos mittaus tehdään jokaisella kaluston laskulla, voidaan saada tietoa reikäveden sähkönjohtavuusprofiilin muutoksesta mittauskampanjan aikana.

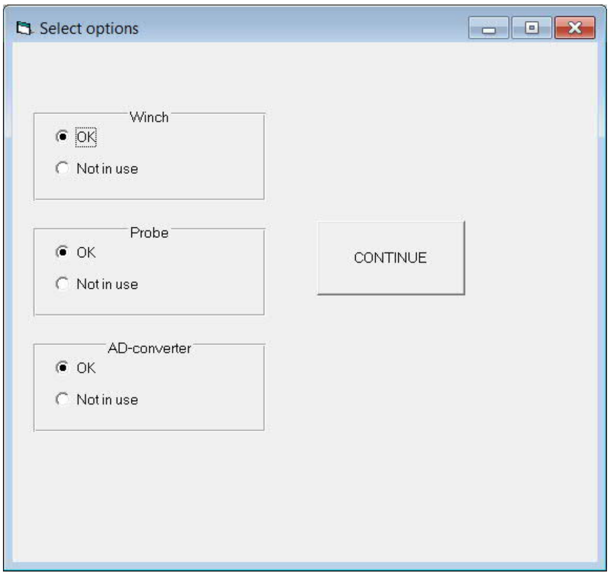
5.1 PFL-ohjelmiston käynnistys ja mittausvalmistelut

Aluksi mittakoneelta tulee käynnistää PFL-mittausohjelmisto. Ohjelmisto on helpointa käynnistää mittakoneen työpöydällä olevasta pikakuvakkeesta, Kuva 5-1.



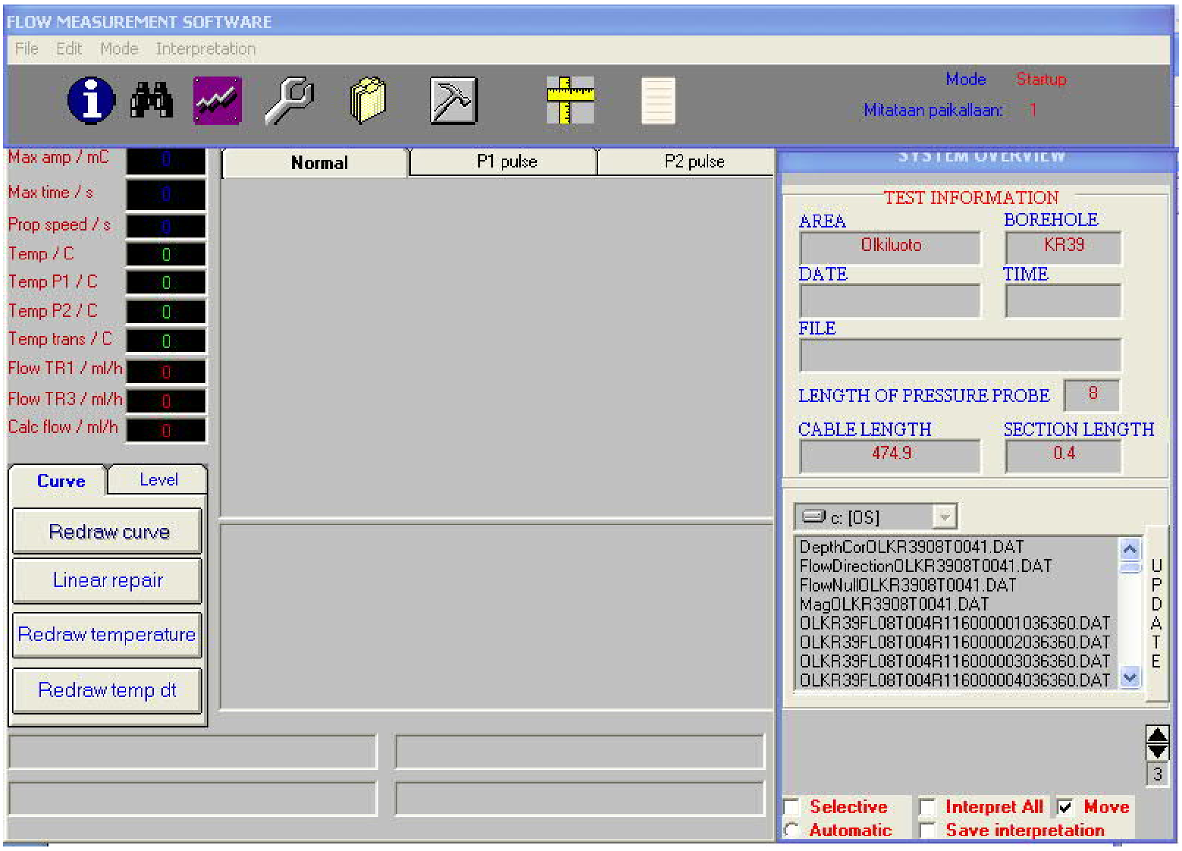
Kuva 5-1. Mittakoneen työpöytä. PFL-Mittausohjelmiston pikakuvake punaisen ympyrän sisällä.

PFL-mittausohjelmisto toimii Microsoft Visual Basic 6.0 ohjelmankehitysympäristön alla. Mittausohjelman polku on C:\FlowLog\FlowLogSofta\FlowlogSofta.Vbp. Kun PFL-Mittausohjelmisto on käynnistetty, painetaan F5-näppäintä tai Start-nappia ohjelman yläpalkista. Tällöin näytölle tulee Kuva 5-2 mukainen valikko. Kaikkiin kohtiin valitaan ”OK” ja painetaan ”CONTINUE”. Tällöin vinssi, Virtauseromittari ja AD-muunnin ovat käytössä. Toisin sanoen niiden portit ovat ohjelmassa auki.



Kuva 5-2. Select options -ikkuna.

Samalla aukeaa ohjelman pääikkuna, Kuva 5-3. Päänäytössä on ylimpänä valikkorivi. Valikkorivin alapuolella on työkalurivi, jossa on erilaisia kuvakkeita. Valikkorivin alapuolella vasemmalla on ohjelman piirto-osa ja oikealla ”System Overview” -ikkuna.



Kuva 5-3. PFL-Mittausohjelmiston päänäyttö.

Ennen kuin voidaan edetä PFL-mittausohjelmistossa eteenpäin, tulee mittakoneelle luoda tarvittavat mittauskansiot mittakoneen resurssienhallinnassa. Mittakoneelle luodaan kansio mitattavalle reiälle OLKR41. Tämän kansion alle luodaan Meas-kansio, joka on muotoa Measyyyymmdd, jossa y=vuosi, m=kuukasi ja d=päivä. Päivämäärä määräytyy mittausten aloituspäivän mukaan. Esimerkiksi jos mittaukset aloitettaisiin 31.5.2018, olisi Meas-kansion nimi Meas20180531.

Meas-kansion alle luodaan mittauskansio. Esimerkiksi reiällä OL-KR41 ilman pumppausta tehtävän Reikä-EC-mittauksen ensimmäisen toiston mittauskansion nimi olisi AOLKR41_005m_T1, jossa:

A = mittauksen kirjain alkuarvoissa
(A: reikä-EC-mittaus ilmanpumppausta
D: Reikä-EC-mittaus pumppauksella
B: Virtausmittaus ilman pumppausta
E: pidemmän mittavälin virtausmittaus pumppauksen aikana
G: virtausmittaus ja rako-EC mittaus pumppauksen aikana)

OLKR41 = reiän nimi

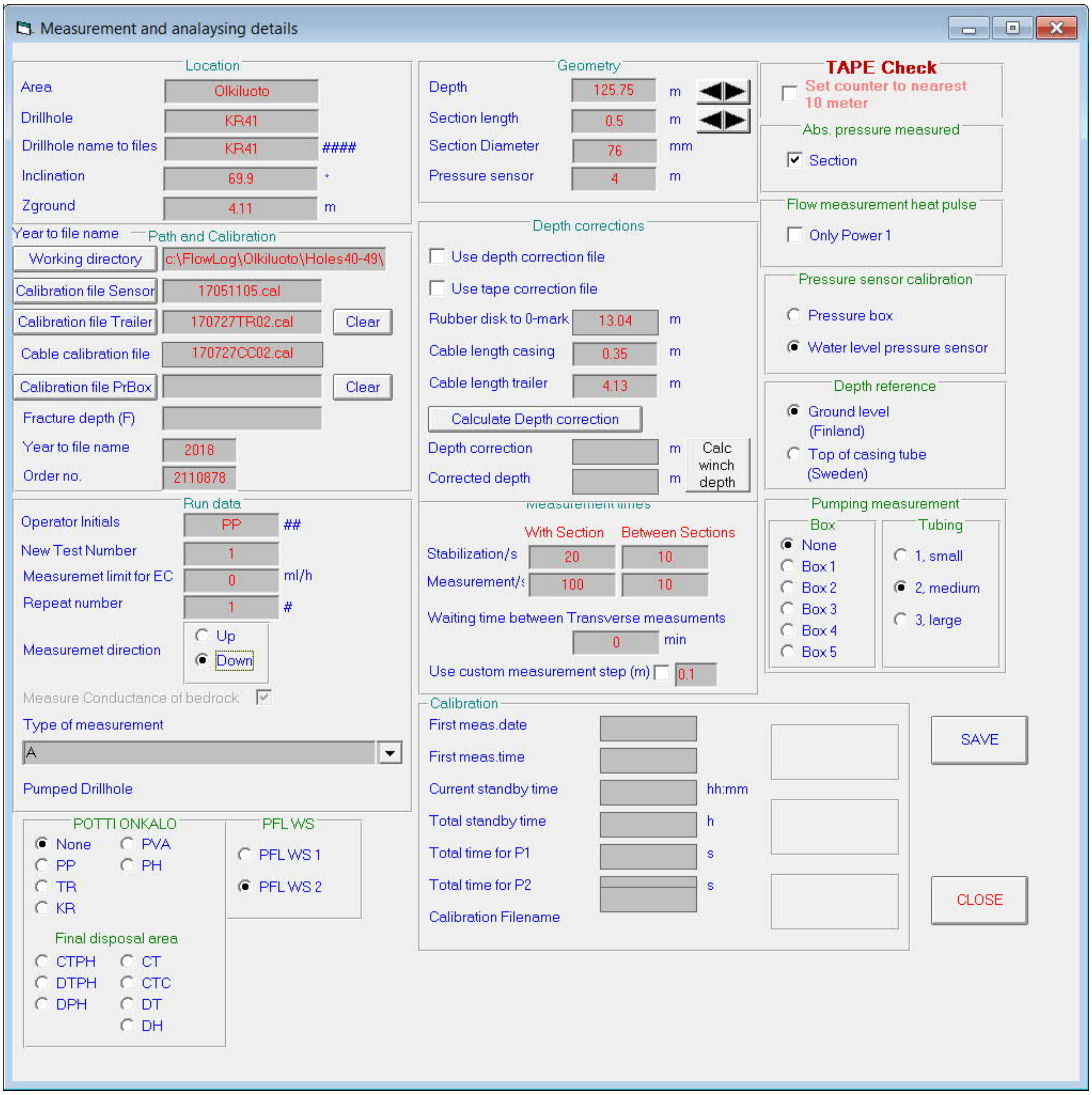
005m = mittavälin pituus kymmenissä senttimetreissä (jos ei käytetä alahetuloita tämä jää pois)

T1 = toiston numero

Mittauskansioon tulee kopioida alkuarvotiedot sisältävä Borehole.bin-tiedosto jostain aiemmasta mittauksesta. Mikäli mitattavalla reiällä on tehty aiemmin mittauksia, niin Borehole.bin-tiedosto kannattaa kopioida näiden mittausten kansiosta. Tällöin reiän nimi, kaade ja maanpinnan taso ovat todennäköisesti jo valmiiksi oikein. Nämä pitää kuitenkin aina tarkistaa.

5.2 Alkuarvot

Mittauskansion luomisen jälkeen mennään takaisin PFL-mittausohjelmistoon ja asetetaan sen työkansioksi juuri luotu mittauksen kansio. Työkansio valitaan menemällä PFL-Mittausohjelmistossa avaamalla valikkoriviltä ”Edit” ja Sieltä ”Starting values”. Tällöin avautuu ”Alkuarvoikkuna”-ikkuna (Kuva 5-4).



Kuva 5-4. Alkuarvoikkuna.

Alkuarvoikkunassa asetetaan mittauksen alkuarvot kuntoon, kuten muun muassa reiän tiedot, anturin kalibrointitiedostot, aloitussyvyys ja reikäpaineanturin syvyys. Tarkemmat selitykset alkuarvoikkunan tiedoista on esitetty Taulukko 5-1.

Taulukko 5-1 Alkuarvonäytön valinnat ja niiden selitykset.

Kenttä/Painike	Selitys
Location	
[illegible]r[illegible]	[illegible]
Dr[illegible]	M[illegible]r[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Path and calibration	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Run data	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
POTTI ONKALO	[illegible]
PFL WS	[illegible]
Geometry	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Depth corrections	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Measurement times	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Calibration	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
TAPE Check	
[illegible]	[illegible]
Abs pressure measured	
[illegible]	[illegible]
Flow measurement heat pulse	
[illegible]	[illegible]
Pressure sensor calibration	
[illegible]	[illegible]
[illegible]	[illegible]
Depth reference	
[illegible]	[illegible]
Pumping measurement	
[illegible]	[illegible]
[illegible]	[illegible]

SAVE	[illegible]
CLOSE	[illegible]

Alkuarvoikkunan avauduttua PFL-Mittausohjelmistoon **TÄYTYY EHDOTTOMASTI** asettaa ensin oikea mittauskansio, muuten alkuarvoihin asetetut tiedot ovat väärässä paikassa (kansioissa). Mittauskansio valitaan painamalla ”Working directory”-painiketta ja sitten valitaan mittauskansio.

Seuraavaksi käydään kaikki tarpeelliset kentät läpi aloittaen vasemmalta ylhäältä ”**Location**” -kentästä, jonne laitetaan paikka-, nimi- ja kaadetiedot. Reikätiedot pitää pyytää tilaajalta ennen mittausta. Reikätiedoista tärkeimmät ovat reiän nimi, reiän kaade ja reiän suun korkeustaso merenpinnasta.

Seuraavassa kentässä ”**Path and Calibration**” valitaan mittauskansion lisäksi virtauseromittarille ja mittauskärrylle (Trailerille) oikeat (viimeisimmät) kalibrointitiedostot. Lisäksi asetetaan mittausten tekovuosi ja tilausnumero. Tilausnumero ei ole tässä vaiheessa pakollinen tieto, mutta se on suositeltavaa kirjata alkuarvoihin jo tässä vaiheessa.

”**Run data**”- kenttään kirjataan operaattorin kirjaimet (Operator Initials), testinumero (New Test Number), virtausraja-arvo rako-EC mittaukselle (Measurement limit for EC), toiston numero (Repeat number), mittaussuunta (Measurement direction) ja mittauksen kirjain (Type of measurement)

”**POTTI ONKALO**” -kenttään laitetaan ”None”. Nämä on käytössä pelkästään ONKALO mittauksissa.

”**Geometry**” -kenttään tulee mittauksen aloitussyvyys (Depth). Syvyys, joka on vinssin matkamittarilla mittauksen alkaessa (Kuva 5-7). Mittavälin pituudeksi (Section length) ylä ja alahetuloiden välimatka. Reikä-EC-mittauksessa 0.5, vaikka sektoria ei varsinaisesti olekaan, kun käytössä on vain ylähetulat. Sektorin halkaisija (Section diameter) eli reiän halkaisija. Reikäpaineanturin etäisyys (Pressure sensor) suojaputken suulta.

”**Depth corrections**” valitaan molemmat ”Use depth correction file” ja "Use tape correction file". Tiedostot on käytössä jos tiedostot löytyy. Jos nimenomaan halutaan jostain syystä tulkita ilman syvyyskorjausta otetaan täppä pois. ”Cable length casing” -kohtaan merkataan suojaputken maanpäällisen osuuden pituus. ”Cable length trailer” -kohtaan laitetaan mitta, joka on etäisyys vinssin optiselta anturilta suojaputken/reiän suulle.

”**Measurement times**” -kenttään laitetaan stabilointi ja mittausajat virtausmittauksille sektorin välein (With Section) ja sektorin sisäisille (Between Sections) mittauksille. Eri mittauksille asetettavat ajat ovat alla. Jos E-mittauksessa on havaittu virtauksia kallioon päin, niin ajat ovat G-mittauksessa samat kuin E-mittauksessa, muutoin taulukon mukaan. Pidemmillä mittausajoilla saadaan selville virtauksen suunta myös pienimmillä virtauksilla.

	B		E		G	
	With	Betw.	With	Betw.	With	Betw.
Stabilization	50	20	20	2	2	10
Measurement	100	10	100	10	2	10

”**Calibration**” -kenttään ei tarvitse tehdä mitään ellei Virtauseromittaria oteta käyttöön ensimmäistä kertaa kalibroinnin jälkeen. Mikäli Virtauseromittari otetaan käyttöön ensimmäistä kertaa kalibroinnin jälkeen painetaan aluksi ”Set CAL file” -nappia. Tämä asettaa anturiin ” **Path and Calibration**” -kenttään asetetun (uusimman) Virtauseromittarin kalibrointitiedoston. Seuraavaksi painetaan ”Set time” -nappia, jolla anturi otetaan käyttöön (ajastin lähtee päälle).

”**TAPE Check**” Jos mitataan reikä ensimmäistä kertaa eikä ole aiempaa dataa johon mittaus voidaan syvyyskohdistaa tätä pitää käyttää. Jos mittauksen syvyyskohdistus tehdään aiempaan mittaukseen, tämä ole ei välttämätön, mutta voidaan tehdä.

”**Abs. pressure measured**” valitaan ”Section”

”**Pressure sensor calibration**” -kentän valinta tehdään sen mukaan käytetäänkö vesipinnan mittaukseen paineyksikköä (Pressure box) vai vesipinta-anturia (Water level pressure sensor). Nykyään yleensä käytössä on aina vesipinta-anturi.

”**Depth reference**” -kenttään valitaan syvyyskorjauksen referenssipiste, joko maanpinnan taso tai suojaputken suuaukon taso. Posivalla maanpinnan taso.

Mikäli tehdään mittausta pumppauksen aikana, ”**Pumping measurement**” -kenttään valitaan pumppausta mittaava tuottomittari (Box) sen numeron mukaan. Lisäksi valitaan myös mitä tuottomittarin linjaa (Tubing) käytetään. Mikäli ei käytetä pumppausta, ”Box” -valinta on ”None.”

Kun kaikki valinnat on tehty, painetaan ”SAVE”-nappia. Tällöin alkuarvot tallentuvat muistiin mittauskansiossa olevaan Borehole.bin-tiedostoon.

5.3 Vinssin käyttö ja mittausasetukset

Vinssiin laitetaan virrat päälle mittauskärryn takaosassa oikealla olevasta sähkökeskuksesta (Kuva 5-5). Aluksi pitää tarkistaa ettei Hätä-seis -nappi ole pohjassa. Sitten painetaan Hätä-seis kuittaus -painiketta (H-S KUITTAUS, Kuva 5-5) ja tämän jälkeen laitetaan virrat vinssille kääntämällä Hätä-Seis painikkeen alla oleva vipu START-asentoon, jolloin vinssille tulee sähköt. Vipu palautuu automaattisesti 1-asentoon, jossa sen myös tulee olla vinssiä käytettäessä.

Kuva 5-5. Mittakärryn sähkökeskus.

Vinssin optiselle anturille kohdistetaan lähin syvyysmerkki ja asetetaan sen mukainen lukema vinssin matkamittarille. Esim. jos kohdistetaan 10 m syvyysmerkki, niin asetetaan vinssin matkamittarille **10.00**. Matkamittarin lukeman voi asettaa joko PFL-Mittausohjelmistossa ”Winch” ikkunassa (Kuva 5-8) tai pyörittämällä käsin vinssin matkapyörää.

Kuva 5-6. Vinssin ohjausyksikkö.

Syvyysmerkin kohdistamisen (Kuva 5-7) jälkeen ajetaan Virtauseromittari mittauksen aloitussyvyydelle ja asetetaan syvyys alkuarvoihin. Tässä vaiheessa on syytä muistaa, että mittauksen aloitussyvyys on oltava vesipinta-anturin alapuolella. Myös vesipinta-anturi kannattaa tässä vaiheessa asettaa paikoilleen. Vesipinta-anturin johto kannattaa kiinnittää esimerkiksi nippusiteellä taittopyörän runkoon jotta vesipinta-anturi pysyy oikealla syvyydellä.

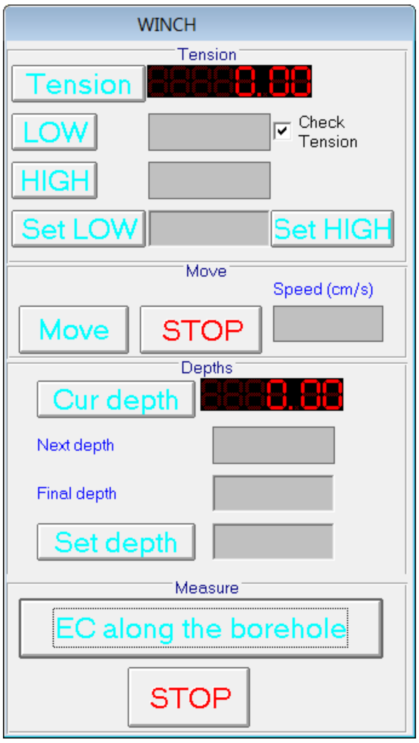

Kuva 5-7. Syvyysmerkki vinssin optisella anturilla.

Vinssin ohjausyksikölle (Kuva 5-6) tulee asettaa oikeat asetukset ennen mittauksen aloittamista, jotta vinssiä voidaan ohjata PFL-mittausohjelmiston kautta mittauksen aikana. Ohjausyksikössä on vipu, jolla valitaan ”Local” tai ”Computer.” Local-valinnalla vinssiä ohjataan manuaalisesti ylös tai alas (suunta valitaan UP / DOWN -kytkimestä) säätämällä vinssin nopeutta ohjausyksikössä olevasta potentiometristä

(Kuva 5-6). Computer-valinnalla vinssiä voidaan ohjata PFL-mittausohjelmiston kautta. Tällöinkin vinssin nopeus määritetään säätämällä potentiometriä, mutta vinssin liike voidaan pysäyttää tai käynnistää PFL-mittausohjelmiston kautta. Ohjausyksikössä on vielä valintavipu ”Remote” Tai ”Local” asetukselle. Remote-valinnalla vinssiä voidaan liikuttaa ohjausyksikössä kiinni olevan kaukosäätimen kautta. Kaukosäätimeltä saa valittua suunnan ja lisäksi siinä on myös oma potentiometri, jolla voi säätää nopeutta. Tämä vipu tulee asettaa Local-asentoon, jotta vinssiä voidaan ohjata PFL-mittausohjelmistolla.

Potentiometrillä säädettävä nopeus on kokeiltava erikseen. Sopiva nopeus Reikä-EC-mittaukselle on noin 10 cm/s. Virtausmittausten aikana käytetään 2 cm/s nopeutta. Nopeuden näkee PFL-mittausohjelmiston ”Winch”-ikkunasta ja sitä voi säätää kesken mittauksen.

Mittausohjelmiston ”Winch” -ikkunaan (Kuva 5-8) asetetaan kaapelin jännityksen ala- ja ylärajat, mittauksen lopetussyvyys sekä varmistetaan virtauseromittarin oikea syvyys aloitushetkellä.



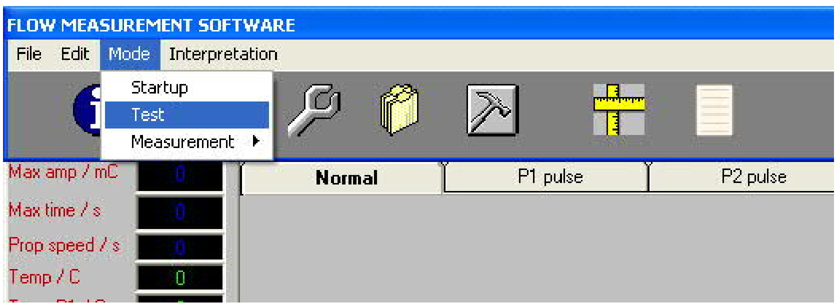
Kuva 5-8. Winch-ikkuna. Näkyvissä olevat painikkeet riippuvat valitusta mittauksesta.

”Winch” -ikkunan toiminnot	
Tension	Näyttää kaapelin jännityksen (kg).
Low	Näyttää kaapelin jännityksen alarajan (kg).

High	Näyttää kaapelin jännityksen ylärajan (kg).
Set Low / High	Ala- ja ylärajat asetetaan kirjoittamalla haluttu arvo ruutuun ja painamalla haluttua painiketta.
Move	Liikuttaa anturin asetettuun syvyyteen.
STOP	Pysäyttää vinssin liikkeen.
Cur depth	Painike päivittää näytölle anturin syvyyslukeman. Näytölle päivittyy anturin syvyyslukema siirtojen aikana.
Next depth	Näyttää Virtauseromittarin siirron tai maadoitusvastusmittauksen kohdesyvyyden. Virtauseromittauksessa, automaattimittauksen ollessa valittuna, tässä näkyy seuraavan mittauspisteen syvyys. Ei ole editoitavissa.
Final depth	Tähän kenttään asetetaan haluttu syvyys, jolle anturin siirto, maadoitusvastusmittaus, automaattinen erovirtausmittaus tai Reikä-EC-mittaus lopetetaan.
Set depth	Painikkeella asetetaan vinssille haluttu syvyys (esim. teipin kohdistuksen yhteydessä).

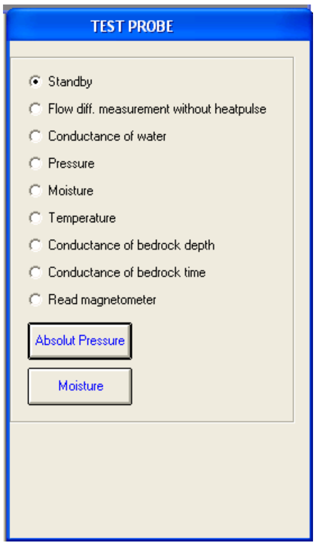
5.4 Virtauseromittarin ja vesipinta-anturin testaus

Vielä ennen mittauksen aloittamista tulee testata Virtauseromittarin toiminta. Virtauseromittarin toimintojen tarkistaminen tapahtuu klikkaamalla ”Mode” → ”Test” (Kuva 5-9). Reiässä olevasta virtauseromittarista tulee tarkastaa signaalit niiltä osin, kun se on mahdollista. Reiässä olevasta virtauseromittarista voidaan testata signaalit: Flow diff. measurement without heatpulse, Conductance of water, Temperature, Conductance of bedrock depth, Absolut pressure (painike) ja Moisture (painike). Testatessa tulee katsoa, että signaalit toimivat ja niiden arvot näyttävät järkeviltä. Reiässä olevan virtauseromittarin testauksen yhteydessä pitää testata myös reiän vesipinta-anturin toiminta.

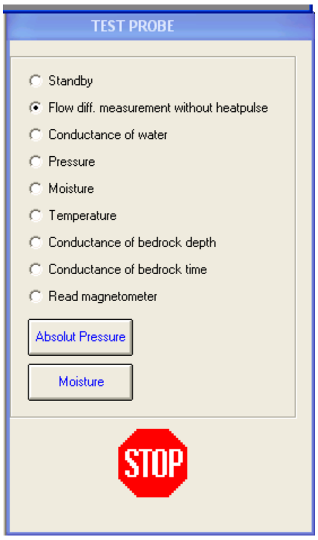


Kuva 5-9. Test mode -valinta.

Valitsemalla "Test" -tila avautuu näytölle automaattisesti ”Test Probe” -ikkuna (Kuva 5-10 ja Kuva 5-11). ”Test Probe” -ikkuna saadaan auki myös painamalla työkaluriviltä ”Test” -näppäintä (Kuva 5-9).



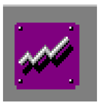
Kuva 5-10. Test probe -ikkuna.



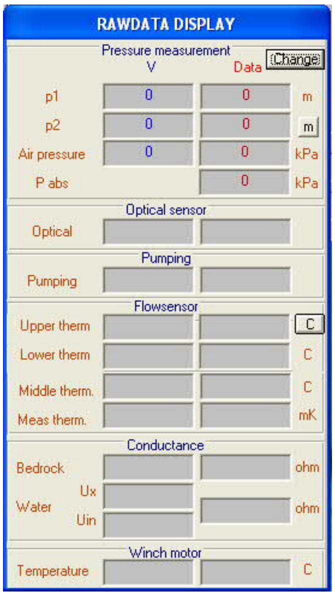
Kuva 5-11. Test probe -ikkunan lopetuspainike.

Test probe -ikkunassa valitaan yksi testattava kohde kerrallaan, jolloin myös testauksen lopetuspainike ”STOP” tulee aktiiviseksi (Kuva 5-11). Testattavat signaalit ja tarkemmat ohjeet testaukseen silloin kun anturi ei ole reiässä on esitelty luvussa 5.5

Signaalit (Taulukko 5-2) tarkistetaan painamalla ”Työkalut/RawData” (Kuva 5-12). Avautuvaan ”RawData Display” -ikkunaan (Kuva 5-13) tulostuvat sekä kalibroimattomat että kalibroidut arvot.



Kuva 5-12. RawData-ikkunan valintapainike.



Kuva 5-13. Rawdata-ikkuna.

Taulukko 5-2. Rawdata display.

KENTTÄ	V	DATA	SELITYS
[illegible]			[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Taulukko 5-3. Rawdata display:n Pressure box -tila.

KENTTÄ	V	DATA	SELITYS
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

5.5 Testattavat signaalit

”Test Probe” -ikkunasta valitaan testattavat signaalit, jotka selostetaan seuraavassa.

<u>Flow diff. measurement without heatpulse:</u>

Mittaus on sama kuin virtausmittauksen stabilointivaiheessa, jonka aikana mitataan mittaustermistorien välistä lämpötilaeroa. Aina mittauksen alussa ensimmäinen piste asetetaan nollatasoksi, jonka jälkeen muut lukemat ovat suoraan lämpötilaeroa alkuun nähden. Toimivuus on helpointa testata puhaltamalla virtausanturin sisään anturin ollessa ilmassa, jolloin lukemien tulisi muuttua hyvin voimakkaasti.

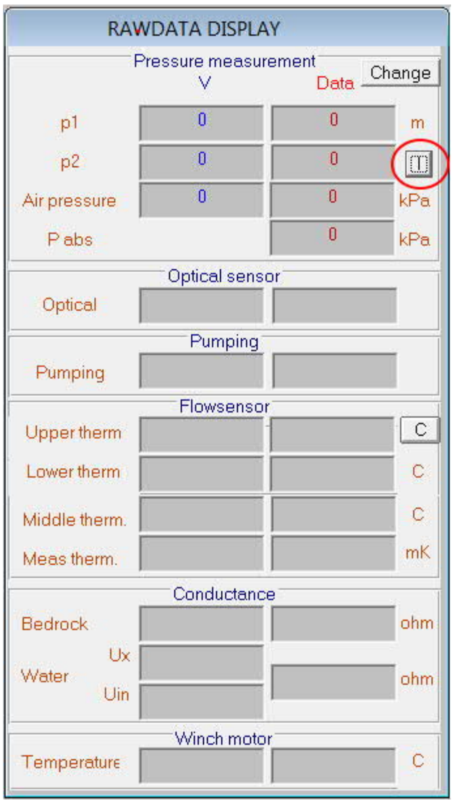
<u>Conductance of water:</u>

Mitataan veden sähkönjohtavuutta nelipiste-elektrodilla, jolloin sekä elektrodiin syötettävä virta (Uin) ja mittauselektrodien välinen jännite (Ux) mitataan. Elektrodin testaaminen tapahtuu ainoastaan sähkönjohtavuudeltaan tunnetussa nesteessä. Ilmassa elektrodin toimivuutta ei voi luotettavasti testata.

<u>Pressure:</u>

Reikäveden pinnan mittaamiseen tarkoitetut paineanturit (p1 tai p2) ovat 4–20 mA:n virtalähettimellä varustettuja. Virta syötetään analogiakortin liittimellä olevan vastuksen yli, jossa virtaviesti muutetaan jännitteeksi. Vastukset on sovitettu siten, että kortilla mitattava maksimijännite 10 V ei ylity.

Reikäveden pintaa mittaavan paineanturin eli vesipinta-anturin testaus tehdään asettamalla vesipinta-anturi halutulle syvyydelle kairareikään ja asettamalla tämä syvyys ”Starting values” -ikkunaan sille tarkoitettuun kohtaan. Sitten painetaan ” Flow diff. measurement without heatpulse” -painiketta, jolloin myös vesipinnan syvyys päivittyy ”RawData display” -ikkunassa. Vesipinnan esitystavaksi pitää valita ”RawData display” -ikkunassa vesipinnan etäisyys reiän suulta. Tämä tapahtuu painamalla ”RawData display” -ikkunassa Kuva 5-14 näkyvää punaisella ympyröityä painiketta, niin että siinä näkyy ”□”, kuten kuvassa. Jos kyseisen painikkeen kohdalla on ”□”, niin tällöin näytöllä on pystysuoran vesipatsaan korkeus (m) vesipinta-anturin päällä. Lopuksi verrataan vesipintamittarilla mitatun ja ”RawData display” -ikkunassa olevan vesipinnan arvoja. Vesipinta-anturin näyttämä arvo tulee olla ±10 cm vesipintamittarilla mitatusta arvosta.



Kuva 5-14. RawData display -ikkunan vesipinnan näytön valinta.

Ilmanpaineanturi (Air pressure) lähettää jänniteviestin 0–5 V, mikä vastaa ilmanpainetta välillä 800–1600 mbar.

Moisture:
Toimivuus testataan ainoastaan anturiputken ollessa avoimena. Elektroniikkakortin alapäässä on kosteusanturi, johon puhaltamalla ja sen jälkeen kuivalla ilmalla tuulettamalla pitäisi muutoksen näkyä.

Temperature:
Mitataan virtausanturin sisällä olevilla termistoreilla lämpötilaa. Puhaltamalla suoraan virtausanturiin nähdään lämpötilan muuttuminen. Mikäli Virtauseromittari on vedessä, niin termistoreiden pitäisi näyttää veden lämpötilaa 0.1 asteen sisällä toisistaan.

Conductance of bedrock depth:
Mitataan yksipistevastusta ja samanaikaisesti liikutetaan anturia vinssin avulla. Ennen mittauksen aloittamista alkuarvoissa täytyy olla aloitussyvyys ja ”Winch/Final Depth”-kentässä lopetussyvyys.

Conductance of bedrock time:

Mitataan yksipistevastusta ilman anturin liikuttamista. Mittauksen kesto on sekuntipohjainen. Anturin ollessa ilmassa voidaan tarkistus suorittaa kytkemällä erisuuruisia vastuksia hetuloiden välissä olevan elektrodin ja anturin rungon välille. ”RawData” -ikkunassa oleva kalibroitu tulos pitäisi olla sama kuin vastuksen vastusarvo yleismittarilla mitattuna.

Absolut pressure (painike):
Anturiputken sisällä olevan absoluuttipaineanturin (Pabs) tulos kilopascaleina.

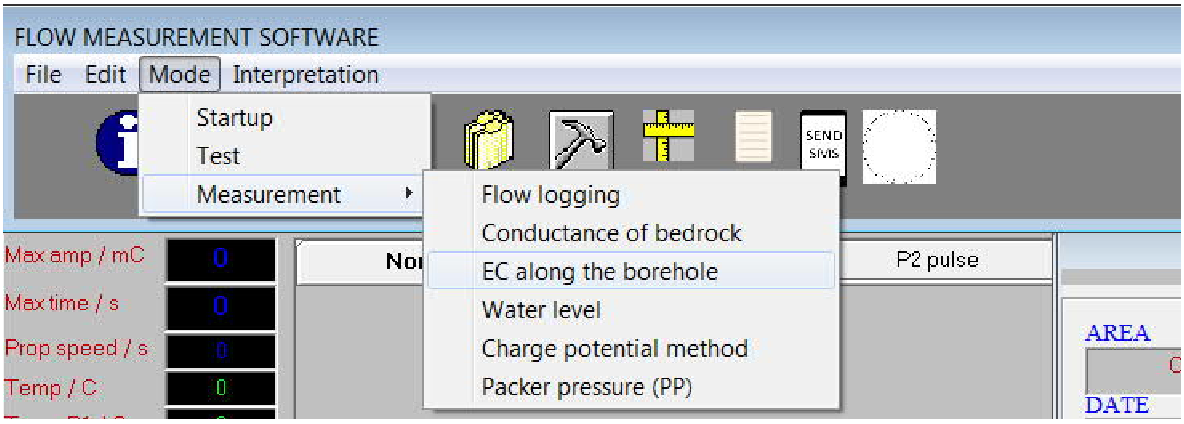
Moisture (painike):
Elektroniikkaputken sisällä on Päällä/Pois -tyyppinen kosteusindikaattori, mikä on asennettu lähelle elektroniikkaputken alapäätä. Jos anturin sisällä on kosteutta, niin muodostuu virtasilmukka elektroniikan kautta maadoitukseen. Painiketta painettaessa saadaan seuraavanlaiset ilmoitukset:
”Moisture sensor alarms !!!” elektroniikkaputkessa on kosteutta.
”No moisture in the tool !” elektroniikkaputkessa ei ole kosteutta.

6 Mittaaminen PFL-ohjelmistolla

Seuraavassa on esitetty mittauskohtaiset ohjeet mittauksen suorittamiseen. Alkuarvojen asettaminen on ohjeistettu kappaleessa 5 joten tässä vaiheessa oletetaan alkuarvojen olevan oikein.

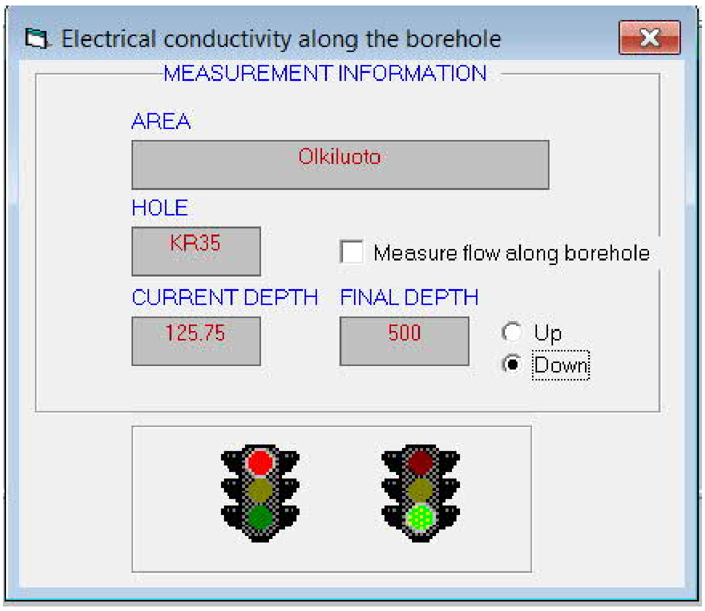
6.1 Reikä EC-mittaus ja reiän suuntaisen virtauksen mittaus (A ja D mittaukset)

Reikä-EC mittaustila valitaan työkaluriviltä ”Mode → Measurement → EC along the borehole” (Kuva 6-1). Tällöin avautuu ”Winch” -ikkuna (Kuva 5-8). Tässä vaiheessa asetetaan mittauksen lopetussyvyys ja klikataan painiketta ”EC along the borehole” Seuraavaksi avautuu ”Electrical conductivity along the borehole” -ikkuna (Kuva 6-2), jossa varmistetaan vielä aloitus- ja lopetussyvyys sekä mittaussuunta. Jos mitataan reiän suuntainen virtaus valitaan "Measure flow along borehole". Tiedot hyväksytään ja mittaus aloitetaan klikkaamalla vihreää liikennevaloa.



Kuva 6-1. Mittauksen valinta.

Ennen mittauksen käynnistystä pitää valita mitataanko Reikä-EC-mittauksen aikana pystyvirtausmittausta vai ei. Tämä tapahtuu ”Measure flow along borehole” check box -valinnalla. Jos laatikossa on merkki, niin pystyvirtaus mitataan, muuten ei. Oletusarvona laatikossa on merkki, jolloin pystyvirtaus mitataan. Oletuksena on, että reiän suuntainen virtaus mitataan noin 2 m välein. Mittaussuunnaksi valitaan alhaalta ylöspäin ”Up” tai ylhäältä alaspäin ”Down”.



Kuva 6-2. Electrical conductivity along the borehole -ikkuna.

kun asetettu lopetussyvyys on saavutettu, mittaus pysähtyy automaattisesti. Ylhäältä alas tehtävässä mittauksessa reikä mitataan yleensä pohjalle saakka. Poikkeustapauksissa, jos esimerkiksi tiedetään että reiässä on jokin este, voidaan mitata vain osa reiästä. Ylöspäin mitattaessa pitää varmistaa, ettei mitata liian ylös. Normaalisti reiässä käytetään reikäpaineanturia ja näin ollen Reikä-EC-mittaus pitää lopettaa reikäpaineanturin alapuolelle, ettei Virtauseromittari osu reikäpaineanturiin.

Mikäli alaspäin tehdyn mittauksen lopetussyvyys on asetettu siten että, Virtauseromittari ei ole mennyt pohjalle saakka, voidaan reikä mitata loppuun asettamalla uusi lopetussyvyys, joka on niin syvällä, että Virtauseromittarin menee pohjalle saakka. Sitten mittaus pysäytetään PFL-Mittausohjelmiston ”STOP” -napista, kun anturi tulee pohjalle.

Reikä-EC-mittauksen valmistuttua pitää lopuksi tarkistaa lähimmän kaapelin syvyysmerkin ja vinssin matkamittarin välinen ero. Ero tarkistetaan liikuttamalla kaapelia (Virtauseromittari liikkuu mukana), niin että syvyysmerkki ajetaan vinssin optisen anturin kohdalle. Nyt verrataan matkamittarin lukemaa syvyysmerkkiin. Esimerkiksi jos matkamittarin lukema on 390.43 kun 390 m:n syvyysmerkki on optisen anturin kohdalla, niin ero on 43 cm. Tämä kirjataan ylös reikäkohtaiseen Hole.txt muistioon ja asetetaan matkamittarin lukemaksi 390.00 seuraavan mittauksen aloitusta varten.

6.2 Virtausmittaus mittavälistä (B, E ja G mittaukset)

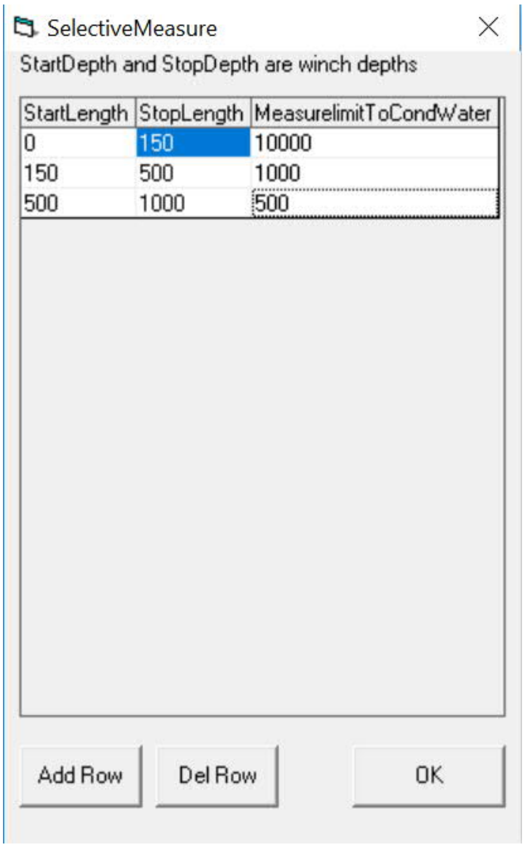
Virtausmittauksen mittaustila valitaan työkaluriviltä ”Mode → Measurement → Flow logging” (Kuva 6-1). Tällöin "System Overview" ilmestyy "Start New measurement" painike. Ennen mittausta asetetaan mittauksen lopetussyvyys "Winch" -ikkunaan. Kuva 6-3 "Automatic" pitää valita jotta mittaus jatkuu automaatilla lopetussyvyyteen asti. Kaksoisklikkaamalla "Automatic" täppää voidaan valinta poistaa ja silloin jokainen virtausmittaus piste pitää aloittaa klikkaamalla "Start New measurement". "Move" valittuna vinssi siirtää anturia jokaisen virtausmittauksen välillä. Jos "Move" ei ole valittuna anturi ei siirry uuteen syvyyteen vaan mittauksia tehdään useita samalla syvyydellä.

Kuva 6-3. Virtausmittauksen aloituspainike.

"Start New measurement" painikkeen klikkaamisen jälkeen mittaus alkaa. Virtausmittauksen aikana mittausdataa ei kannata kopioida omalle koneelle tulkintoja varten vaan mittaus tulee pysäyttää kopioinnin ajaksi. Mittaus voidaan pysäyttää kaksoisklikkaamalla "Automatic" täppää anturin liikkumisen aikana jolloin anturi siirtyy uuteen mittauspisteeseen, mutta virtausmittaus ei ala. Tässä vaiheessa data voidaan kopioida ja kopioinnin jälkeen mittausta jatketaan asettamalla "Automatic" täppä ja klikkaamalla "Start New measurement".

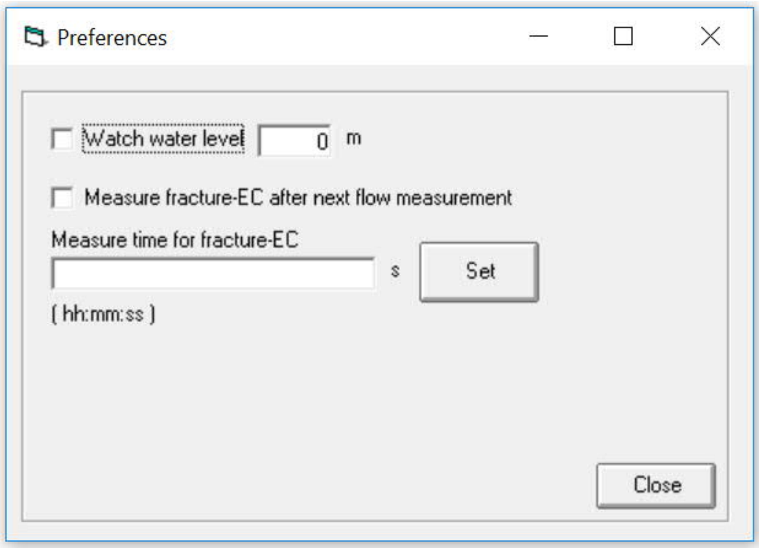
6.3 Rakoveden sähkönjohtavuusmittaus

Rakoveden sähkönjohtavuusmittaus on yleensä osa lyhyellä mittavälillä pumppauksen aikana suoritettavaa mittausta. Ennen mittauksen aloitusta pitää määrittää mistä raoista veden sähkönjohtavuus mitataan. Käytännössä tämä tehdään asettamalla raja rakovirtaukselle mistä suuremmista virtauksista sähkönjohtavuus mitataan. Jos käytetään samaa rajaa koko reiässä, se voidaan asettaa alkuarvoissa kohtaan "Measurement limit for EC" (Kuva 5-4). Jos raja vaihtelee syvyyden mukaan, raja asetetaan taulukkoon syvyyden perusteella klikkaamalla "Selective" (Kuva 6-3). Tämä aukaisee ikkunan "SelectiveMeasure" (Kuva 6-4) johon asetetaan raja-arvot halutuille syvyysväleille. Pidemmällä mittavälillä tehdyn mittauksen perusteella voidaan raja-arvot määrittää vaikka rakokohtaisesti, mutta tarkkoja syvyysrajoja määritettäessä tulee muistaa, että taulukoon annettavat syvyydet ovat vinssin syvyyksiä eikä todellista syvyyttä joten syvyyskorjaus tulee ottaa huomioon.



Kuva 6-4. Rako-EC mittauksen virtausraja-arvojen määrittäminen syvyysväleille.

Automaattimittauksen aikana rako-EC mittaus alkaa kun virtausraja-arvo ylittyy neljässä peräkkäisessä pisteessä jolloin rako on vielä mittavälissä. Rako-EC mittausaika määrittyy sen mukaan, että mittavälissä oleva vesimäärä ehtii vaihtua kolme kertaa ennen kuin mittaus jatkuu eteenpäin reiässä. 0.5 m mittaväliä käytettäessä mittavälin tilavuus on 1825 mL. Joissain tapauksissa EC arvo ei tasaannu tässä ajassa ja on tarpeen pidentää aikaa. Rako-EC mittauksen ollessa päällä mittausajan voi asettaa haluamakseen valitsemalla päävalikosta "Edit → Preferences" josta aukeaa "Preferences" -ikkuna (Kuva 6-5). Kohtaan "Measure time for fracture-EC" kirjoitetaan aika sekunteina ja Klikataan "Set". Asettamalla lyhyen ajan voidaan lopettaa EC-mittaus ko. raolla, jos esimerkiksi anturi on pysähtynyt väärälle raolle tai pitkästä virtausanomaliasta johtuen rako-EC mittaus on alkanut samalla raolla uudestaan. Rako-EC mittauksen ollessa päällä jäljellä olevan ajan näkee softan pääikkunasta.



Kuva 6-5. Preferences-ikkuna

6.4 Pumppauksen mittaus

Kairareikää pumpatessa pumppausmäärä (L/min) pitää mitata. Virtausmittauksen ollessa päällä pumpun tuottomittarin lukema tallennetaan automaattisesti, mutta alkuarvoissa pitää olla asetettu tuottomittarin numero ja käytetty kanava. Pumppauksen aloitus- ja lopetusajat pitää tallentaa tiedostoon Meas20180531/PumpingRateAutomatic/PumpingTime.DAT. Tiedostossa pitää olla aloitus- ja lopetusajan lisäksi myös kaikki pumppauksen keskeytykset, koska tämän tiedoston (Kuva 6-6) tietojen mukaan tehdään pumppausdatan käsittely.

```
Date,Time,Start/Stop
19.04.2013,9:05,Start
29.04.2013,15:32,Stop
29.04.2013,16:49,Start
13.5.2013,15:49,Stop
```

Kuva 6-6. Pumppauksen aloitus ja lopetus aikojen tiedostomuoto.

6.5 Vesipintamittaus

Erityisesti kairareiän pumppauksen aikana ja muutenkin koko mittauskampanjan aikana on hyvä tallentaa kairareiän vesipinnan taso myös silloin kun virtaus- tai EC-mittausta ei ole käynnissä. Tätä varten voidaan tallentaa vesipinta dataa halutulla taajuudella. Mittaus käynnistetään päävalikosta ”Mode → Measurement → Water level”. Tämän valinnan jälkeen softa kysyy mittaustaajuutta mikä valitaan sen mukaan miten nopeita muutoksia on odotettavissa. Jos pumppaus on juuri käynnistetty, on tarkoituksen mukaista tallentaa minuutin välein, mutta jos vesipinta on tasaantunut ja mitataan pidemmän ajan yli, noin 10 minuuttia on riittävä taajuus. Mittaus tallentaa ilmanpaineen ja kairareiän vesipinnan tason sekä paineen anturin syvyydellä jos anturi on reiässä.

7 Tulkinta

Tulkintoja tehdään maastossa ja toimistolla. Maastossa tulkintojen tarkoituksena on varmistua siitä, että mittaukset on tehty oikein ja kalusto on toiminut. Mittauksissa voidaan joutua tekemään uusintamittauksia jos tulokset eivät ole täysin kunnossa. Tämän päätöksen pohjana on maastossa tehdyt tulkinnat. Toimistolla tulkintoja jatketaan mittausten jälkeen. Selvää rajaa maastotulkintojen ja toimistotulkintojen välillä ei kuitenkaan ole vaan ajan salliessa lähes kaikki tulkinnat on mahdollista tehdä jo maastossa. Maastotulkinnoiksi merkityt tulkinnat on minimivaatimus maastossa tehtäville tulkinnoille.

7.1 Maastotulkinnat

Meas-kansion alle tehdään Maastotulkinta-kansio, joka on seuraavan näköinen:

\MaastoTulkinta
- \DraftResults (mittausten aikana lähetetyt tulospaketit)
- \FlowLogging (kaikki Grapher-kuvat ja csv-tiedostot)
- \Tarkastuslista (laadunvarmennuksen tarkastuslista)

Käytännössä kansio kopioidaan soveltuvan vanhan mittauksen Tulkitut-kansiosta, jolloin vanhat Grapher-kuvat tulevat pohjiksi uusille kuville. Jos muutoksia kuvapohjiin on tullut paljon, voi joutua hakemaan uusimpia kuvapohjia useastakin vanhasta mittauksesta. Uudet kuvat voi tehdä esim. avaamalla aluksi kuvan, poistamalla näkyvistä (huom! älä poista kokonaan) muut vanhat käyrät, vaihtamalla uuden datatiedoston (csv) vanhan tilalle ja sen jälkeen poistamalla vielä vanhan datatiedoston. Jos joku käyrä unohtuu tässä prosessissa vaihtaa, niin kuvaa uudelleen avatessa Grapher pyytää uutta datatiedostoa, koska vanhaa ei enää löydy. Jos näin käy, niin Grapherin kysymykseen ei saa missään nimessä vastata ”No”, koska silloin koko käyrä poistuu kuvasta. Pahimmassa tapauksessa kuvapohjasta voi tulla lähes käyttökelvoton. Tästä työtavasta saatava etu on se, että Grapher-kuvaan tehtävien muutoksien määrä pystytään tällä tavalla pitämään mahdollisimman pienenä, ja kaikista kuvista tulee mahdollisimman samanlaisia eri reikien välillä.

7.1.1 Reikä-EC (A ja D-mittaukset)

Valitse aluksi mittaussoftan alkuarvoista työhakemistoksi mittauskansio (Edit – Starting Values – Working directory). Tämä pitää tehdä aina jokaiselle mittaukselle, kun niiden tulkinta aloitetaan. Kaikki tulkitut tiedostot tulevat tähän samaan kansioon, josta ne kopioidaan Maastotulkinnan FlowLogging-kansioon.

Ennen tulosten käsittelyä mittauskansiosta tulee löytyä myös elevation-tiedosto jossa on kairareiän taipumatieto (Z-koordinaatti kairareiän pituuden suhteen). Tyhjä elevation-tiedosto tehdään valikosta "Interpretation → Make elevation file". Tiedosto täydennetään taipumatiedoilla ja valmis tiedosto on alla olevan mukainen (Kuva 7-1). Tiedostoon tulee merkitä mistä taipumadata on saatu. Jos taipumatietoa ei ole saatavilla tulkinta tehdään ilman tiedostoa jolloin tulokset lasketaan olettaen, että kaade säilyy samana reiän alusta loppuun.

```
Maxibor_lis_OLKR40_ver2.txt,2006-11-16 from Tomas Lehtimäki/JP-Fintact Oy,Data: MAXIBOR SURVEY
Depth(m),Elevation(masl)
0,4.15
3,1.33
6,-1.5
9,-4.31
12,-7.12
15,-9.93
18,-12.73
```

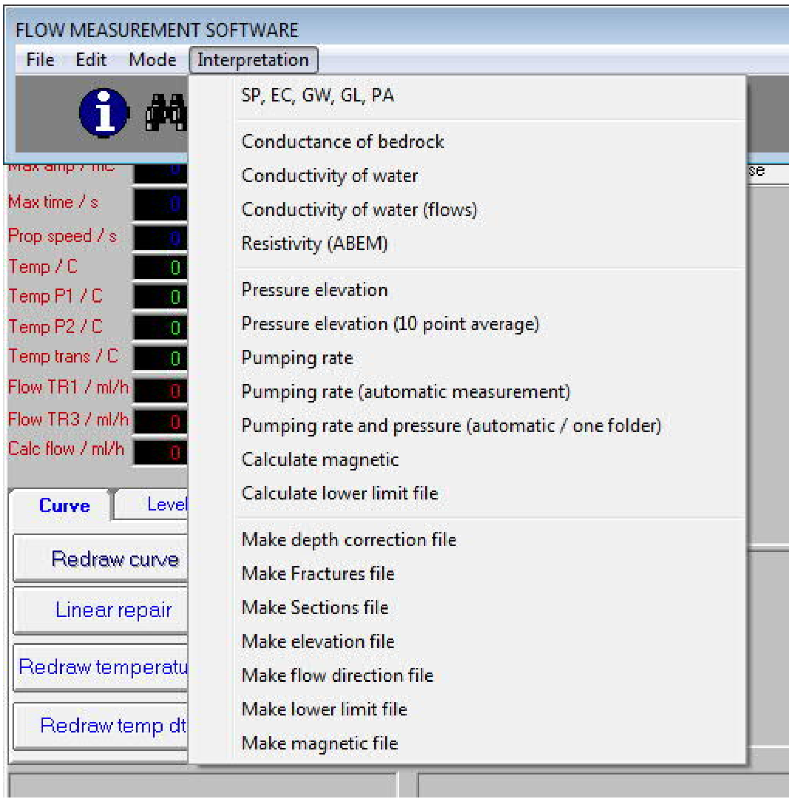
Kuva 7-1. Esimerkki elevation-tiedostosta.

Tulkinnoissa ensimmäinen tehtävä on syvyyskorjauksen kirjaaminen syvyyskorjaus tiedostoon. Tiedoston pohja tehdään valitsemalla "Interpretation → Make depth correction file" Reikä-EC mittauksen syvyyskorjaus tehdään lineaarisesti koko mitatulle matkalle. Mittauksen alussa korjaus on nolla koska on tehty teipin kohdistus ennen mittauksen aloitusta. Lopetus syvyys määritetään ajamalla vinssillä teippi optisen anturin kohdella ja katsotaan mikä on etäisyys lähimpää kymmenlukuun.

Jos esim. A-mittauksen toistossa 1 (mitattu ylhäältä alas) nollateippi on kohdistettu ja 500 m teipin kohdalla vinssin lukema on 499.16 m, niin korjaus 500 m syvyydellä on silloin -0.84 m. Tässä tapauksessa syvyyskorjaustiedoston sisältö olla alla kuvatun mukainen (Kuva 7-2).

```
Depth(m),Correction(m)
0,0
500,-0.84
```

Kuva 7-2. Esimerkki reikä-EC mittauksen syvyyskorjauksesta.



Kuva 7-3. Tulkinta-valikko.

Itse tulkinta tehdään valitsemalla tulkittavat suureet mittausohjelman Interpretation-valikosta (Kuva 7-3). Interpretation-valikosta valitaan tulkittavaksi Conductivity of water (veden sähkönjohtokyky) ja Pressure elevation (paine).

Automaattinen pumppausdata tulkitaan Interpretation-valikon kohdasta Pumping rate and pressure (automatic / one folder). Tulkinta vaatii sen, että PumpingRateAutomatic-kansioon (softan tekemä kansio) on täytetty PumpingTime.dat-tiedostoa. Siihen merkitään pumppauksen aloitukset ja lopetukset (Kuva 6-6).

Tulkitut csv-tiedostot siirretään Maastotulkinta-kansion alle FlowLogging-kansioon ja plotataan data Grapher kuviin. Kuviin pitää plotata EC, lämpötila, painekorkeus (masl), vesipinnan taso (masl), ilmanpaine, pumpun tuotto ja EC-elektrodin karsta. Reiän suuntaisen virtauksen mittaus tehdään yleensä osana D-mittausta, mutta sen tulkinta on selostettu muiden virtausmittausten yhteydessä.

7.1.2 Virtausmittaus ilman pumppausta (B-mittaus)

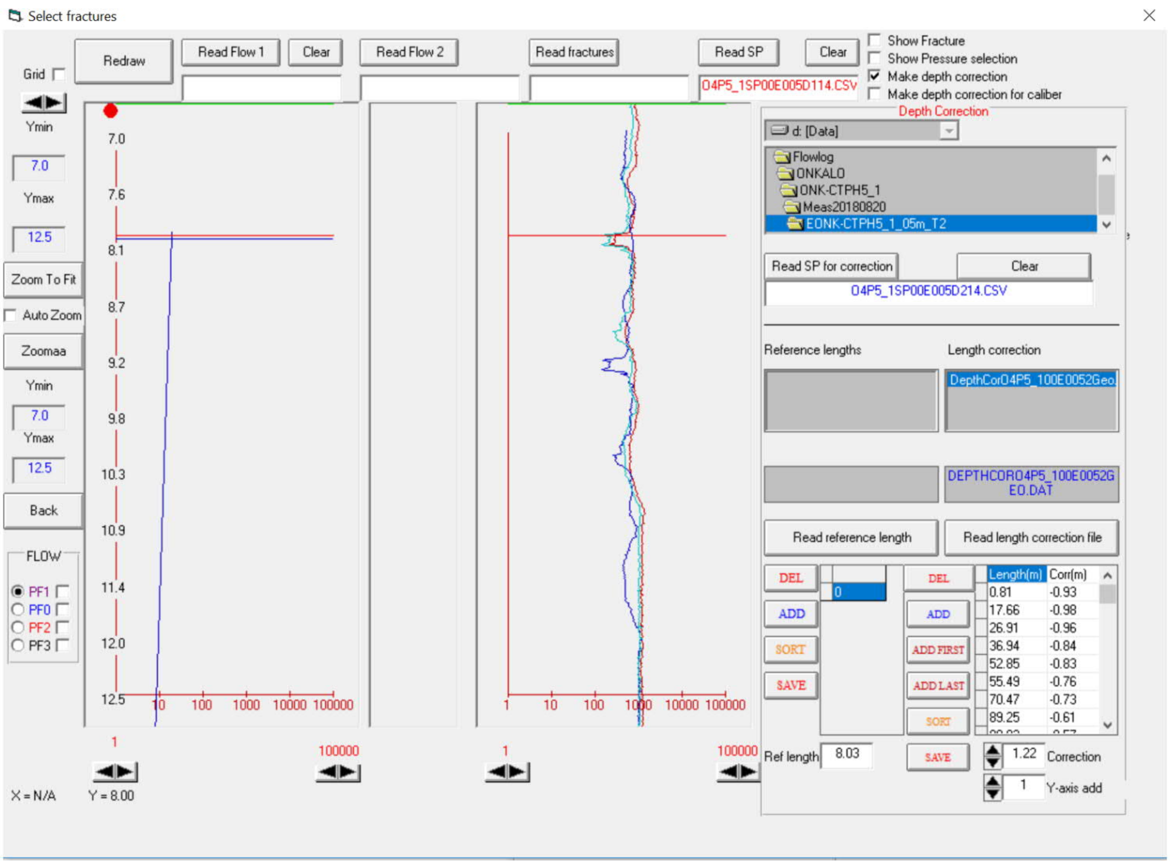
Virtausmittaus ilman pumppausta on mittauskampanjan ensimmäinen mittaus jossa tehdään SPR-mittaus, joten on mahdollista, että syvyysreferenssitietoa johon mittauksen voisi syvyyskohdistaa, ei ole. Syvyysreferenssi voi kuitenkin olla muukin kuin virtausmittaus esim. geofysiikan soveltuva mittaus. Jos referenssitietoa ei ole tulosten syvyys tulee pelkästään PFL laitteiston vinssin syvyydestä.

Käytettäessä pelkästään vinssin matkamittarin lukemaa syvyystiedon määrittämiseen alkuarvoissa tulee olla määritettynä "Use tape correction file". Tätä pitää käyttää jos mittauksen aikana kaapelin syvyysmerkkejä on käytetty vinssin matkapyörän lukeman kohdistukseen. Jos syvyysmerkit on kohdistettu mittauksen aikana, mutta tulkinnassa ei käytä teippi tiedostoa syvyyskohdistus ei toimi.

SPR tulkinta tehdään valitsemalla Interpretation - Conductance of bedrock. Tuloksena on tiedosto OLKR46SP06B020D105.CSV.

Syvyysreferenssin ollessa käytössä SPR mittaustulos kohdistetaan referenssiin. Syvyyskorjauksessa haetaan SPR datasta anomalioita jotka toistuvat samanlaisina eri mittauksissa ja ne on helppo kohdistaan toisiinsa. Mittauskampanjan ensimmäinen mittaus jossa on mitattu SPR, voidaan kohdistaa geofysiikan dataan tai ennalta tunneituihin kairareiän ominaisuuksiin, jos ne voidaan luotettavasti havaita SPR mittauksella. Mittauskampanjan seuraavat mittaukset kohdistetaan ensimmäiseen mittaukseen jolloin kaikki PFL DIFF mittaukset on kohdistettu keskenään.

Softalla tehdään kyseiselle mittaukselle syvyyskorjaustiedoston pohja (Interpretation – Make depth correction file). Syvyyskorjaus aloitetaan syvyyskorjausikkunassa laittamalla aluksi täppä kohtaan Make depth correction. Seuraavaksi luetaan napeilla Read SP referenssimittaus ja Read SP for correction syvyyskorjattava mittaus (tässä järjestyksessä!). Tämän jälkeen valitaan syvyyskorjaus tiedosto valitsemalla tiedosto kohdasta "Length correction" ja klikkaamalla Read length correction file. Kuva 7-4 referenssimittaus on punaisella, syvyyskorjaamaton mittaus sinisellä ja syvyyskorjattu mittaus vaalean sinisellä.



Kuva 7-4. Syvyyskorjaus ikkuna

Yllä (Kuva 7-4) on tilanne, jossa korjausta on aloitettu tekemään kohtaan 8.03 m. Syvyys on valittu asettamalla punainen viiva SPR anomalian kohdalle klikkaamalla haluttua syvyyttä. Sen jälkeen kohdistetaan punaisen ja vaalean sinisen datan anomaliat samaan kohtaan asettamalla korjaus kohtaan "Correction". Kun datat on kohdistettu keskenään klikataan ADD ja Save jolloin syvyyskorjaus tiedostoon tallentuu haluttu syvyyskorjaus halutulle syvyydelle. Syvyyskohdistus tehdään koko reiän syvyydeltä vertaamalla havaittuja SPR anomalioita ja asettamalla ne kohdalleen syvyyskorjauksella. Syvyyskorjauspisteiden välillä softa tekee syvyyskorjauksen lineaarisesti ottaen huomioon kaksi viereistä syvyyskorjaus pistettä. Alla on esitetty syvyyskorjaustiedon malli.

Depth(m),Correction(m)
0,0
49,0.01
100,0.02
149,0.055

200,0.03
250,0.075
300,0.11
353,0.145
400,0.17
435,0.15
438.57,0.15

Syvyyskorjaus pisteiden pitää kattaa koko mittausalue. Tästä syystä ylimmän ja alimman syvyyskorjaus pisteen pitää olla mittausalueen ulkopuolella. Kun syvyyskorjaus on valmis, kaikki mittausdatat pitää tulkita uudestaan läpi syvyyskorjaustiedostoa käyttäen. Tämä pätee siis aina jokaiseen syvyyskorjattuun mittaukseen. Jos syvyyskorjauksessa on virhe, niin uusi korjaus pitää tehdä alkuperäisen, syvyyskorjaamattoman SPR-käyrän perusteella.

Virtaustulkinta
Virtaustulkinta tehdään System Overview-ikkunassa (Kuva 7-6). Aluksi valitaan Interpret All ja Save Interpretation, jonka jälkeen klikataan ylintä datatiedostoa (merkitty nuolella kuvassa). Tämän jälkeen avautuvasta Select interpretation-ikkunasta valitaan Positive, negative and direction files. Jos tulkintaa joskus tehdään uudestaan, niin silloin kannattaa myös valita Overwrite old files, ettei tule vahingossa tiedostoja, joissa sama data esiintyy kaksi kertaa tms. Tulkinta tuottaa kolme virtaustiedostoa. Alla esimerkki tiedostojen nimistä.

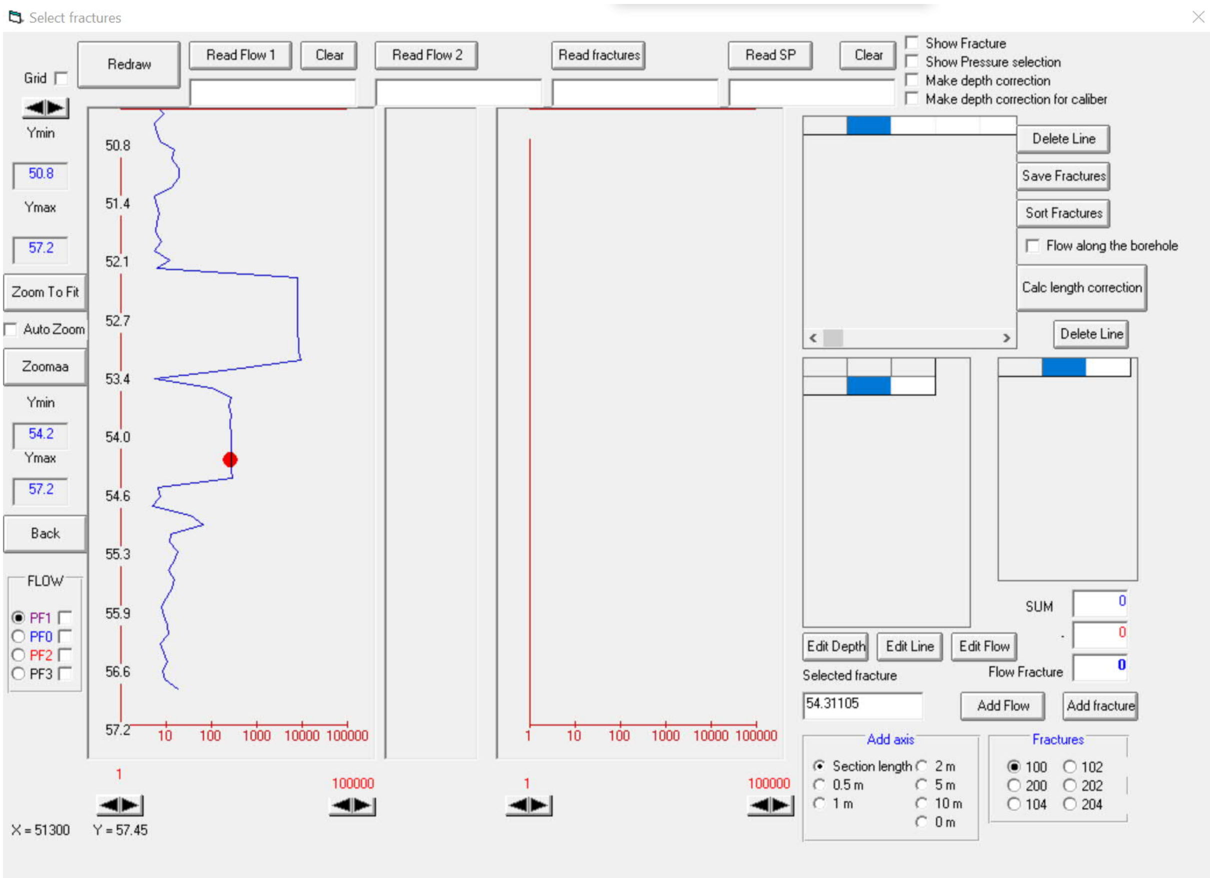
OLKR46FL02B020C105.CSV
OLKR46FL02B020S105.CSV
OLKR46FL02B020S105_GRF.CSV

C-tiedosto sisältää virtausten lisäksi paljon teknistä tietoa mittauksista. C-tiedostoa käytetään mm. ns. kontrollikuvien tekoon. S-tiedostoon virtausten suunnat on taas merkitty suuntatiedoston mukaisesti, ja sitä (GRF-versiota) käytetään virtauskuvissa.

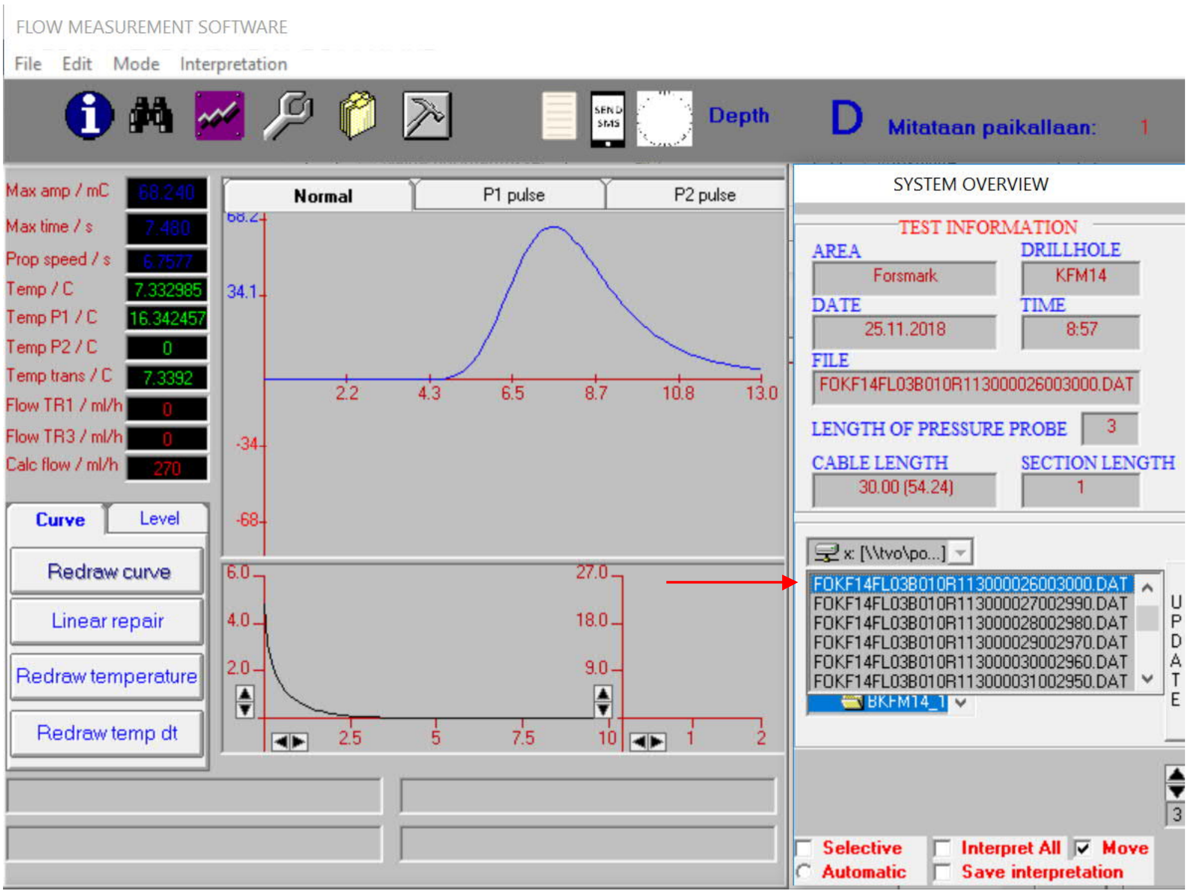
Ensimmäinen tulkinta on tehty ilman virtauksen suuntatiedostoa jotta saadaan selville rakojen paikat. Seuraavaksi katsotaan virtausten suunnat jotta virtausten suuruudet voidaan tulkita. Virtaussuunnat määritellään virtausmittauksen lämpöpulssin mukaan. Virtaustulkinnan aikana pidetään auki softan "Select fractures" -ikkuna jolloin ikkunaan piirtyy virtaus syvyyden funktiona (Kuva 7-5). Virtauksen suunta nähdään klikkaamalla virtausanomaliaa (punainen piste kuvassa) jolloin "System Overview" ikkunaan tulee ko. virtausmittauksen lämpöpulssi (Kuva 7-6). Tässä tapauksessa virtaus on positiivinen eli kalliosta reikään. Negatiivisen virtauksen tapauksessa pulssi on alaspäin.

Virtaussuunnista tehdään suuntatiedosto Interpretation-valikon Make flow direction file (FlowDirection…. .DAT), johon merkitään korjattu syvyys, jossa suunta vaihtuu sekä virtauksen suunta (P=Positive eli virtaus kalliosta reikään, N=Negative eli virtaus reiästä kallioon). Suunnan muutos pyritään tekemään tasan 20 m:n kohdalle (220, 560, 780), jolloin mahdollinen ”saumakohta” tulee sivun vaihdon kohdalle. Kannattaa varmistaa, että virtaustiedoston tiedot kattavat reiän koko sen syvyydeltä. Kun suuntatulkinta on valmis, virtaustulkinta pitää tehdä uudelleen. Virtaussuuntatiedoston pitää alkaa aina syvyydeltä 0 m. Alla on esitetty suuntatiedoston malli.

Depth(m),FlowDirection(P/N)
0,P
55,N
100,P



Kuva 7-5. Rakovirtaussuuntien tulkinta.



Kuva 7-6. Suuntatulkinta. Valittu virtaustiedosto (jonka virtaus tässä positiivinen) on merkitty nuolella. Sektorin välein tehdään pidempiaikainen mittaus, josta voi nähdä pienienkin virtausten suunnan. Kuvan virtaus on kuitenkin ollut tarpeeksi suuri näkyäkseen lyhyen mittausajan tuloksessa.

Kun virtaussuuntatiedosto on valmis, tehdään virtaustulkinta uudestaan jolloin virtaukset tulkitaan oikeilla funktioilla ottaen huomioon virtaussuunta anturin läpi. Vasta näissä tuloksissa virtaus määrät ovat oikein ja niiden perusteella voidaan laskea reiän virtausten balanssia eli reikään sisään ja ulos virtaavan veden määrä tasapainossa.

Veden sähkönjohtavuusmittauksen tulkinta valitaan Interpretation - Conductivity of water. Tuloksena ovat tiedostot OLKR46EC02B020D105.CSV ja karsta-tiedosto. .CSV-tiedostossa on tulkittu veden sähkönjohtavuus ja lämpötila. Karsta-tiedosto sisältää tietoa EC-elektrodin toiminnasta ja mahdollisesta karstasta elektrodin pinnalla.

Painetulkinta tehdään valitsemalla Interpretation - Pressure elevation. Tuloksena on OLKR46WG02B020D105.CSV jossa on anturilla mitattu paine, vesipinta-anturilla mitattu paine ja ilman painemittarilla mitattu ilmanpaine.

7.1.3 Virtausmittaus pumppauksen aikana (E-mittaus)

Pumppauksen aikaisen virtausmittauksen tulkinta on täysin samanlainen kuin ilmanpumppausta tehtävän virtausmittauksen. Rakovirtauksen ovat yleensä pelkästään kalliosta reikään päin pumppauksesta johtuen, mutta virtausten suunnat pitää silti varmistaa.

7.1.4 Virtausmittaus pumppauksen aikana ja rako-EC mittaus (G-mittaus)

Lyhyemmällä mittavälillä suoritettavan virtausmittauksen aikana tehdään myös rako-EC mittauksia valituista raoista. Kriteeri valittaville raoille ohjeistetaan mittauskohtaisessa ohjeistuksessa. Edellä mainittujen virtausmittaustulkintojen lisäksi tulkitaan rako-EC mittaus valitsemalla Interpretation - Conductivity of water (flows). Tämä tulkinta tuottaa kolme eri tiedostoa joissa on rakokohtaisen EC mittauksen tulokset eri muodoista joista tulokset on yksinkertaista plotata tuloskuviin.

OLKR46EC02G005T105.CSV
OLKR46EC02G005U105.CSV
OLKR46EC02G005W105.CSV

Näiden datojen perusteella tehdään tuloskuvat joiden perusteella voidaan arvioida mittauksen edustavuutta. Mittaus tehdään osana automaattimittausta joten käytännössä tuloksia tarkastellaan jälkeenpäin ja mittauksia uusitaan tarpeen mukaan.

7.2 Toimistotulkinnat

Toimistolla tehtävien tulkintojen tarkoituksena on täydentää kentällä tehtyjä syvyyskorjauksia ja virtaussuuntahavaintoja. Näiden lisäksi toimistolla tehdään vielä rako- ja sektoritulkinnat ja rakojen EC. Lopuksi tulkinnat kootaan asiakkaan haluamaan muotoon ja muokataan Grapherissa. Ulkoasu selviää hyvin vanhoista raporteista tai tiedostoista, ja mielellään tulkinnassa kannattaa käyttää pohjana viimeisimpien mittausten kuvaajia.

Toimistotulkinnat tulee tehdä tässä ohjeessa opastettujen vaiheiden mukaisesti, koska virhe tietyssä vaiheessa tai vaiheen ohittaminen voi aiheuttaa sen, että joudutaan palaamaan tulkinta prosessissa taaksepäin ja tekemään tulkintoja uudelleen.

Maastomittausten aikana on mahdollista tehdä myös tässä ohjeessa toimistotulkinnoiksi luokiteltuja tulkintoja ja sen takia on tärkeää tarkastaa mitä kaikkea on tehty. Toimistotulkintoja ei tehdä uudestaan jos ne on tehty jo maastossa vaan tarkastaminen ja mahdollinen korjailu riittävät.

7.2.1 Aloitus

Toimistotulkintoja varten tehdään Meas-kansion alle Tulkitut-kansio, joka tulkinnan aluksi on kopio Maastotulkinta-kansiosta. Kun Tulkitut-kansio on tehty, Maastotulkinta-kansion kaikkien hakemistojen sisältö tulee pakata zip-muotoon (kaikki muut tiedostot poistetaan). Ideana tässä on se, että kovalevyjen toiminta hidastuu, jos levyllä on useita tiedostoja ja se, että Grapher saattaa hakea dataa väärästä paikasta. Grapher muistaa datatiedostojen polut, ja jos Maastotulkinta-kansiossa on datatiedostoja, Tulkitut-kansion Grapher-kuvat käyttävät oletuksena niitä. **Tämä voi johtaa erittäin merkittäviin ongelmiin.**

Aluksi on syytä tarkistaa, että virtausten suuntatiedosto on tehty oikein.

Seuraavassa vaiheessa kannattaa tarkistaa, että syvyyskorjaus on tehty oikein (ensimmäinen SPR mittaus) ja että seuraavat mittaukset on kohdistettu tarkasti samaan mittaukseen. Syvyyskorjauksen tarkastus pitää tehdä vertaamalla SPR kuvaajia Grapher kuvassa. Yleensä SPR anomaliat on mahdollista kohdistaa keskenään muutaman senttimetrin tarkkuudella.

Seuraavaksi on syytä varmistaa, että kaikki tulkinnat (virtaus, paine, EC) on ajettu läpi syvyyskorjaustiedostoja käyttäen. Jos tästä on epävarmuutta, niin kaikki tulkinnat kannattaa tehdä uudelleen niin, että alkuarvojen Use depth correction file on varmasti ruksattuna. Tulkitut (.CSV) tiedostot pitää myös muistaa kopioida FlowLogging-kansioon.

Kohinatason voi määrittää myös heti aluksi lyhyen kaluston pumppausmittauksen perusteella. Kohinataso-tiedosto (Interpretation – Make lower limit file) täytetään samalla periaatteella kuin suuntatiedostokin paitsi, että suunnan tilalle tulee kohinatason arvo yksikössä ml/h. Kohinatason määrittämiseen kannattaa katsoa mallia jostain vanhasta mittauksesta. Periaatteena on selvittää se taso, jota suuremmat virtausanomaliat voidaan kohtuullisella luotettavuudella tulkita. Kun kohinataso on selvitetty, käydään vielä tekemässä kohinatiedosto Grapher-kuvia varten (Interpretation – Calculate lower limit file).

7.2.2 Rakotulkinta

Ensimmäiseksi tehdään rakotiedoston (fractures-file) pohja valitsemalla Interpretation-valikosta Make Fractures file.

Tässä vaiheessa on hyvä tarkistaa, että FlowLogging-kansiossa on kaikki uusimmat tulkitut tiedostot. Myös mahdolliset vanhat (esim. edelliseltä reiältä jääneet) turhat tiedostot kannattaa putsata pois.

Softa tarvitsee seuraavat tiedostot rakotulkinnan tekoa varten:

- FL-tiedostot: S-tiedostot virtausmittauksista (3 kpl)
- GW-tiedostot: Kaikista virtausmittauksista (3 kpl)
- SP-tiedosto: B-mittauksesta

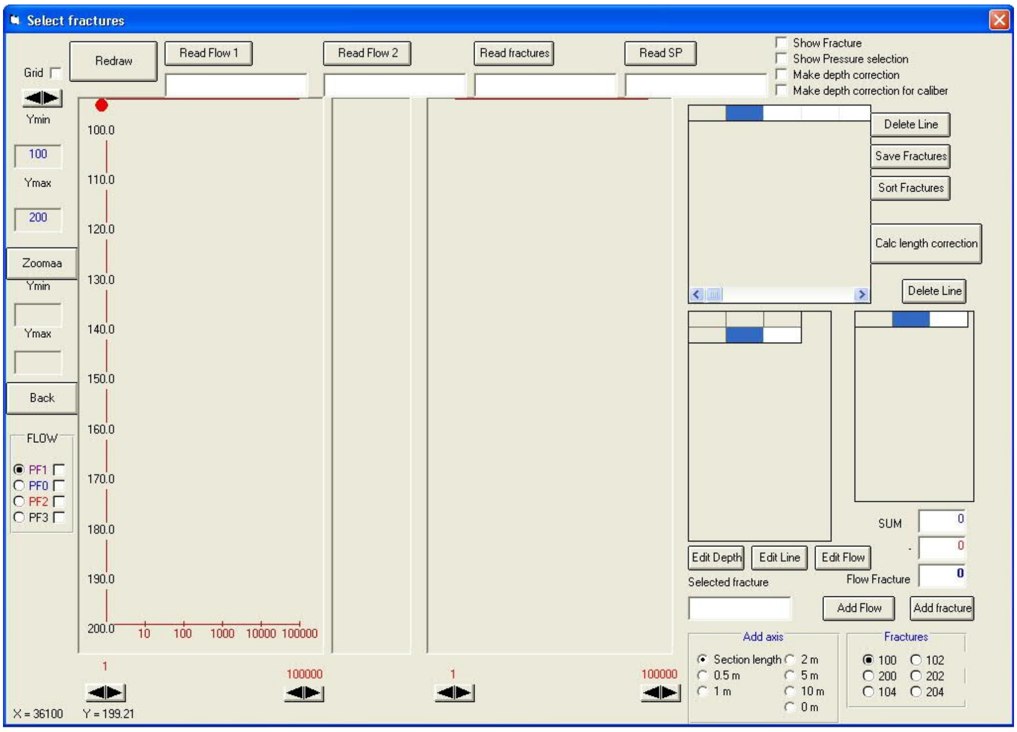
Itse rakotulkinta aloitetaan valitsemalla lisäohjelmista FRACTURES, joka avaa rakotulkinta-ikkunan (Kuva 7-7). Aluksi valitaan käytettävät tiedostot. Käytetään esimerkkinä reikää OL-KR46. Valittavat tiedostot ovat:

Read Flow1: OLKR46FL14G005S102.CSV (Pumppauksen aikainen, lyhyempi mittaväli)
Read Flow2: OLKR46FL02B020S107.CSV (Luonnonvesipinta mittaus)
Read Fractures: KR46Fractures.csv
Read SP: OLKR46SP02B020D107.CSV (B-mittauksesta)

Kohtaan Flow1 valittiin nyt tiedosto, jolle rakotulkinta halutaan tehdä.

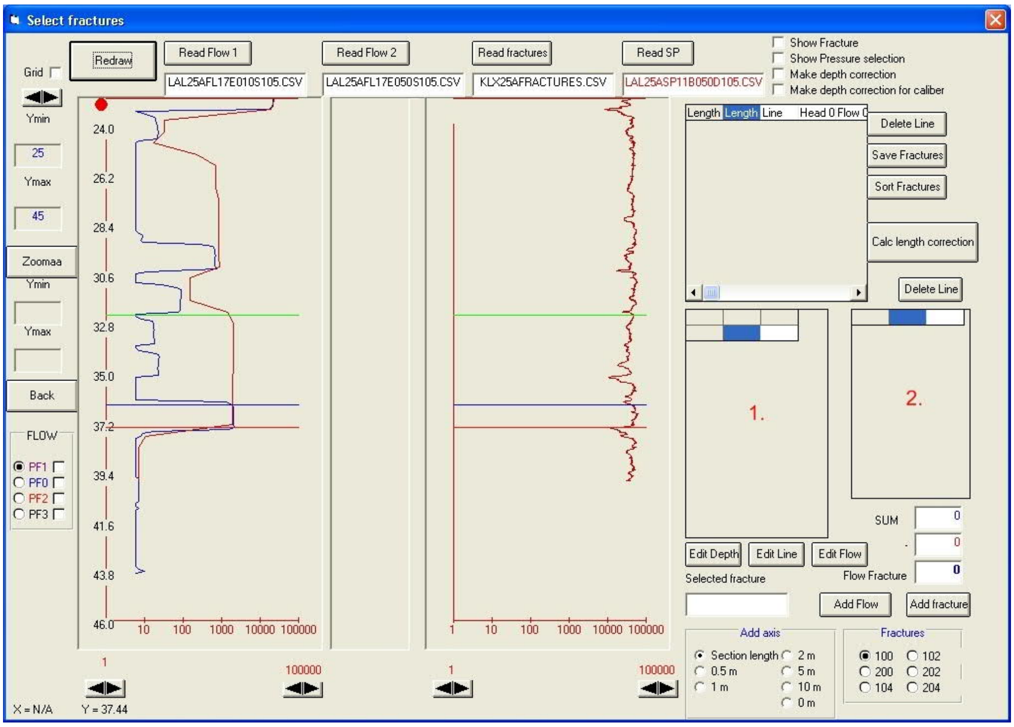
Tämän jälkeen voi painaa Redraw-nappia, niin käyrät tulevat näkyviin. Virtauskäyräkuvan päällä voi painaa hiiren oikeaa ja vasenta nappia valitakseen ”zoomausalueen”, jota haluaa tarkastella tarkemmin. Tämän jälkeen pitää vielä painaa Zoomaa-nappia, jotta zoomaus ”astuisi voimaan.” Alueen voi myös rajata kirjoittamalla ikkunan vasemman reunan ylimpiin Ymin- ja Ymax-tekstikehyksiin haluamansa alueen ja painamalla sen jälkeen Redraw-nappia.

Rakotulkinta-ikkunan kohdasta FLOW (ikkunan vasen reuna) voidaan valita, mitä rakotiedoston saraketta täytetään. Normaali lyhyen kaluston pumppausmittaus on PF1, joka on valittuna kuvassa 3-2. PF0 on normaali LVP mittaus. PF2 ja PF3 on varattu mahdollisille uusintamittauksille. FLOW-kohdasta voidaan myös valita rasti ruutuun periaatteella, mitkä raot piirretään, kun painetaan Redraw-nappia.



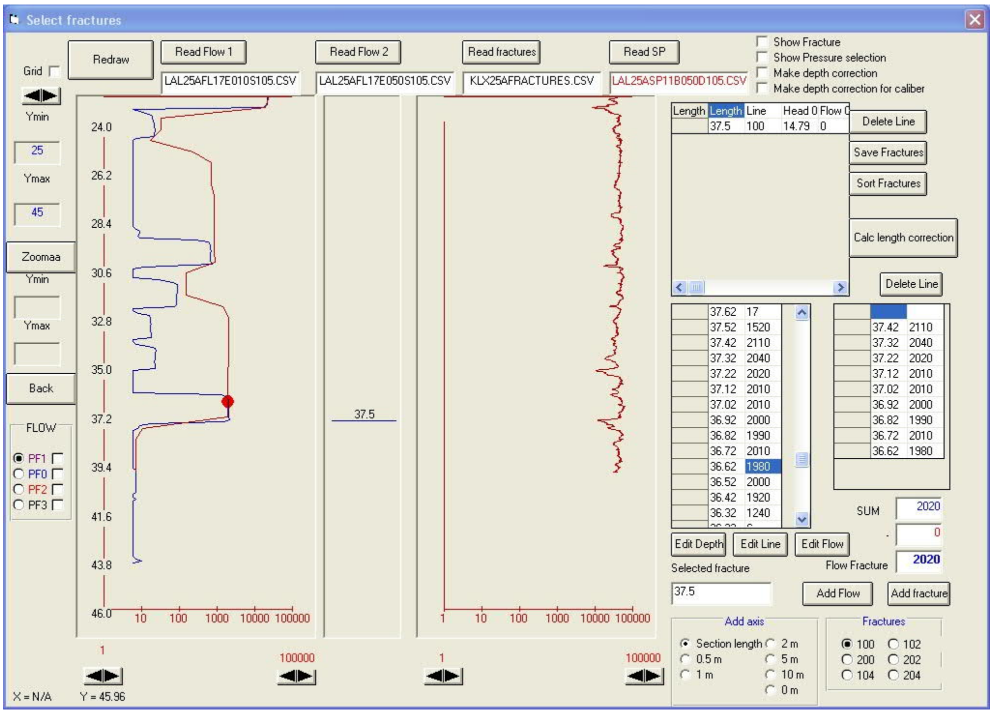
Kuva 7-7. Rakotulkinta-ikkuna.

Alkutoimien jälkeen voidaan aloittaa itse rakopaikkojen haku. Rakopaikan voi hakea hiirellä SP-käyrän kohdalta. Kuva 7-8 punainen vaakaviiva osoittaa raolle valitun paikan. Sininen ja vihreä viiva ovat mittaussektorien pituuksia. Rako valitaan painamalla hiiren vasenta nappia. Tämän jälkeen ikkunaan 1 (kts. Kuva 7-9) tulee lista rakokohtaa ympäröivistä mittauspisteistä ja niissä mitatuista virtauksista. Klikkaamalla jotain virtausta, virtauskuvassa oleva punainen pallo siirtyy sen kohdalle. Tuplaklikkaamalla jotain virtausta se siirtyy ikkunaan 2 ja tulee osaksi raon virtauksen laskentaa. Kuva 7-8 virtauksen laskennassa oikea tapa on tuplaklikata punaisen ja sinisen viivan välissä olevia virtauksia. Näistä valituista virtauksista softa laskee automaattisesti keskiarvon kohtaan SUM. SUM-määrästä voi vielä vähentää (punainen numero SUM-kohdan alla) esim. edellisen raon virtauksen, jos raot olisivat alle sektorin välein toisistaan. Tässä tapauksessa se ei ole tarpeellista, joten vähennetään luku nolla.



Kuva 7-8. Rakopaikan valinta.

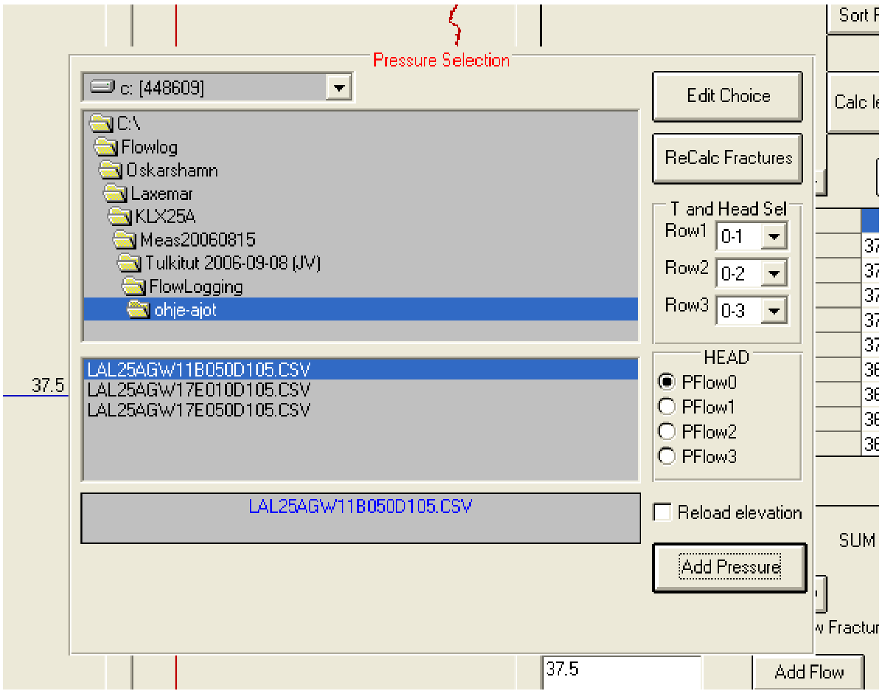
Kun virtaus on saatu määritettyä, se pitää lisätä rakotiedostoon. Tämä tehdään painamalla Add fracture-nappia. Lopputulos näkyy kuvassa 3-4.



Kuva 7-9. Ensimmäinen rako tulkittu. Huomaa, että raon paikka ei ole punaisen pallon kohdalla vaan kohdassa 37.5 m, joka näkyy viivana virtaus- ja SP-käyrien välissä.

Kuva 7-9 oikeaan ylimmäiseen ikkunaan on nyt ilmestynyt rivi, joka on rakotaulukon ensimmäinen rivi, ja ensimmäinen rako on nyt paikannettu ja sen virtaus laskettu. Muut raot selvitetään samalla tavalla.

Kun kaikki raot on paikannettu, on syytä lisätä mittausten head-arvot rakotaulukkoon. Tämä tehdään Show Pressure selection–kohdan kautta.



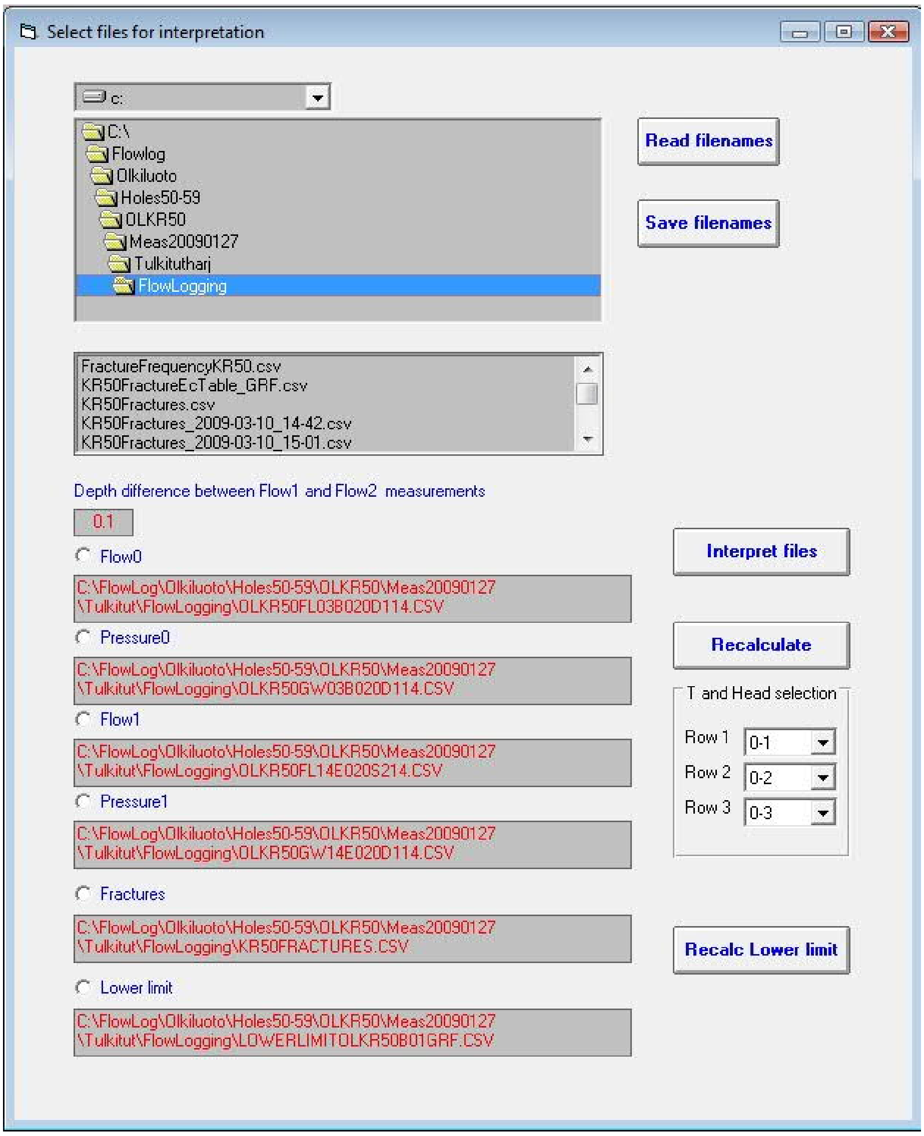
Kuva 7-10. Pressure selection-ikkuna. Ikkuna avautuu rakotulkintaikkunan päälle.

Aluksi kohdasta HEAD valitaan se virtausmittaus, jolle painekorkeudet halutaan laskea. Yleensä mittaus 0 on LVP-mittaus, ja mittaus 1 lyhyellä kalustolla tehty mittaus pumppauksen aikana. Kun valinta on tehty, klikataan mittausta vastaavaa GW-tiedostoa (tiedostojen on oltava valmiina työhakemistossa). Tämän jälkeen painetaan Add Pressure-nappia. Kun kaikkien mittausten painekorkeudet on lisätty, painetaan ReCalc Fractures-nappia, jolloin ohjelma laskee rakokohtaiset painekorkeudet ja transmissiviteetit. Tämän jälkeen laitetaan Pressure selection-ikkuna pois näkyvistä ja tallennetaan rakotaulukko.

LVP rakotulkinta tehdään samalla periaatteella valitsemalla Flow1 (Read Flow 1)virtaukseksi LVP-mittauksen virtaustiedosto ja valitsemalla FLOW-kohdasta PF0. Tässä vaiheessa riittää, että määrittää virtaukset edellisessä vaiheessa määritellyille raoille. Valitse taulukosta rako, määritä virtaus ja klikkaa Add Flow-nappia. Lopuksi varmista, että kaikki raot on tulkittu, koska voi olla mahdollista, että rako näkyy pelkästään ilman pumppausta.

7.3 Sektoritulkinta

Sektoritulkinta tehdään rakotulkinnan jälkeen. Kopioi aluksi valmis Fractures-tiedosto B-mittauksen kansioon ja tulkitse B-mittauksen virtaukset läpi uudelleen. Valitse virtaustulkinnan Select interpretation -ikkunasta tällä kertaa kohta Flow after measurement section (use fractures file). Seuraavasta ikkunasta valitaan Fractures-tiedosto. Tulkinnasta tulee D-tiedosto (esim. OLKR50FL03B020D114.CSV), joka kopioidaan virtaustulkintakansioon. Tämän jälkeen virtaustulkintakansio valitaan työhakemistoksi, mennään lisäohjelmiin (Kuva 7-11) ja painetaan Int Flow Section-nappia, josta päästään automaattiseen sektoritulkintaan.



Kuva 7-11. Automaattinen sektoritulkinta.

Avautuvaan Select files for interpretation –ikkunaan valitaan tiedostot seuraavasti:

Flow0: B-mittauksen D-tiedosto LVP-virtaustiedosto
Pressure0: Flow0:aa vastaava GW tiedosto
Flow1: Pitkän kaluston pumppauksen aikainen virtaustiedosto (S)
Pressure1: Flow1:stä vastaava GW tiedosto
Fractures: Fractures tiedosto
Lower limit: Lower limit tiedosto

Kun tiedostot on valittu voidaan painaa Save filenames –nappia, jolloin tiedostoja ei enää tarvitse valita uudestaan myöhemmissä tulkinnan vaiheissa. Tämän jälkeen painetaan Interpret files ja Recalculate -nappeja tässä järjestyksessä. Ohjelma on nyt tehnyt sektoritiedoston (esim. KR50Sections.csv). Ohjelma merkitsee automaattisesti sektorivirtaukset kohtiin, joissa on ollut rakovirtauksia.

Kohta Depth difference between Flow1 and Flow2 measurements kertoo miltä väliltä sektoripareja etsitään. Jos sektoritulkinassa tulee ongelmia, niin arvon kasvattaminen (esim. 0,2) ja uuden sektoritulkinnan (Interpret files) tekeminen voi auttaa. Jos mittauspisteiden väli on 0.25 m, arvolla 0.13 pitäisi löytyä pari jokaiselle virtauspisteelle.

Jos jostain syystä kohinatiedostoa on tarvis muuttaa, niin silloin pitää käydä myös korjaamassa sektoritiedosto painamalla Recalc Lower limit –nappia.

Kun automaattinen sektoritulkinta on tehty, virtauskuvista pitää tarkistaa sektoritulkinnan oikeellisuus. Muutoksia automaattiseen tulkintaan joutuu tekemään lähes aina. Yleensä virtauksien suuruuksia pitää paikoin korjata (Jos esim. transmissiviteettivertailukuvassa on selviä eroja, LVP sektori on kohinan ”joukossa” tms.). Korjaukset voi tehdä käsin sektoritiedostoon. Kun korjaukset on tehty, pitää vielä laskea T- ja h-arvot uudestaan. Tämä tehdään painamalla Recalculate-nappia. Jos tässä vaiheessa klikkaa Interpret files kaikki käsin tehdyt muutokset komoutuvat.

Sektoritulkinnan jälkeen tehdään FractureFrequency-tiedosto lisäohjelmien Fracture frequency –napilla. Jos sektoritulkintaa muuttaa, pitää muistaa aina tehdä myös uusi FractureFrequency-tiedosto. Tiedostoa käytetään rako- ja sektoritransmissiviteettien vertailukuvassa.

7.4 Rako-EC

Rako-EC tulkinnassa toimistolla tulee käyttää valmista fractures-tiedostoa (Conductivity of water (flows) –tulkinnasta valitaan fractures-tiedosto käyttöön). Tällöin saadaan rako-EC –taulukko, jota käytetään mm. raporteissa. Virtaustulkinta pitää ajaa myös uudelleen läpi. Lisäohjelmien painikkeella "EC-table" muodostetaan rako-EC taulukko raportointia varten.

MX WINCH AND CONTROLLER

Mount Sopris Instrument Co., Inc.
Golden, CO. U. S. A.
April 25, 2006

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General Information

The MX winch is a logging hoist capable of positioning a geophysical probe or other tools in a borehole. The system is equipped with slipring and connections through which surface instrumentation can communicate with the probe. A precision measuring wheel and rotary encoder are also included to allow the amount of cable played out to be tracked. The cable is automatically wrapped on the drum in even layers through the level wind mechanism. The motor is controlled by an 110V (or 220V depending on the model) four-quadrant motor speed controller that allows the speed to remain constant with a varying loads and prevents overhauling with heavy loads. The winch is designed to be used in conjunction with the MGX II console and a portable PC to achieve a complete logging system. **NOTE: When using a DC inverter to power the winch, a *true sine-wave* inverter is required for smooth winch operation. Minimum power requirement for such an inverter is 600 watts, which should also allow operation of the logger.**

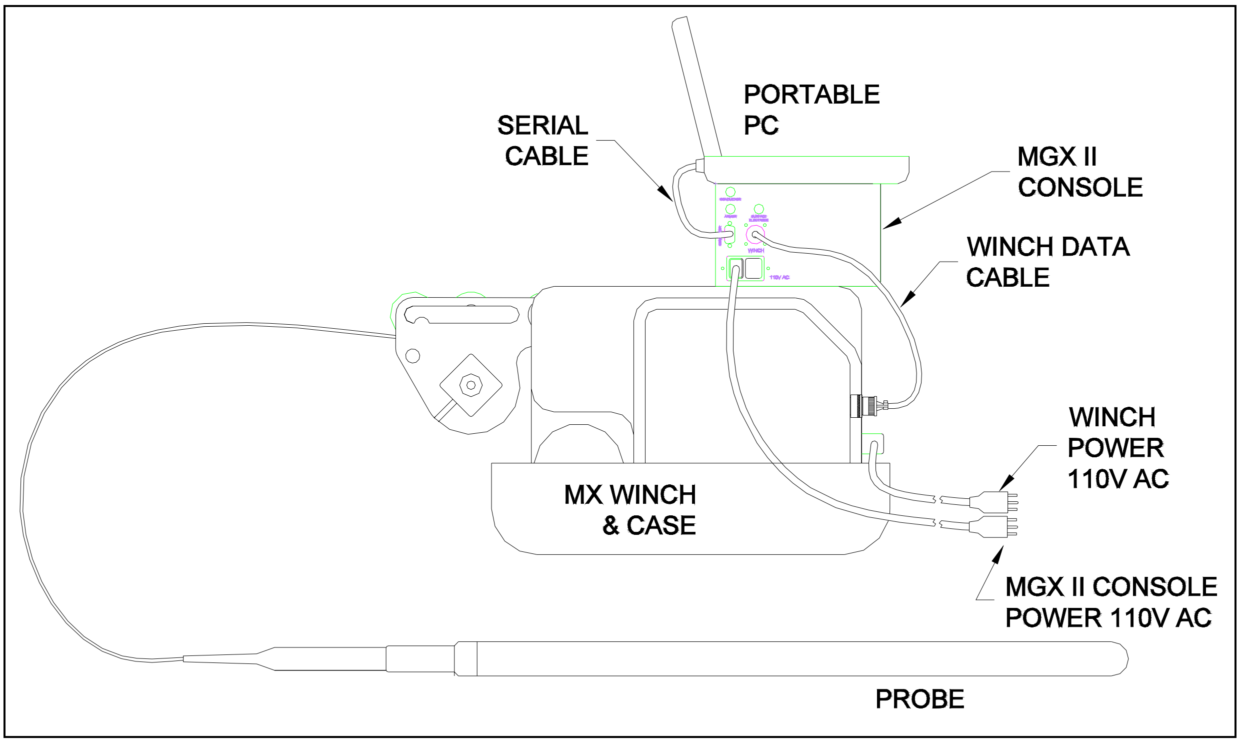


Figure 1

Winch Setup

To operate the winch in a borehole environment the following steps should be followed:

1. If the winch is in a carrying case, the case top should be un-latched and removed. Care should be taken not to snag any cables or other winch parts. Rotate the MEASURE HEAD from its stored position to the operation position.
2. Lift the PRESSURE WHEEL on the MEASURE HEAD and slip the cable between the PINCH WHEEL and the MEASURE WHEEL. Rotate the CABLE KEEPER knob until the keeper wheel is as close as possible to the FORWARD GUIDE WHEEL.

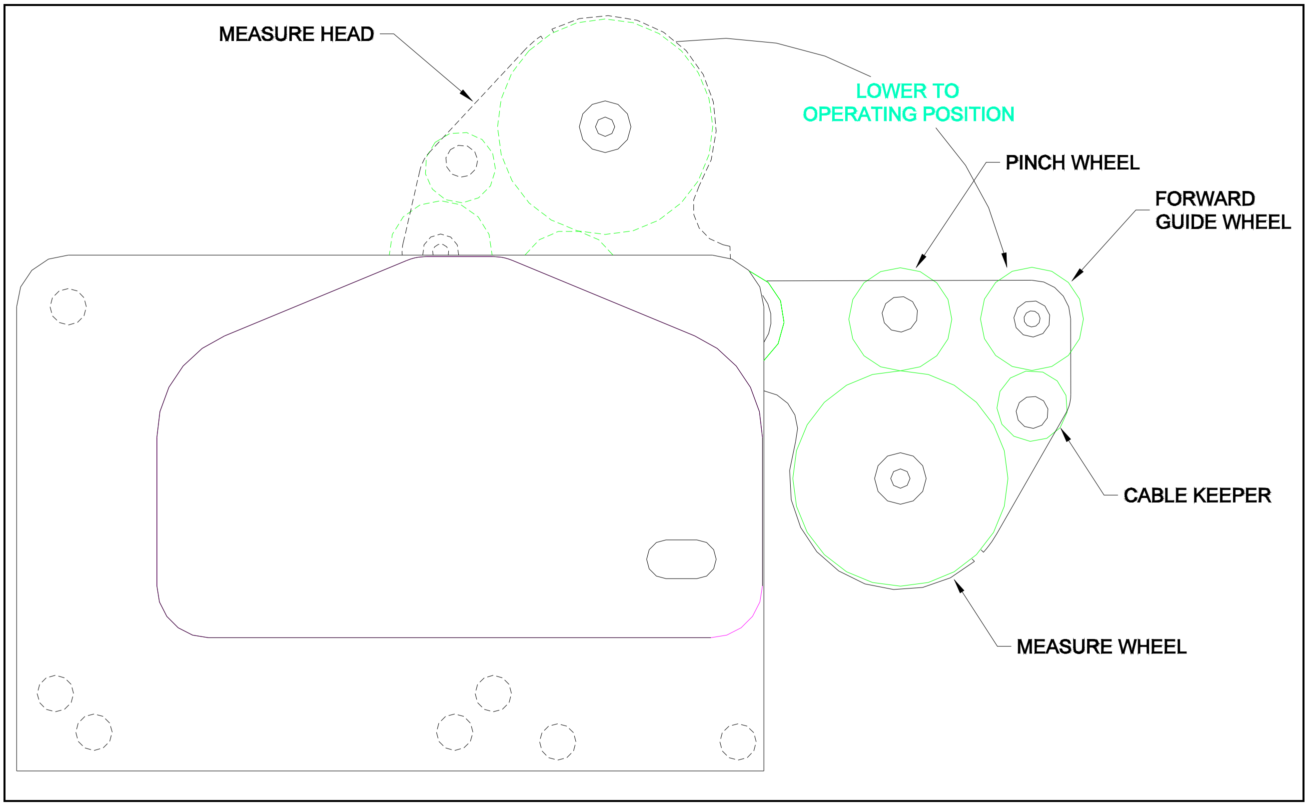
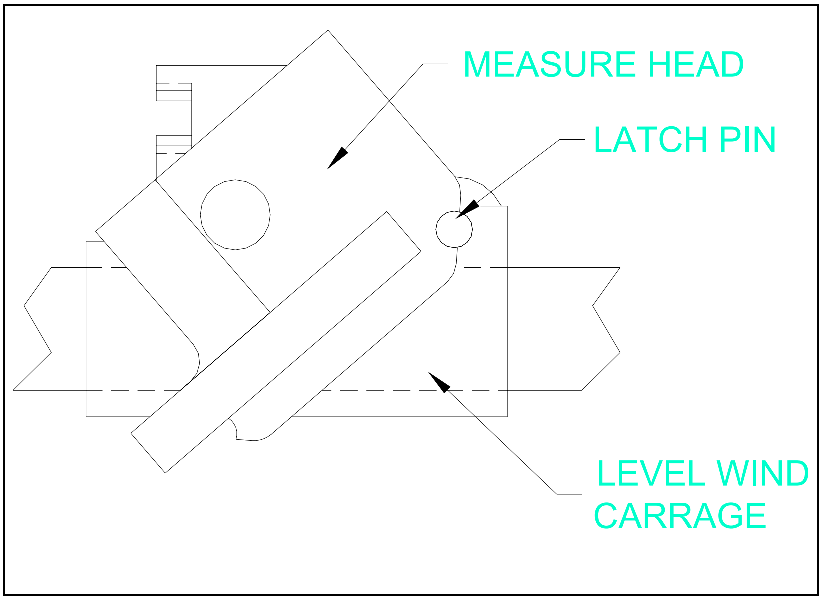


Figure 2

3. Release the MEASURE HEAD by pushing the LATCH PIN down.

Figure 3



4. Set the winch so the cable path will be within the limits of the measure head.
   These limits are:
   45° up
   5° down
   10° left, right

See figures 3 & 4

IF THE CABLE PATH MUST LOG MORE THAN 5 DEGREES BELOW HORIZONTAL THE MEASURE HEAD SHOULD BE REMOVED AND TURNED UP SIDE DOWN. THE CABLE PATH WILL NOW GO OVER THE TOP OF THE REAR GUIDE WHEEL. See Figure 5 & 6

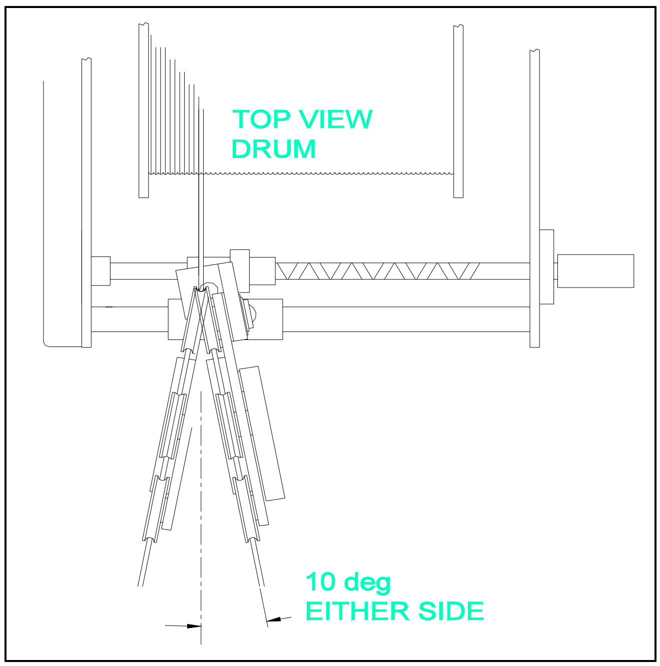


Figure 4

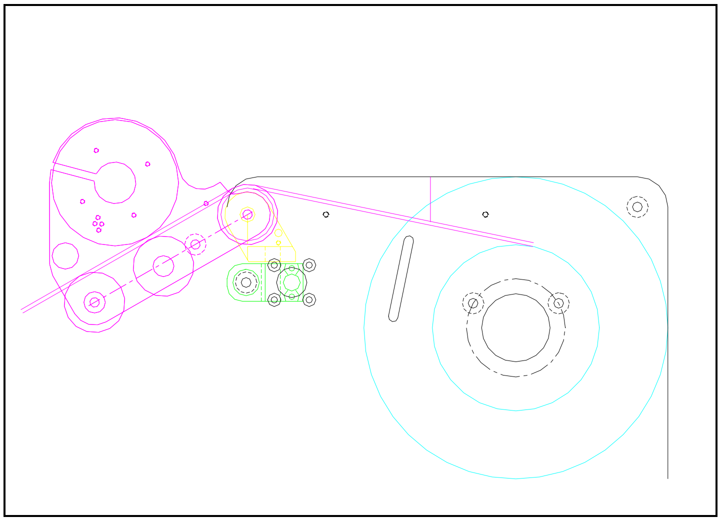


Figure 6 - When logging more than 5° down

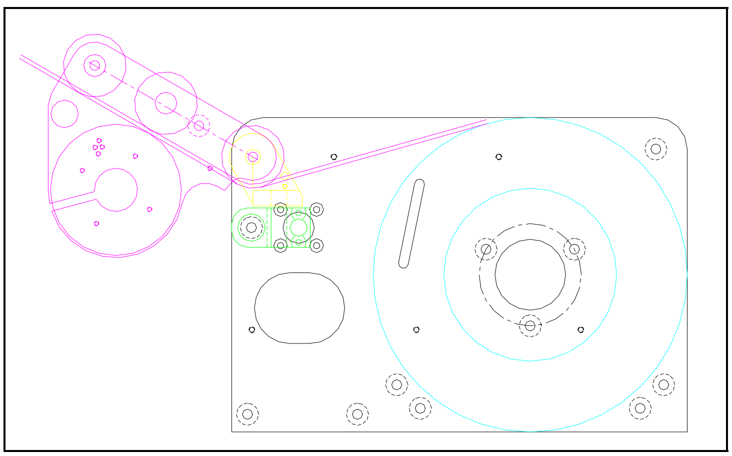


Figure 5 - Normal logging

5. Switch the RUN - STOP switch to the RUN position and the UP/DOWN switch to the center (HOLD) position. Manually pull enough cable off the drum to attach the probe and lower it into the hole.

MAKE SURE THE WINCH IS SECURE BEFORE APPLYING A LOAD TO THE CABLE LINE!!

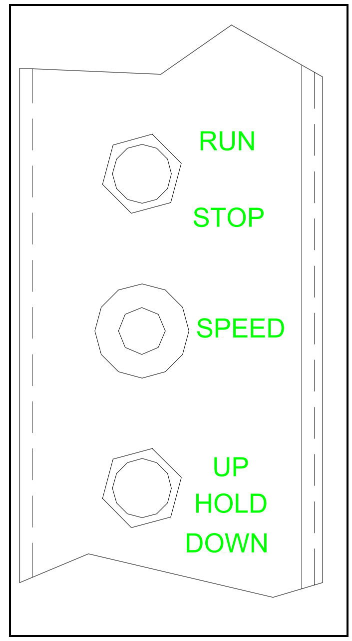


Figure 7

6. Attach the probe to the cable head and check to see that the logger and power cables are connected to the winch control panel as in FIGURE 8. It is good practice to insure that the switch on the AC (110V or 220V) connector is in the O or off position and the WINCH direction switch is in the center position before plugging the other end into an AC outlet. Note the cable connecting the winch to the logger has identical connectors on both end. Either end can be plugged into the winch.

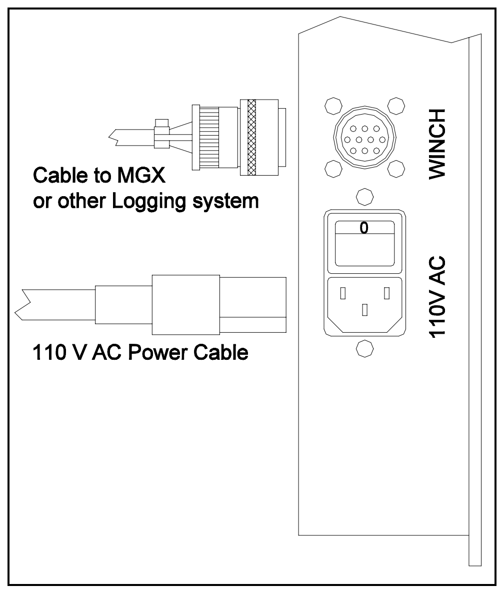


Figure 8

7. Turn on the winch and logging system, and confirm probe operation.

8. With the probe in standby mode, lower the probe into the hole.

9. Once the load of the probe has been applied to the winch make sure the MEASURE HEAD is at the proper angle. The cable should not touch the CABLE KEEPER WHEEL but be fully in the groove of the FORWARD GUIDE WHEEL.

To re-pack the winch, reverse these procedures.

Operation

Once the winch and logging system have been setup, the probe can be run or positioned in the borehole using the following procedures.

IMPORTANT: The MX winch has two "STOP" modes. Read the following carefully, to understand <u>BOTH</u> applications….

EMERGENCY STOP MODE vs. RUN MODE

1. With the RUN – EMERGENCY STOP switch in **EMERGENCY STOP** mode the controller will apply a dynamic braking force to the motor. This mode is used as an <u>emergency brake</u> only. It can be used when shipping the winch (to prevent undesired "back lash" of the cable during transport, or in case of a power failure, it will prevent the winch from "running away", even though it might move down hole slowly with a heavy probe in some instances. This switch has three positions: RUN is all the way up. EMERGENCY STOP is all the way down. The center position, although a position, has no function. Placing the switch in this position disables the dynamic braking and disables power to the controller. This position can be used to pull cable from the winch prior to logging or to set up to begin logging.

IF POWER IS LOST, THE RUN – EMERGENCY STOP SWITCH SHOULD BE PUT IN EMERGENCY STOP POSITION TO PREVENT PROBE RUNAWAY.

2. As long as **<u>power is applied</u>** to the optical encoder (from the **MGX II console or some other depth display unit** controller and the POWER SWITCH IS ON) the RUN – EMERGENCY STOP switch should be in **RUN** mode. When in this mode, the controller is capable of holding the position of a load when the direction switch is in the HOLD position. An electronic circuit in the controller enclosure senses motion from the depth measure wheel, and applies a reverse force to hold the winch drum stationary. This feature allows the winch to hold heavy probes completely still at maximum depth. It is only active if the winch direction control is in the **center** position, the mode switch is in **RUN,** and the encoder is powered by the MGX II or some external depth display. This feature <u>does not</u> <u>function if the winch is not connected to an external depth encoder supply</u> (such as the MGX II).

TO RUN DOWN

a. Rotate the SPEED knob fully counter-clockwise.
b. Move the UP - DOWN switch to DOWN. Note that this switch is a hesitation switch and will need to be put into a neutral (center) position during direction transition.
c. Rotate the SPEED knob clockwise until the desired speed is achieved.

TO RUN UP

a. Rotate the SPEED knob fully counter-clockwise.
b. Move the UP - DOWN switch to UP. Note that this switch is a hesitation switch and will need to be put into a neutral (center) position during direction transition.
c. Rotate the SPEED knob clockwise until the desired speed is achieved.

TO HOLD POSITION

Moving the UP/ DOWN switch to its center position will cause the winch to hold its current position or "Brake". Rotating the SPEED knob fully counter-clockwise before moving to the center (hold) position to minimize abrupt direction changes to the system.

Maintenance

Wireline

The standard 1/10" or 1/8" wireline is steel armored with an insulated center conductor. The wireline should be examined periodically for kinks, separated strands and other damage. At least monthly the cablehead should be disassembled and the cone and sleeve termination examined for mechanical integrity.

As the wireline is steel it can rust, this is particularly a problem around the cone and sleeve assembly where severe rust may lead to mechanical failure of this attachment resulting in loss of a probe Downhole.

The wireline should often be tested for electrical integrity with an ohmmeter, capable of measuring resistance of at least 20 million Ohms, perhaps before beginning each days logging and particularly if there is any problem with tool operation or communications.

Consult **SingleConductorReheadInstructions.pdf** for detailed instructions on troubleshooting and re-heading of the wireline.

Lubrication

The BALL SCREW, the level wind carriage SUPPORT SHAFT as well as the drum and level wind drive chain should be lightly lubricated with 10W30 motor oil. The bearing supporting the drum and the ball screw are sealed bearings and should not require lubrication.

Chain Maintenance

The DRUM drive chain should be kept free of excessive slack. When the top of the chain is taut the sag in the lower portion of the chain should not be allowed to drag the front cross member. To tighten the drum drive chain loosen the four screws holding the motor on to the motor mount plate. This may require the winch to be removed from the case. Slide the motor forward and re-tighten the screws.

To remove the winch from the case:

1. Extend the measuring head assembly into a normal, horizontal logging attitude.
2. Remove the Logger from the top of the winch and disconnect power and signal cables.
3. Turn the winch upside down by rotating it towards the side away from the measuring head being careful to not let it drop suddenly.
4. Do not allow the measuring head to take any of the weight of the winch.
5. Remove the mounting screws from the bottom of the plastic shipping case.
6. When reattaching the shipping case be sure to clean the bolts and apply blue locktite to their threads

The level wind drive chain does not need to be as tight as the drum drive chain. These chains are under very little tension and 1/8" of chain slack is acceptable. As the system is used the chains will develop more slack and can be adjusted be loosening the screw through the center of the axle of the center sprockets. The eccentric axle will allow the tension for the front and rear chains to be adjusted independently.

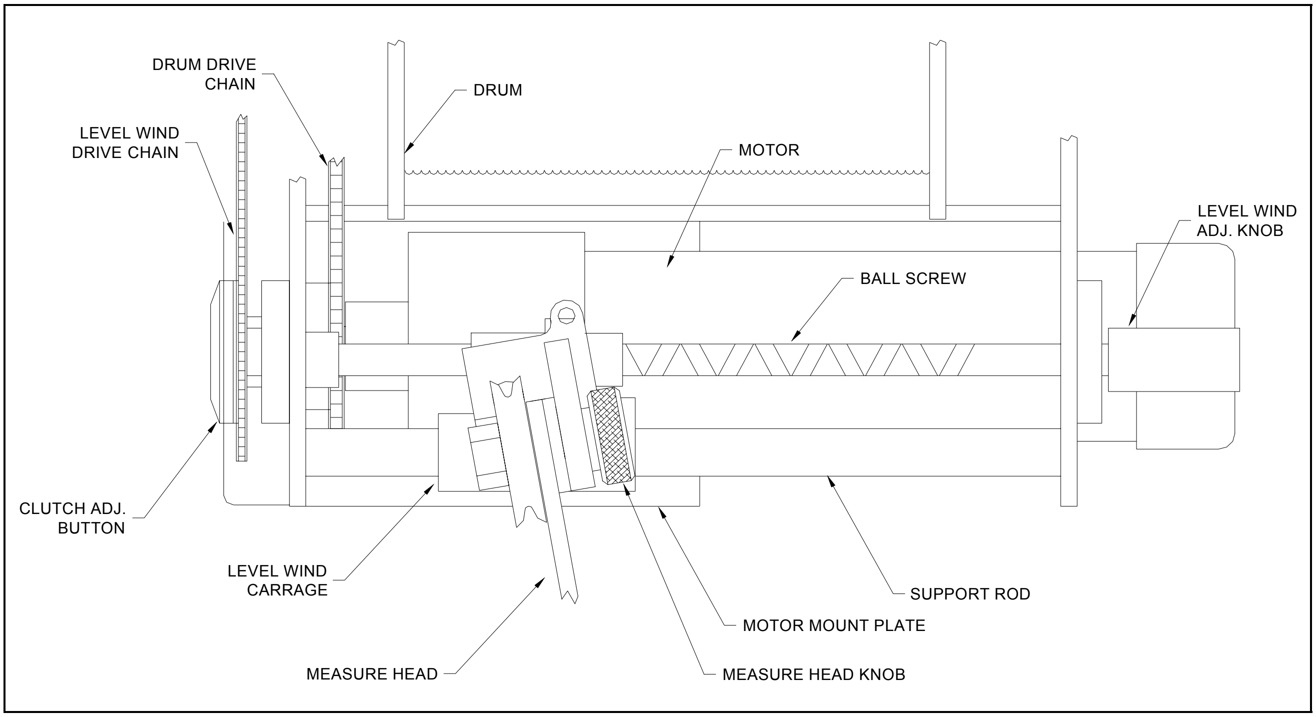


Figure 9

Level Wind Adjustment

The motion of the level wind carriage has been carefully timed with the drum rotation. This timing should keep the cable wound evenly on the drum. If adjustments are needed push in the CLUTCH ADJ.BUTTON and turn the knurled LEVELWIND ADJ. KNOB on the opposite end of the level wind ball screw. **SEE ILLUSTRATIONS ON FOLLLOWING PAGE (Figure 10)**

The CLUTCH ADJ. BUTTON, shown in the drawing on the left, is pushed in so that the hex-lock on the level wind shaft is free to be turned using the LEVELWIND ADJ. KNOB (shown in the drawing on the right). You must hold this button in while turning the knob.

Figure 10

When the level wind carriage is positioned as needed, release the CLUTCH ADJ.BUTTON and turn the knob slightly to reengage the clutch. The ball screw is coupled to the drive sprockets through an index clutch. The rotation of the level wind ball screw is geared to the drum through the level wind drive train sprockets.

Re-Spooling The Winch

If the winch is ever re-spooled completely or cable is removed from the bottom layer, the following measures must be observed.

FOR 1/10" CABLE

76.5 wraps should be put on the bottom layer. Subsequent layers should follow this pattern.
The gearing for 1/10" cable is different from 1/8". Note the drive train chain sequence.

FOR 1/8 CABLE

62.5 wraps should be put on the bottom layer. Subsequent layers should follow this pattern.

Emergency Cable Retrieval

IF POWER TO THE WINCH IS INTERRUPTED THE RUN - STOP SWITCH SHOULD BE MOVED TO STOP.
THIS WILL PREVENT THE WINCH FROM LETTING OUT CABLE.

In the event power to the winch is lost, the cable can still be retrieved. The motor gearing is a spur gear system that will allow the unit to be cranked manually. Locate the manual hand crank pictured below and proceed as follows.

a. Insert the manual crank handle into the coupler in the right side of the winch.
b. With a firm grip on the crank, move the RUN - STOP switch to RUN.
c. Turning the crank counter clockwise should spool the cable back onto the drum. The level wind system should work as normal.
d. If a good deal of cable must be reeled in, there is a locking set screw on the coupler that can be accessed by removing the level wind chain guard. This will lock the crank into the coupler.

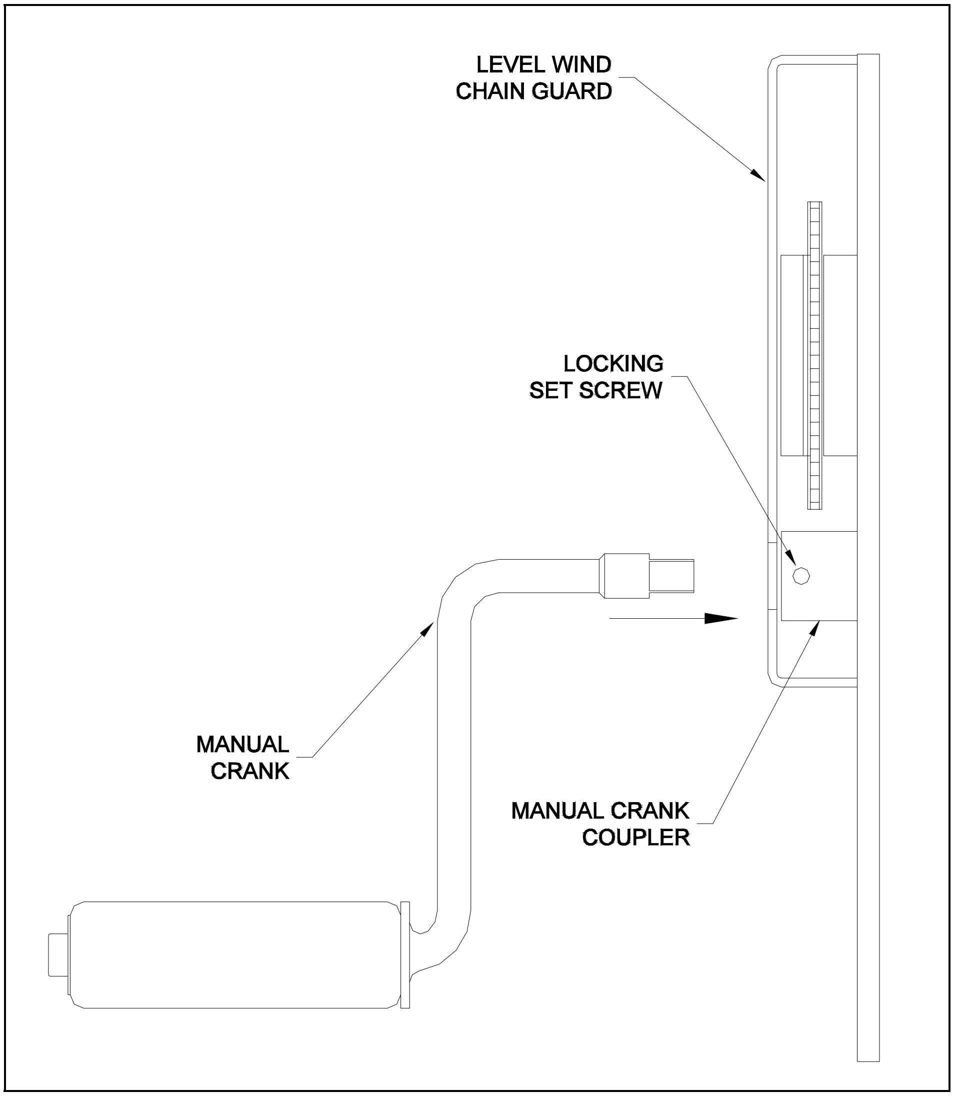

LEVEL WIND
CHAIN GUARD
LOCKING
SET SCREW
MANUAL
CRANK
MANUAL CRANK
COUPLER

Figure11

Troubleshooting

In the event the Winch Control develops a problem, follow the trouble shooting procedure listed below.

Problems With The Winch Mechanism

Problem: The cable is not wrapping smoothly.

Solution 1: The level wind screw needs to be adjusted to align the incoming cable with the correct path.

Solution 2: The cable has been run out past the bottom row and does not have the proper amount of wraps designated for the cable size.

Problems With The Winch Controller

Problem: Control does not turn on or motor on winch will not function.

Solution 1. Is the power cord plugged in and the switch turned on?

Solution 2. Check AC power source.

Solution 3. Check that the RUN, STOP switch is in the RUN position.

Solution 4. Place the UP, DOWN switch in either position other than the center position and rotate the SPEED knob clockwise.

Solution 5. If there is no response from #4 then consult Mount Sopris.

The Control should never be disassembled unless service is necessary. In the event service is necessary, **only** Mount Sopris Instrument Company personell, or a **qualified** technician should perform it.

Connections & Specifications

Connections

AC. 110V
This is simply the 110-volt input for the unit. Located on this connector is an on, off switch which gives the unit its main power. Overseas models will have a sticker labeled 220v.

WINCH
This connector carries the cable lines and the encoder signals. The connector is compatible with the MGX series of console logging modules.

MOTOR PWR.

Pin	Signal	Origin
WHT WIRE	D.C. voltage -	Speed controller
BLK WIRE	D.C. voltage +	Speed controller

WINCH

Pin	Signal	Origin
A	ARMOR	Cable line
B	Center Conductor	Cable line
C	Encoder GND	Encoder
D	Encoder PWR (+5V)	Encoder
E	Encoder B+	Encoder
G	Encoder A+	Encoder

Specifications

Motor:	1/4 hp, SCR type
Controller:	4 quadrant, with current limit
Speed:	0 to 85 ft/min
Load:	100 lbs
Cable Capacity:	2624ft (800M) 1/10 in 1640ft (500m) 1/8 in
Shipping Weight:	125 lbs
Winch Size:	16 wide x 20.5 long x 12 high
Case Size:	17 wide x 17 long x 18 high in the case
Cable off-axis tolerance:	10° left, 10° right, 12° down, 45° up See figure 3,4

NOTE: When using a DC inverter to power the winch, a *true sine-wave* inverter is required for smooth winch operation. Minimum power requirement for such an inverter is 600 watts, which should also allow operation of the logger.

Schematics

Drawing	Title:	4MXA2600.S01	Sheet 1
		4MXA2600.S02	Sheet 2
		4MXA2600.S03	Sheet 3
		5002103A.S01	Sheet 4
		05002077A.S01	Sheet 5

MOUNT SOPRIS INSTRUMENTS

Advanced Logic Technology

Logger

Software Application Guide

Version 13.0

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Table of Contents

1 General Information

1.1 Compatibility

This manual refers to the **Logger** software application which is part of the **LoggerSuite version 13.0**. The following hardware and firmware versions are supported.

	System controller	Modem controller	PSU controller
SCOUT PRO	211	117	-
OPAL–SCOUT	211	115	-
BBOX-ALTLOGGER Jazz	113	-	-
MATRIX	113	117	100
ABOX - ALTLOGGER USB Plugin	No specific version required		

The following MS Windows operating systems and versions are supported.

OPAL – SCOUT & SCOUT PRO	Win7, Win8,Win10	32 and 64 bit
BBOX - ALTLOGGER Jazz	Win7, Win8,Win10	32 and 64 bit
MATRIX	Win7, Win8,Win10	32 and 64 bit
ABOX - ALTLOGGER USB Plugin	Win7, Win8,Win10	32 bit

1.2 Terminology

Throughout this manual some terms specific to or describing a product will be used. A short description of the most important terms will be given hereafter for clarity.

Logger: The term is used for the data acquisition software but sometimes refers also to the data acquisition unit.

LoggerSettings: A specific software application installed together with Logger allowing the setting up and configuring of the logging system. Please refer to the manual devoted to the LoggerSettings application.

LoggerSuite: Name for the entire software package of which Logger and LoggerSettings are an integral part. It must be installed to operate the data acquisition hardware.

Dashboard: Main graphical user interface described in Chapter 3.

Browsers and Processors: Client processes or windows starting up when a tool is selected. An explanation of the most common browsers will be given in Chapter 4, for tools specific browsers consult the corresponding tool manual.

WellCAD: Windows compatible software package for borehole and logging data management, presentation and interpretation.

WellCAD Browser: It is an optional add-on module activated on a WellCAD license enabling WellCAD to be connected to a logging system and used as a browser. WellCAD then receives and displays the logged data in real time allowing layout formatting and data processing tasks to be executed in the field.

TFD2LAS: A specific application (protected by a USB hard-lock) allowing the conversion of TFD to LAS file versions 2.0 and 3.0. Only curve data can be converted. TFD2LAS replaces the obsolete LASWriter.

1.3 Output formats

When data is recorded with the Logger it will be saved into a file with extension TFD. The file format is proprietary and depends on the tools / stacks operated. TFD files can only be opened with the **WellCAD software** - **version 5.0 build 1103 onwards**, the TFD2LAS application and the Logger itself when replaying a data set.
If you would like an output in LAS format you can obtain a license of the TFD2LAS application converting curve data from a TFD file into a LAS file versions 2.0 and 3.0. The license is commercially available and is activated free of charge on a WellCAD license
Using the WellCAD Browser you can save the data received from the Logger in a variety of file formats.
You can create a real time printout of your data using a connected Windows compatible printer. The output will be send to the default printer of your system unless you select a new printer in the MChCurve or other browser supporting printing.

1.4 The Logger in demo mode

When you have the LoggerSuite installed on your computer it is possible to start the Logger in **Demo mode** without any hardware connected . Since the Logger supports multiple data acquisition units it is important to select the correct data acquisition hardware to be simulated when prompted at the startup (Figure 1.1).

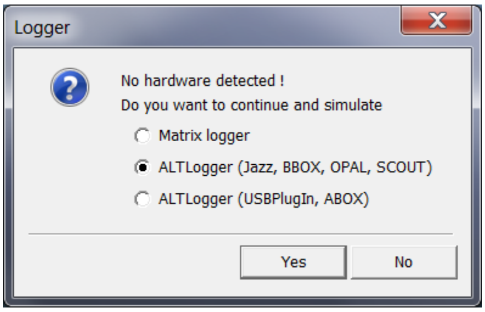


Figure 1.1 – Select hardware to simulate

In Demo mode you can build tool strings in the Tool Stack Factory, edit headers or replay TFD files. It is clearly not possible to “Power ON” a tool or record data. In particular building correct new tool strings (i.e. creating new tool configuration files) depends on the simulated hardware.

2 Getting Started

2.1 Setting up the Logger

For software and initial hardware configuration refer to the corresponding installation or technical manuals.

- Insure the AC power supply cables are connected to the data acquisition unit and winch. AC power must be well regulated, true sine wave. This is particularly important when using DC-AC power inverters.
  Ensure the data acquisition unit corresponds with the power specifications provided at the location it is used.
- Connect the signal cable between data acquisition unit and winch.
- Connect the USB cable between the PC/Laptop and data acquisition unit.
- If a printer will be used connect is as required. (It is not mandatory that a printer is connected but one must be installed.)
- Turn the data acquisition unit on (MATRIX does not have a switch).
- You should have information about data acquisition unit, winch and tools to be used so that the system and software can be properly configured in the LoggerSettings application. Please see the LoggerSettings manual for details on system configuration and installation of tool configuration files (*.TOL, *.SUB or *.STACK files provided with the logging tool).

2.2 Quick Start

Having configured the software environment with LoggerSettings and completed the mechanical set-up of the winch, tool and data acquisition unit you are ready to start logging.

- **Start** the Logger software.
- From the Tool panel drop down list **select the tool** (loads tool configuration).
- Click the top right icon in Depth panel and **zero the tool**. The tool top / cable head joint should be levelled with the ground or other depth reference datum.
- In the Tool panel turn the tool power **On**.
- In the Acquisition panel select the **sampling mode** from the drop down list (Depth up/down recommended, Time only for calibration, static measurements or operational testing) and set the sample rate (Settings button).
- Click the  icon in the Acquisition panel and select and complete the header.
- Turn Sampling **On** (sampling mode Depth up or down). Check validity of communication (Telemetry panel).
- Click on the **Record** button and specify the output filename (or enable auto file naming).
- Raise or lower the tool using the winch controls.
- Observe the **Data** and **Errors** displays as well as the **Bandwidth usage** and **Memory buffer** indicators for valid conditions.
- To stop logging turn recording off by pressing the **Stop** button in the Acquisition panel and bring the tool to a halt using the winch controls.

Further information about logging with a specific tool can be found in the corresponding tool manuals.

Remarks :

If the Logger unit firmware needs to be updated - this may happen after having installed a new version of the acquisition software -, the following dialog unit will be displayed when starting the application. Press “**Upgrade**” to proceed or “**Remind me Later**” to postpone the operation.

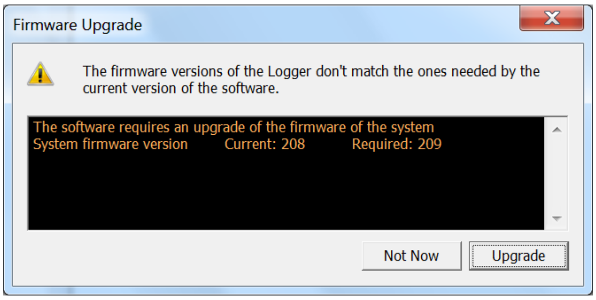


Figure 2.1 – Firmware upgrade

During the upgrade procedure the dialog unit shown below will be displayed providing information on the upgrade status.

Note: Do not turn off the computer or logging system and do not disconnect any cable until the upgrade procedure is completely finished.

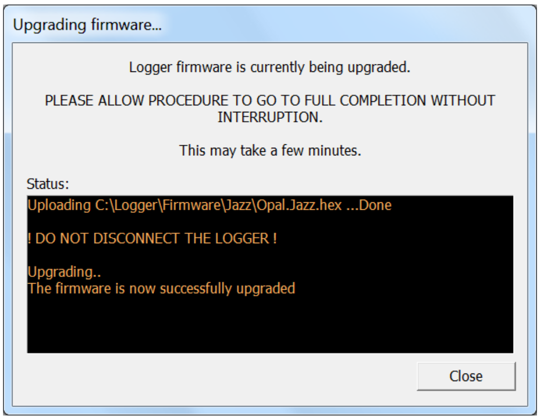


Figure 2.2 – Upgrading firmware

At the end of the procedure, the software will close automatically this dialog unit and will display the dashboard.

3 Dashboard Panel Reference

The Dashboard is the software's graphical user interface allowing the operator to interact with the hardware and to control the logging operation. It appears by default attached to the left of your monitor screen. In order to group different kinds of settings and options the dashboard is subdivided into different panels. Figure 3.1 shows an overview of the different dashboard panels: Application Title (here: "Jazz logging system"), Depth, Tension, Winch, Tool, Telemetry, Acquisition, Browsers & processors and Status panels.

Note: ***The dashboard configuration - more specifically the telemetry panel and the winch/telemetry scheme selection – varies according to the ALT telemetry modem implemented in the acquisition system. Refer to the dashboard illustrations shown in the next pages for more information. The telemetry settings for the different ALT modem configurations are described in the tool operation manuals.***

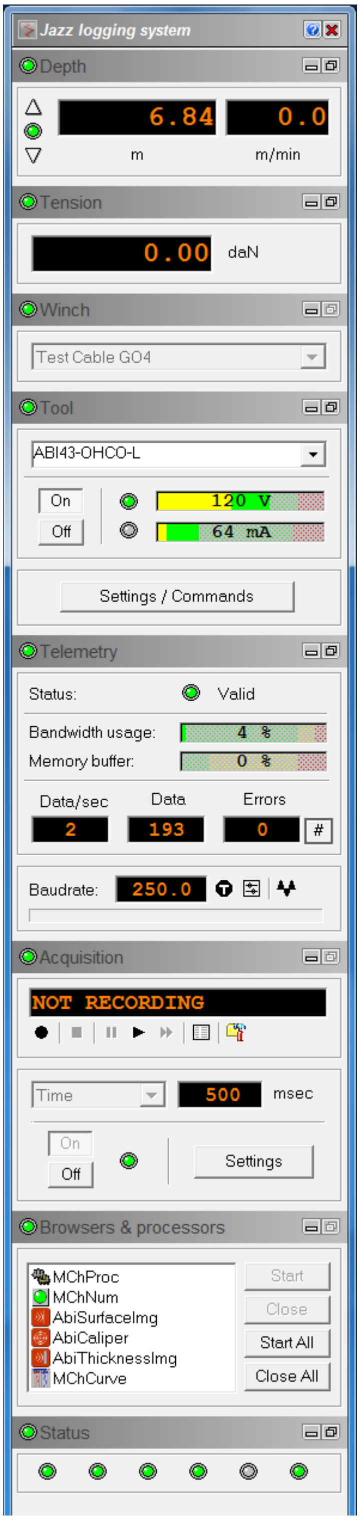


Figure 3.1

Right clicking some place in the Dashboard will open a context menu providing the following options:

Auto Hide: Select this option if you want the Dashboard to automatically disappear as soon as the focus is given to another window on screen. Move the cursor to the left border of your screen to see the Dashboard sliding in. It will now stay in this position until you click in another window.

If the Auto Hide option is turned off the Dashboard will permanently stay attached to the left of your screen.

If you prefer the Dashboard being docked to the right of your screen you have to hold the left mouse button down while the cursor is outside of the frames surrounding the dashboard's controls and drag it over to the other side of your screen.

Help Index…: Click to get access to the help file of your Logger.

About…: The **About** dialogue unit provides information about the software's version and build number. Build numbers change when patches are compiled and released. The higher the build number the more current is the version of your software.

Under **Hardware description** details about the connected hardware are provided (Figure 3.2).

Exit: Select this option to terminate all current operations and leave the application. A message unit will be displayed to reassure you want to stop the software.

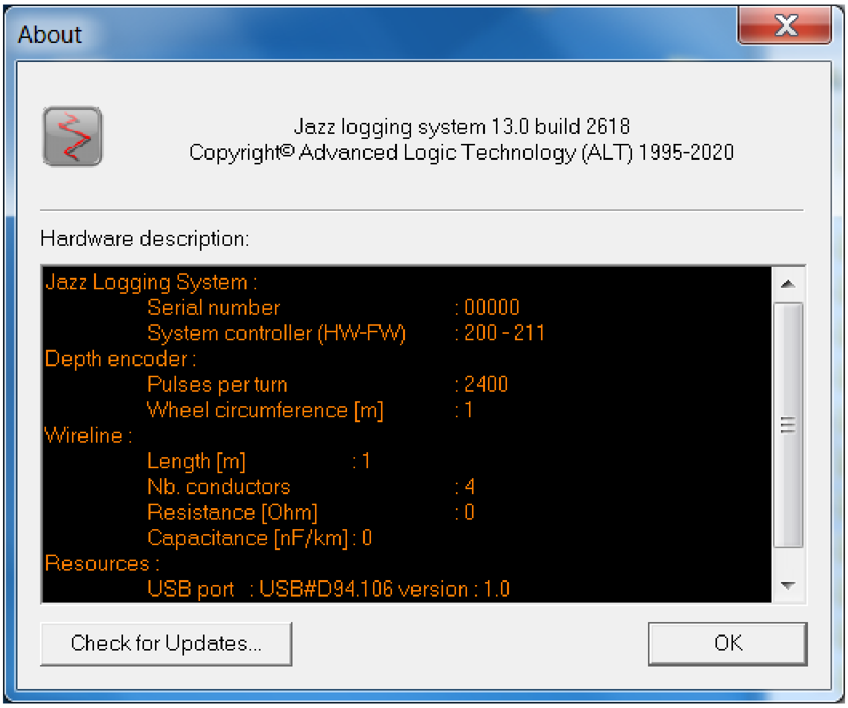


Figure 3.2 – About dialog unit

If a tool has been selected an additional option to hide the **Tool Stack Manager** becomes available. Simply check this option if you do not want to display the tool stack information attached to the Dashboard all the time. The Tool Stack Manager is explained in a later paragraph.

Each panel has a header displaying the title of the panel, showing a System Status LED which turns red if a problem occurs related to one of the options provided in this panel and shows two control buttons (Figure 3.3).

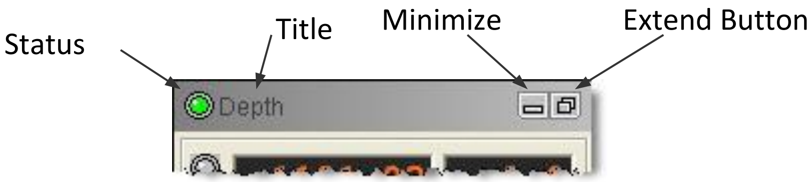


Figure 3.3 – Panel header

Clicking the left **Minimize Button** collapses the panel so that just the panel's header is visible. This feature is particularly useful on smaller display devices – such as laptop screens – where the vertical extension is not sufficient to display the complete Dashboard. Clicking the **Minimize Button** again will expand the panel.
The right **Extend Button** is only active on Depth, Acquisition and Status panels and provides access to further options. Details will be explained in the corresponding paragraphs below.

The following **Reference Chart** can be used to quickly navigate to options and settings provided by the different dashboard panels.

Dashboard display with the ALT MODEM adapter (OPAL-SCOUT acquisition systems)

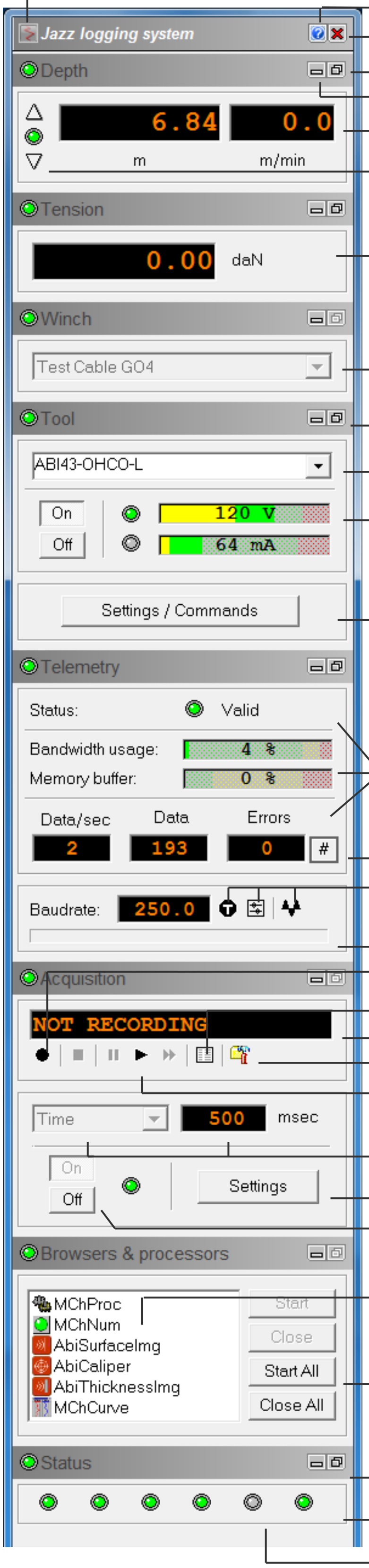


Figure 3.4 – Dashboard – ALT Modem

About Dialog box: System information

Help File

Exit application

Depth settings dialog box: Zero Tool, Change Depth and Change Depth By

Minimize panel

Actual **Depth** and logging **Speed** display

Logging direction indicator: Upper LED on > logging up; Lower LED on > logging down

Tension panel only available if tension gauge is connected to system

Winch configuration - Telemetry Scheme selection

Tool Power Control dialog box: Power and current settings

Tool Selection; start **ToolStack Factory**

Tool power On/Off and power / current monitoring

Tool specific **settings** and **commands** (active if available)

Monitoring of telemetry details during data acquisition

Reset of Data numerical displays

Telemetry **Tuning** – **Settings** and **Scope View**

Telemetry **Tuning progress bar**

Specify output file and **record** data

Header selection and edition

Actual **file name**

Auto file naming options

Select file and **start replay**

Select **sampling mode**; Display of actual **sample rate**

Tool Sampling Settings dialog: Select sample rate

Turn data sampling **On** / **Off**

List of available **Browsers** and **Processors**

Start / **Close** buttons for **Browsers** and **Processors**

Opens window with system status sketch

Monitoring of **system status**

Right click anywhere to display context menu to hide **ToolStack Manager**, enable **Autohide** option for dashboard, access **Help** and open the **About** dialog box.

Dashboard display with the ALT SHALLOW adapter (BBOX-ALTLOGGER acquisition systems)

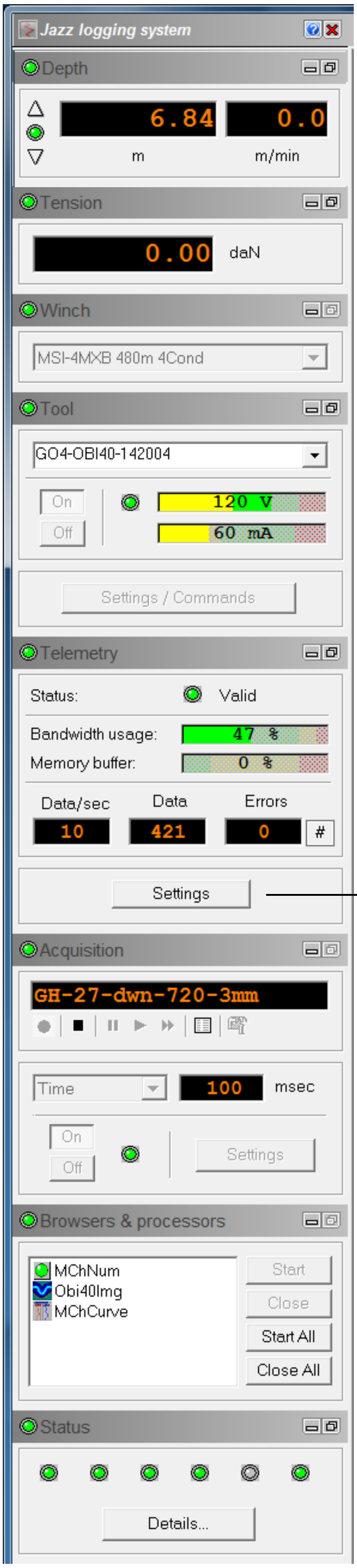


Figure 3.5 – Dashboard – ALT Shallow

The dashboard options and general features are presented in page 9.

For this dashboard display click on **"Settings"** button in the Telemetry Panel to access to the telemetry settings dialog.

Dashboard display with MATRIX interface (MATRIX acquisition systems)

The general dashboard options and features are presented in page 9.

Only the main differences specific to the Matrix hardware configuration are shown on this figure.

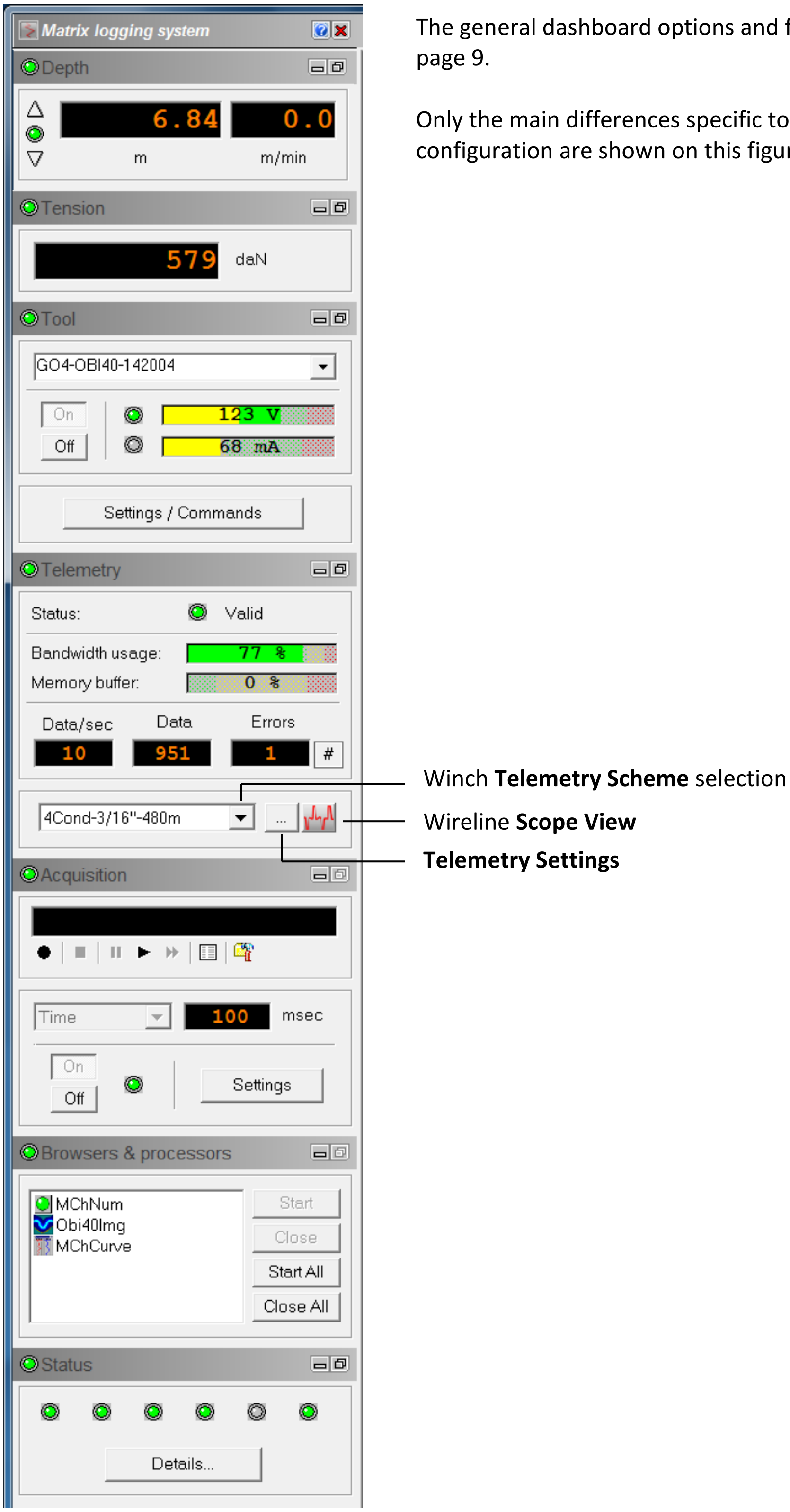


Figure 3.6 – Dashboard - Matrix

3.1 Application Title

Located at the top of the Dashboard is the **Application Title** (Figure 3.7). Since the Logger software application can be used with different data acquisition units the title updates according to the detected hardware.

Figure 3.7 – Application Title

To access the help file click the corresponding Help button and to close the application and terminate all processes the Close button can be used.

Clicking on the **Logger icon** displayed on the left of the **Application Title** will bring up the **About** dialogue unit providing version and build numbers of the software.

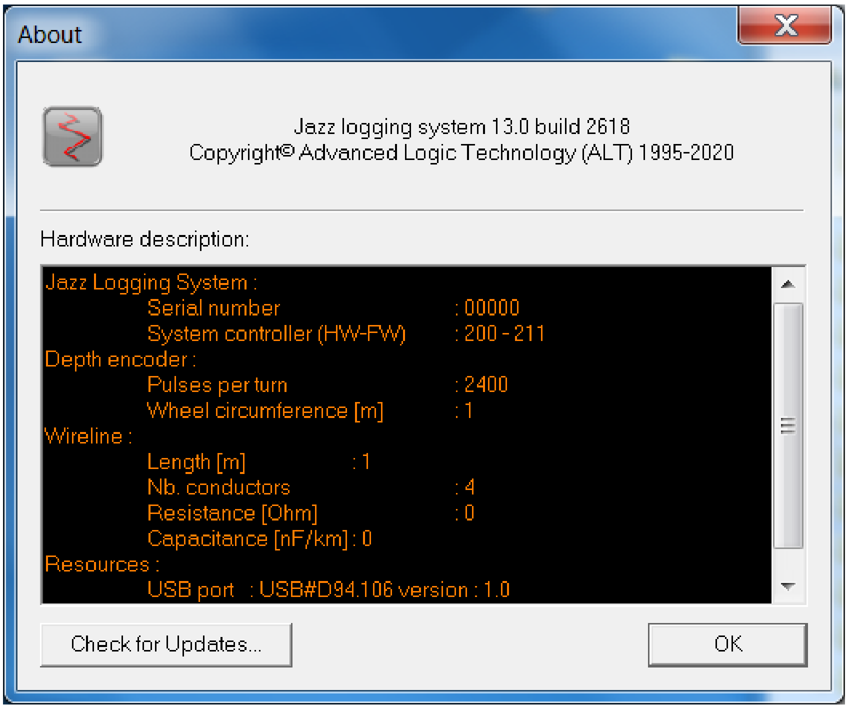


Figure 3.8 – System software and hardware description

Click on the **Check for Updates** button to check for any new versions of the software.

If a new version is available, a dialog listing the new features is displayed. Click on **Download** to download the new installation package. You may proceed automatically with the installation once downloaded.

Click on **Skip This Version** if you do not want to upgrade the software. Click on **Remind Me Later** if you want to proceed with the upgrade later.

3.2 Depth panel

Figure 3.9 – Depth Panel

The Depth panel (Figure 3.9) shows the current depth and cable speed in Metric or Imperial units. Three light indicators located on the left of the panel indicate the direction of logging. If the triangle at the top is orange the direction of logging is from bottom to top. The triangle at the bottom is orange when logging from top to bottom and a stopped winch is indicated by a green LED in the middle (Figure 3.10).

Figure 3.10 – Logging Direction Indicator

Speed and depth units:
In order to change to your preferred depth and speed display units you have to use the Logger Settings application, which has been installed as part of the Logger Suite on your computer. To do so, exit the Logger application and start the Logger Settings program. There select the **Units** option listed under your type of data acquisition system from the control bar. Select either Metric or Imperial units and set the number of decimals displayed. Please note that depth is always counted positive downwards.

3.2.1 Setting the depth reference

Clicking on the **Extend Button** in the header of the depth panel (Figure 3.3) will display the **Depth** settings dialog unit (Figure 3.11).

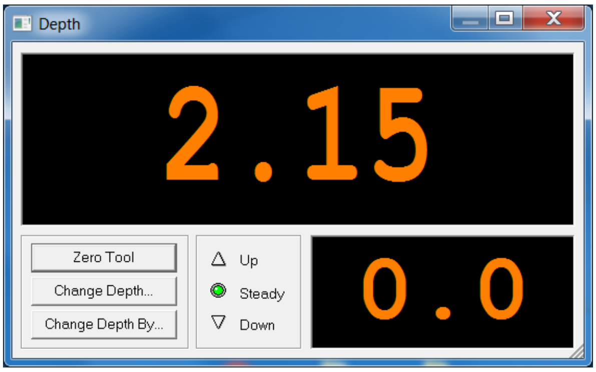


Figure 3.11 – Depth Settings

The dialog unit provides the same numerical displays for depth and speed as the Depth panel. Even though you can click into the displays the numbers cannot be edited. The logging direction indicator is also present. In addition three option buttons are available.

Zero Tool:

When zeroing a tool we want to ensure that the depth recorded during the logging run corresponds to a previously defined reference point of the tool (by default the tool bottom). The configuration files for standalone tools and tool stacks provided by ALT and Mount Sopris Instruments or generated through the Tool Stack Manager contain by default the total length of the tool (i.e. cable head / tool top connection to the tool's bottom).

To zero a tool or tool stack:

- Lower the tool into the borehole until the cable head / tool top connection lines up with the borehole zero reference (Figure 3.12).
- Ensure the correct tool or stack has been selected in the Tool panel.
- Click the **Zero Tool** button. A message unit asking you for a confirmation that the tool's zero referencing point lines up with the borehole zero reference point pops up (Figure 3.13).
- Confirm by clicking the **OK** button. The depth display will be reset and shows the offset between tool zero reference and tool data reference. All other sensor positions will be depth corrected automatically according to the tool configuration files for data display, when imported into WellCAD or converted from TFD to LAS.
  If no tool has been selected the depth counter will be reset to zero

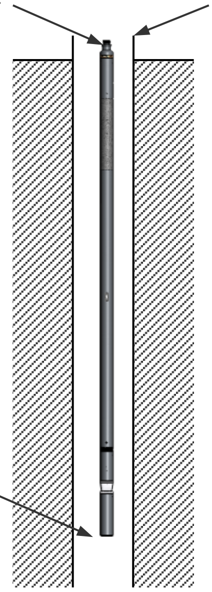


Figure 3.12 – Tool zero references

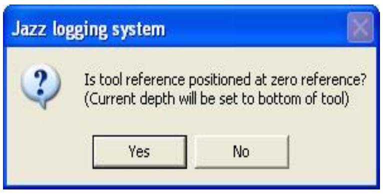


Figure 3.13 – Tool zero confirmation

Change Depth:
If the displayed depth needs to be reset to another value click the **Change Depth** button. The dialogue unit displayed in Figure 3.14 will be displayed. Enter the new depth and confirm with **OK**. The next recorded depth will correspond to the new value.

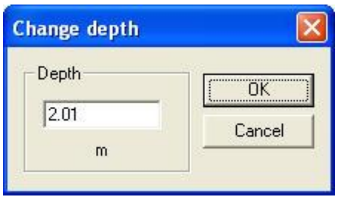


Figure 3.14 – Tool zero confirmation

In the event of a power failure, the current depth information is stored in the data acquisition unit in non-volatile memory. If the tool is kept stationary and power resumes the valid depth will be recovered.

Change Depth By:
If it is necessary to add an additional depth offset to the zeroed tool, the **Change Depth By** option could be used. e.g. when using an isolation bridle for normal resistivity logging the tool zero position is the cable head / bridle connection. If not already accounted for in the selected tool stack you can add the offset (length of the bridle) in the **Change Depth By** dialog unit (Figure 3.15). Enter the depth shift and select whether you want to add it (**Down**) or subtract it (**Up**) from the current depth. You can also use **Change Depth By** dialogue unit to account for offsets between tool zero reference and borehole zero reference.

Figure 3.15 – Tool zero confirmation

3.3 Tension panel

If a tension gauge is connected to your data acquisition system the Tension panel (Figure 3.16) becomes available displaying the current tension value. Calibration of the tension gauge(s) and unit preferences can be set in the **Logger Settings** application.

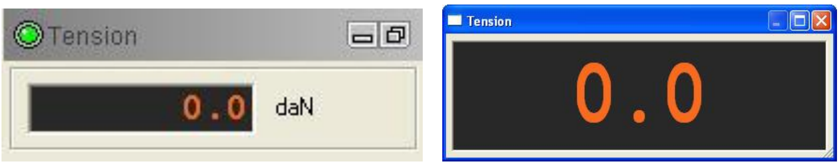


Figure 3.16 – Tension panel (minimized and extended)

3.4 Winch panel

The Winch Panel (Figure 3.17) is only active when the software is run with the OPAL –SCOUT PRO -SCOUT-BBOX-ALTLOGGER acquisition systems. Matrix has a different display for the winch telemetry scheme selection (refer to Figure 3.6).

The Winch Panel is used to select the desired winch configuration and telemetry scheme for the logging operation. Multiple winch configurations can be created and edited in Logger Settings application - refer to Logger Settings manual for more information.

Winch configurations and telemetry schemes are managed and stored into a SQLITE format database. It can be found in the following repository *C:\Logger\Tools\Database*.

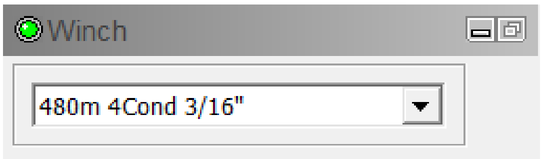


Figure 3.17 – Winch Panel

3.5 Tool panel

The Tool panel (Figure 3.18) is used to select the desired tool for logging, switch tool power on/off, access tool functions such as caliper open/close and to modify tool configuration settings.
Please note that a logging tool must be selected before most of the options provided in the dashboard become accessible.

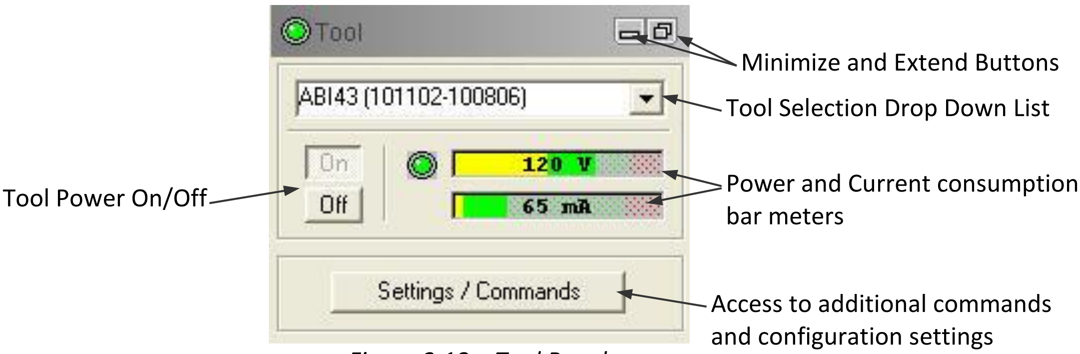


Figure 3.18 – Tool Panel

3.5.1 Selecting a tool

A logging tool or stack is selected by extending the drop down list and choosing the desired tool. The tools listed depend on the items installed using the Logger Settings application. To learn how to add or remove tools from the list refer to the Logger Settings manual.
You can select a tool by simply extending the folders and clicking on an entry. Please note that logging tools belonging to the QL product line are listed as stacks, while older or third party tools can be found under Standalone Tools.
When a logging tool or stack has been selected and the tool is going through the initialization process (tool is Powered On see below) tool specific parameters will be loaded. Irreparable damage may occur to the tool if powered on while an incorrect tool configuration has been loaded.

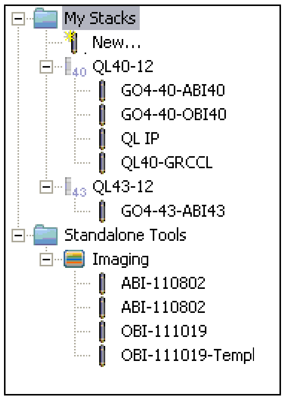


Figure 3.19 – Tool selection drop down list

3.5.2 Using the ToolStack Manager and ToolStack Factory

The **ToolStack Manager** (Figure 3.20) provides a graphical representation of the tool stack and overview of important details of the stack such as total length, weight, pressure and temperature limits. The **ToolStack Manager** is enabled and displayed attached to the dashboard when either a predefined tool stack is selected in the Tool panel or after a new tool stack is defined with the ToolStack Factory.
Right click on the Dashboard or ToolStack Manager and select **Hide ToolStack Manager** to hide the display.
The right margin of the display shows a tool length scale in Metric or Imperial units, depending on the system units settings (LoggerSettings application).
The toolbar (Figure 3.21) above the stack details summary at the bottom of the ToolStack Manager controls different aspects of the stack display.

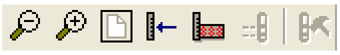


Figure 3.21 – ToolStack display controls

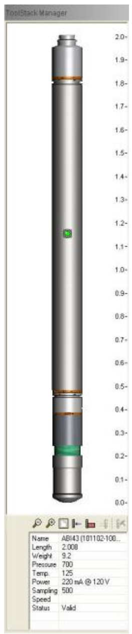


Figure 3.20 – ToolStack Manager

Besides options to **Zoom in**, **Zoom out** and **Zoom all** (back to default view) the following button are available:
Finger: Clicking the finger icon inserts a horizontal marker line that can be moved up and down the stack display by dragging it with the mouse. The distance from the tool bottom can be measured.
Ruler Mode: The ruler mode icon toggles the length scale from being measured positive from bottom up to negative from bottom up.
(The two remaining icons are no longer in use.)

Each sub (i.e. tool top, tool body or bottom plugs) in the display can be selected by left clicking on it. A red frame around the sub will indicate that it is selected. The summary displayed at the bottom of the ToolStack manager will be updated and shows details of the selected item. To unselect an item simply left click in the white area next to a sub.

The following details are displayed in the tool stack summary:
Name: It is a composite of the sub names, starting with the probe top;
Length: Total stack or sub length displayed in meters;
Weight: Total stack or sub weight in Kg;
Pressure: Maximum operating pressure in bars;
Temp.: Maximum operating temperature in degrees C;
Power: Nominal tool current in milli-Amps and voltage;
Sampling: Selected depth or time sampling rate;
Status: Actual stack or sub status (e.g. Disabled, retrieving no data, …) .

ToolStack Factory
In order to build custom tool strings (stacks) made up of predefined sub elements you have to use the **ToolStack Factory**.
To start it select **New** from the **MyStacks** directory in the Tool panel's tool selection drop down list (Figure 3.22).

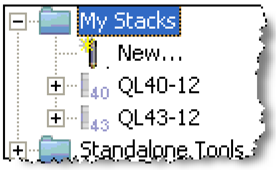


*Figure 3.22 – Select **New** to start ToolStack Factory*

The **Connect Tool…** dialog unit opens, waiting for you to confirm that you would like to configure the system for a new tool stack. Click **Yes** to proceed.

To start the ToolStack Factory to modify and existing tool string select the corresponding entry from the tool selection drop down list. When prompted in the **Connect Tool…** dialog unit (Figure 3.23) check the **Launch ToolStack Factory** option in the lower left of the dialog unit and click **Yes**.

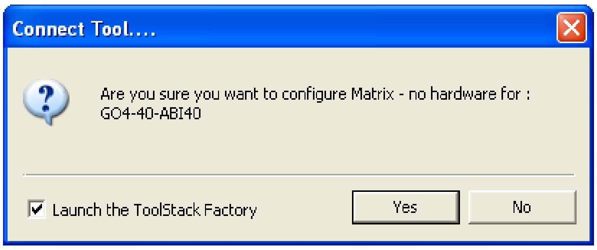


Figure 3.23 – Tick the option unit to start ToolStack Factory

The ToolStack Factory opens with a sub file tree control list in the left pane and a tool stack overview in the right pane (Figure 3.24).

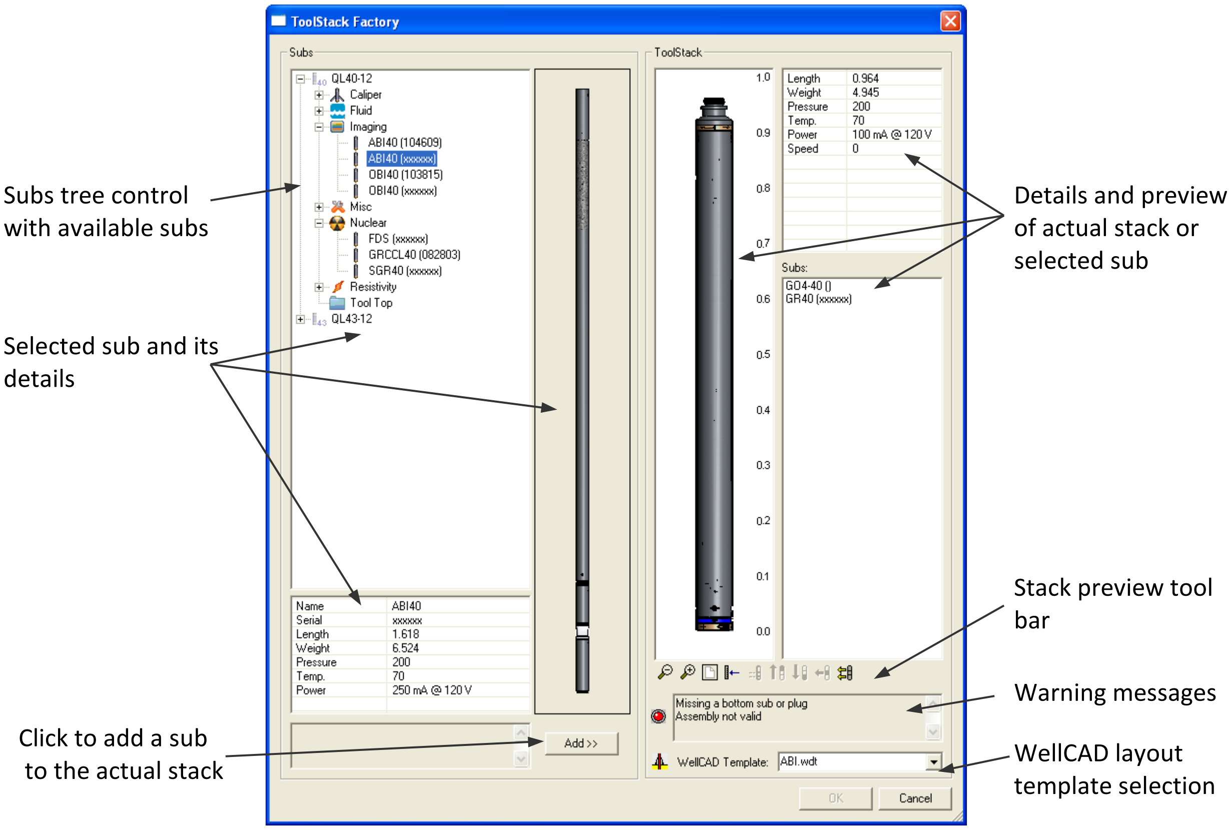
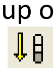


Figure 3.24 – ToolStack Factory

The content of the **Subs** tree control depends on the tool configuration files (*.sub) that were installed with the LoggerSettings application. Subs are organized by product line (e.g. QL40 or QL43) and in different categories such as
Caliper: Multi arms caliper tools;
Fluid: Fluid Temperature & Conductivity (FTC) tool and Water Quality (OCEAN);
Imaging: Acoustic and Optical Televiewer (ABI and OBI);
Nuclear: Total and Spectral Gamma tools;
Resistivity: ELOG, IP and DLL tools;
Misc: Other tools like MagSus or Deviation tools but also items like the bottom plug to "close" inline subs or an inline centralizer;
Tool Top: Tool tops to connect the stack to the cable head.
When selecting an item from the tree control a summary of the sub will be displayed at the bottom of the pane and a bitmap is shown to the right of the control.

Adding subs to a stack

To add a sub to your actual stack simply select the corresponding item from the tree control and click the **Add** button located below the sub preview in the left pane.
The preview and details of the actual stack provided in the right pane will update accordingly. If the actual stack does not allow further items to be added they will appear grayed out in the sub tree control. To move an inline sub up or down select it (left click on it) and click the **Move up**  respectively the **Move down**  icon.
Should you want to remove one or all subs from the stack and start all over click the **Remove**  (left click on the sub first) or **Remove all subs**  icon from the stack preview tool bar (Figure 3.24). The tool bar also provides zoom options and a finger tool similar to the ToolStack Manager explained earlier. All other icons are inactive for the moment.

Warning messages

Keep an eye on the warning message displayed below the stack preview in the right pane. Message text and LED provide feedback about the validity of the current stack assembly.

WellCAD Template

If you would like to associate a WellCAD Document Template file (*.wdt) with your tool stack select it from the **Template** drop down list. The selected template will handle the data layout once the recorded TFD file will be imported into the WellCAD application and when data is streamed into the WellCAD Browser.

Templates can be added to the repository using the LoggerSettings applications. To learn how to create a layout template in WellCAD refer to the WellCAD manual Book 1.

Once you have completed the stack assembly click the **OK** button to close the ToolStack Factory. A dialog unit (Figure 3.25) opens allowing edition of the stack's name and saving the new stack configuration. When clicking **No** the stack will be created but not saved.

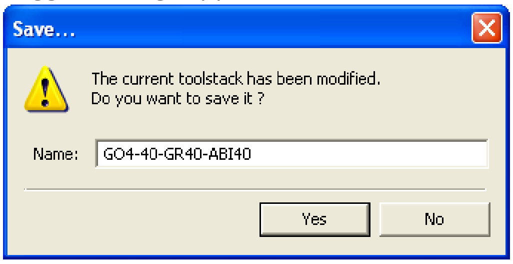


Figure 3.25 – Tool Stack confirmation

3.5.3 Tool power and the Tool Power Control dialogue unit

Two bar meters on the Tool panel (Figure 3.18) display the tool voltage supplied to the wireline and current draw (in-milli-amps) through the wireline. As long as the Power-**Off** button is pressed the current meter is active but should show 0 mA. If the Power-**On** button is pressed the LED next to the power bar meter shows green when the tool power supply is working properly and turns red under error conditions.

The power and current values displayed should be in the green area of the bar meters. If the current is in the red area it is highly recommended to push the Power-Off button. Refer to the Trouble Shooting chapter in the tool's manual for further information.

Clicking on the Extend button in the right corner of the panel header will open the **Tool Power Control** dialogue unit (Figure 3.26).

Power and current settings are part of the tool configuration file that was supplied with your tool and should not be changed without any good reason and knowing the exact specifications of your tool.

WARNING! Tool damage can occur if improper settings are made!

The **Power Supply Status** in the dialogue unit shows green when the tool power supply is working properly. Under error conditions it will stay red.

It is possible to enable a **Tool Protection** by checking the corresponding option. The tool protection option will only limit the power and current range you can set. Click on the **Edit** button to open the **Tool Power Supply Range** dialogue unit (Figure 3.27). By specifying the correct allowable minimum and maximum limits for supplied voltage and power you may prevent erroneous

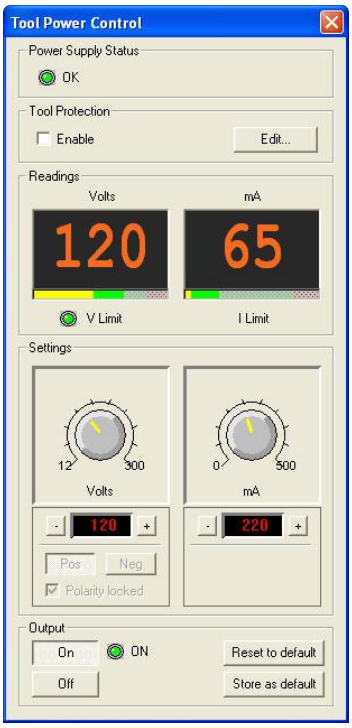


Figure 3.26 – Tool Power Control

user input. As an orientation the nominal (NOM) values as suggested for this type of tool are displayed next to the edit unites.

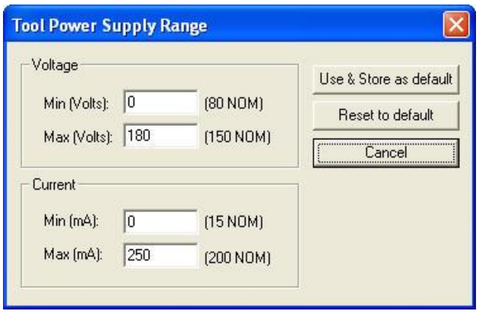


Figure 3.27 – Tool Power Supply Range

Use the **Cancel**, **Reset to default** and **Use & Store as default** buttons as applicable.

Back in the **Tool Power Control** dialogue unit the actual supplied voltage to the wireline and power draw through the wireline can be read from the numerical displays in the **Readings** section (in addition colored bars indicate the quality of power and current). The **V Limit** shows green when a set voltage is reached before a current limit is reached (voltage limit mode). The **I Limit** shows green when a set current is reached before the voltage limit is reached (current limit mode).
Changes to power and current values can be made by turning the corresponding knobs and pushing the +/- buttons in the **Settings** section. Again, remember that improper settings may lead to tool damage!
Clicking the **On** button under the **Output** section will power the tool on. If settings are valid press the **Store as default** button to update the tool configuration. To reset settings to default click on **Reset to default**.

3.5.4 Additional Tool Settings and Commands

Settings or commands specific to a tool type can be accessed - if available - by clicking on the **Settings / Commands** button in Tool panel. For some tools the tool must be powered on before the **Settings / Commands** button becomes active.
Please refer to the tool’s manual to find out which additional options are available.

3.6 Telemetry Panel

As mentioned in the chapter 3 introduction the Telemetry Panel display varies according to the telemetry adapter implemented in the acquisition system. Below is an overview of the three main Telemetry Panel displays and a general description of their functionalities:

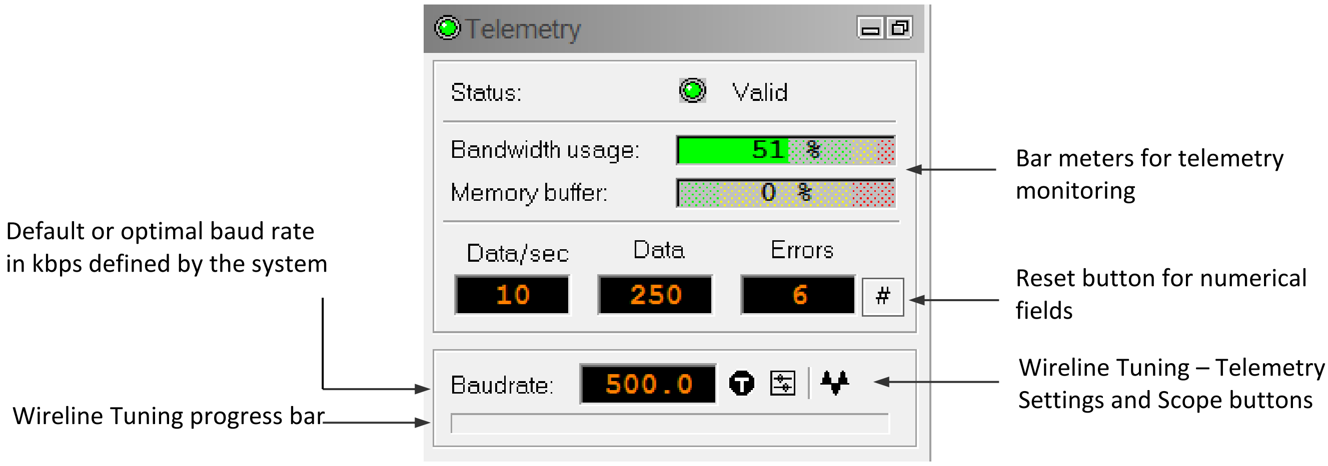


Figure 3.28 – Telemetry Panel – ALT Modem (OPAL – SCOUT PRO- SCOUT)

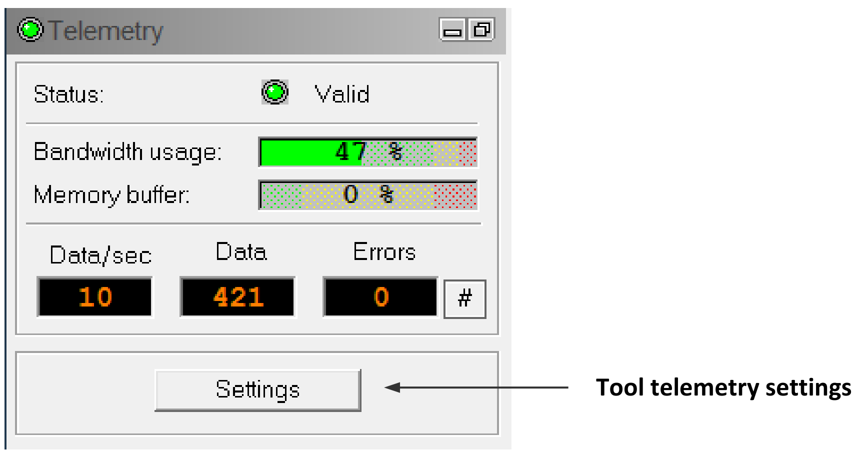


Figure 3.29 – Telemetry Panel – ALT Shallow (BBOX - ALTLOGGER)

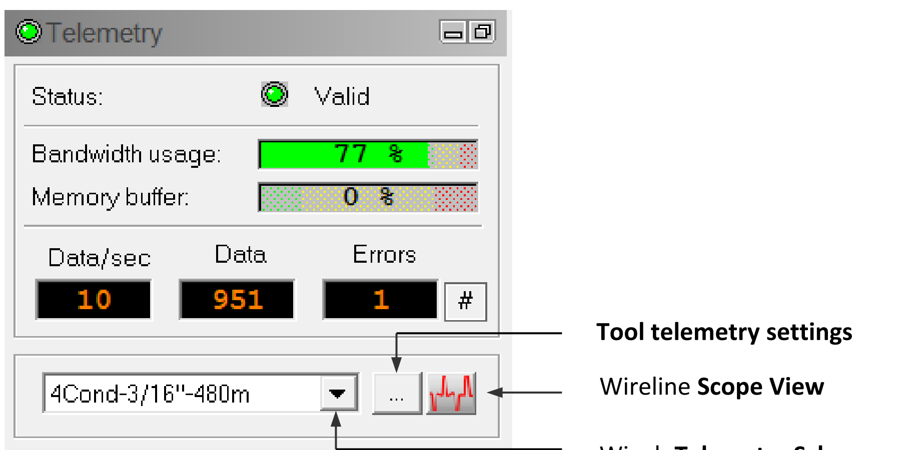


Figure 3.30 – Telemetry Panel – Matrix

Bar meters and numerical fields are available in the Telemetry panel to monitor data sampling and data throughput. It also provides options to tune communication settings.

Note: *For more information regarding the **telemetry settings** refer to the **tool operation manuals** and more specifically to the **Tool Communication** chapter.*

***Status**:*
The Status LED shows green if no error condition occurs. If the Status is not valid (no data or data not correctly received) you should check all connections and verify the telemetry settings as explained below.

***Bandwidth usage**:*
The bar meter indicates the capacity utilization of the logging cable. If 100% is reached the baud rate should be increased up to the highest possible value allowed by your wireline configuration. As a next step reduce the logging speed or resolution (e.g. decrease azimuthal sample step or increase depth sample step).

***Memory buffer**:*
The bar meter shows how much data is being internally buffered for transmittal to the computer. If 100% is reached the connected computer can't receive the incoming data streams fast enough. Ensure that your computer has sufficient resources.

***Data/sec**:*
Shows the rate of data sampling.

***Data**:*
Indicates the number of valid data samples read unique to a recording (also shown during replay). The value is automatically reset to zero when a record is terminated by pushing the Stop button in the Acquisition panel. You can force a reset by clicking the X button.

***Errors**:*
Shows the number of times the system failed to obtain valid data.

3.6.1 Adjusting Tool Communications

Logging tools communicate with the surface by a variety of means including pulse frequencies and several digital encoding schemes. Full digital communications can be achieved by several modem types, which include but are not limited to FSK (Frequency Shift Key) and PCM (Pulse Code Modulation). Within these types, logging tools may operate at different baud (bits per second) rates and frequencies. Older analog tools may convey information to the surface with either pulses or analog voltage levels both AC and DC.
All of these different modes of operation need to be supported by the data acquisition system and furthermore are affected by wireline type and length. There is therefore the need for different schemes of adjustment of the up-hole telemetry unique to particular logging tool and wireline combinations. More information on this subject is available in the "**Tool communication**" chapter of the **tool operation manuals**.

3.7 Acquisition panel

The **Acquisition panel** (Figure 3.31) provides options to
- Select the data sampling mode,
- Set sampling rates,
- Start and stop the data recording,
- Edit information in the log header.

Figure 3.31 – Acquisition panel

To make a recording you should do the following (details for each step will be provided in the paragraphs below):
- Select and complete a **header**.
- Select the **sampling mode** (depth up/down) or time.
- Set the **sampling rate** according to the sample mode.
- Start the **data sampling** and verify that communications are valid.
- Click the **Record button,** set the output file name and commence recording.

3.7.1 Selecting and entering details into a header

In order to select and fill a header you will need a header design. Header designs can be created using the free software application **HeadCAD** available from ALT. Header design files carry the extension *.wch and can be added to your repository using the LoggerSettings application.

By pressing the  or the Extend button of the panel you can open the **Header** dialogue unit (Figure 3.32). A preview of the header is provided and information can be entered into designated text fields (click into a text field and enter the desired information).

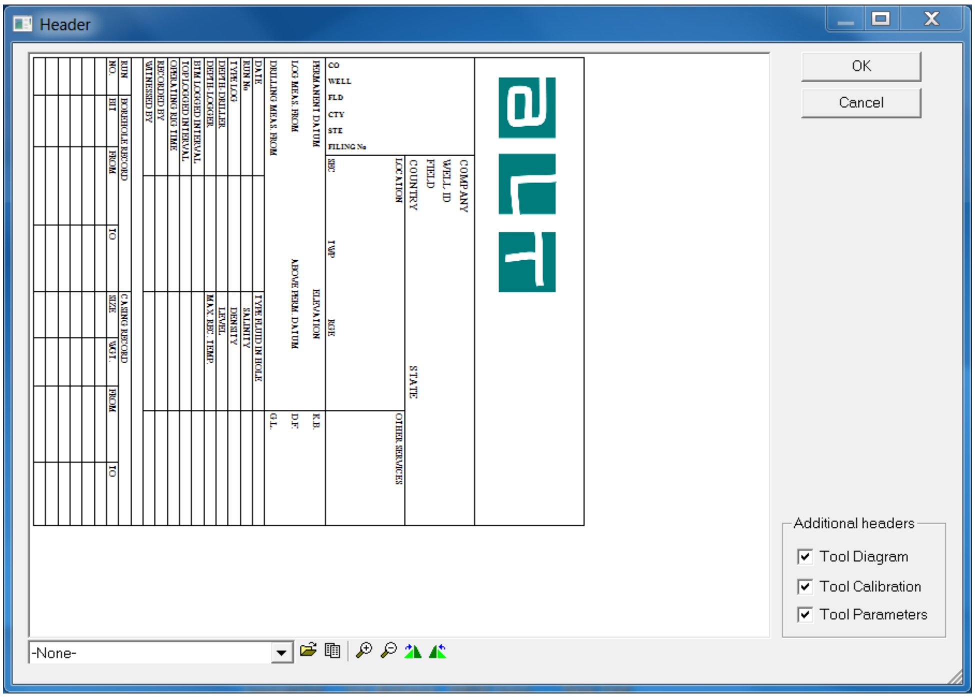


Figure 3.32 – Header dialogue unit

In the lower left of the dialogue unit a toolbar (Figure 3.33) provides further options:

Figure 3.33 – Header tool bar

To select a new header design from the repository, extend the drop down list and click on an entry.
Import Form: Browse and load a new WCH file.
Last content: The content of the last header is remembered on your computer. Click this option to populate your new header with this information. The labels of the header fields in the new header must match the former ones.
Zoom in/out: Increases/decreases the headers preview.
Rotate left/right: Allows rotation of the header preview in order to enter "rotated" text.

After selecting a header and entering the logging details click on **OK**. The **Header Options** dialogue unit (Figure 3.34) will open. By ticking the provided options you can make the selected header design the default header for the currently connected tool or data acquisition system.

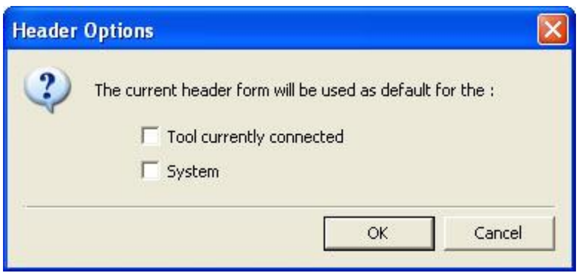


Figure 3.34– Header options dialogue

Additional headers:
Some ALT predefined headers can be added automatically at file import into WellCAD software. By checking the corresponding boxes user has the option to add:

- a "Tool Diagram" - tool stack diagram highlighting the offset position of each measured channels
- a "Tool Calibration" table – table listing all sensor calibration factors
- "Tool parameters" – acoustic televiewer settings & commands used for the record including the full wave form preview

3.7.2 Sample modes and rates

The sampling mode is selected by extending the sampling mode selection drop down list in the Acquisition panel. Options are **Time**, **Depth Up** and **Depth Down**. In Depth mode (recommended) the sampling is directly related to the pulse inputs from the depth encoder device and the corresponding settings stored with the Logger (use LoggerSettings to configure the Logger for a depth encoder). Time mode should be used for calibration, static measurements or operational testing only.
In order to set a sample rate click the **Settings** button in the Acquisition panel.
If the selected tool is a standalone tool the dialog unit in Figure 3.35 opens. Enter the desired time or depth sample rate (numbers are always positive) in the corresponding edit unites. If you would like to make your settings the default for all future runs with this tool, check the **use as default...** option before closing the dialogue unit.

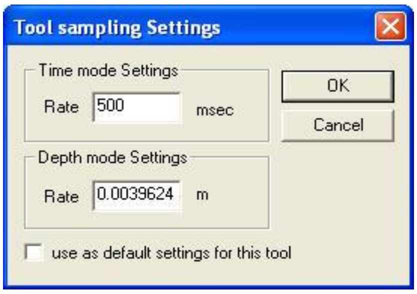


Figure 3.35– Tool sampling options for standalone tools

For tool stacks using multiple subs (e.g. ABI with GR) the dialogue unit in Figure 3.36 opens.

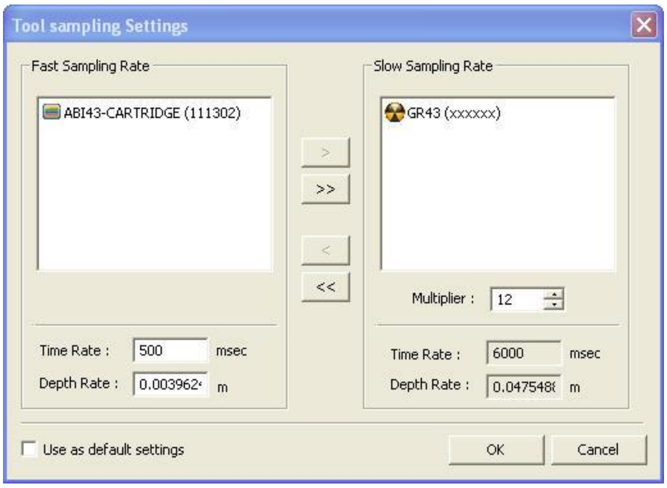


Figure 3.36– Tool sampling options for multi sub tools

The dialogue unit provides the options to define a fast and slow (time / depth) sampling rate and assign the subs within the tool stack accordingly. Use the **>** or **<** buttons to move the subs.
Set the Fast Sampling Rate first and determine the Slow Sampling Rate afterwards by simply defining a multiplication factor of the fast sample rate using the **Multiplier** control.
If you would like to make your settings the default for all future runs with this tool stack, check the **Use as default…** option before closing the dialogue unit.

Note: The depth sample rate cannot be finer than the resolution of the depth encoder. If the encoder signal is 200 pulses per foot then the finest sampling rate is 1/200th of a foot. Details about the depth encoder settings can be found in the LoggerSettings application.

3.7.3 Data recording and replay

Turn the sampling on by clicking the corresponding button in the Acquisition panel. The system is making measurements without recording the data in a file. You can observe the measurements made in the corresponding browser windows. In order to record the data and produce a digital file (*.TFD), click the **Record** button (Figure 3.37).

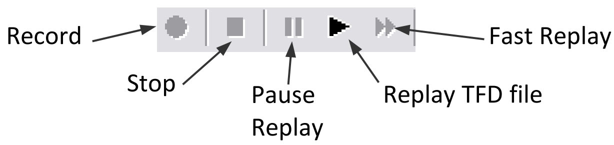


Figure 3.37 – Record and replay options

This opens a file manager dialogue unit in which you can choose the location and set the file name for the data recorded. Immediately after you pressed the **Save** button recording commences. When sampling in depth mode the recording will actually start as soon as the depth encoder sends its signals to the Logger.
To terminate data recording press the **Stop** button. The Logger automatically saves a file with extension TFD to the computer's hard disk.

Auto File Name
If you would like to enable the option to automatically compose file names based on tool, header and acquisition details click the file naming options button . An options dialog unit (Figure 3.38) will open.

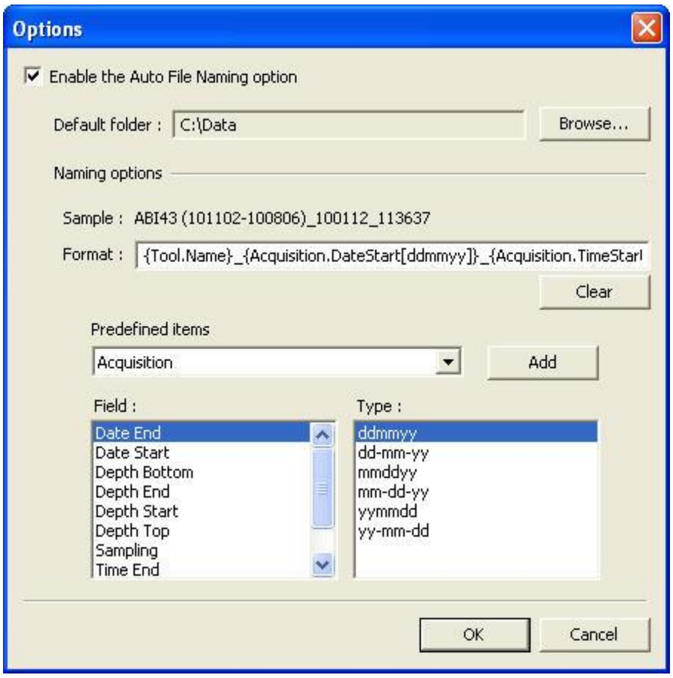


Figure 3.38 – Auto File Naming options

Click the **Enable the Auto File Naming** option in the upper left corner of the dialogue unit to activate the feature and get access to the naming options. Click the **Browse** button to specify a default location and folder for your TFD files.

An auto file name consist of different predefined fields and formats connected by separators or text entered manually into the **Format** text unit.

To select a field and format to add to your file name you have to:

- Select a category from the **Predefined Items** drop down list: You can choose from **Acquisition**, **Header** and **Tool**.
- Select a **Field:** For each predefined item different fields become available. For the **Tool** item you can choose the tool's name or for the **Header** item you can choose from the different text labels available in the selected header. The **Acquisition** system item allows fields like start/stop date, time and depth as well as sampling rate to be used in the file name. Note: While the start and stop depth display the depth at which the recording started respectively ended the top and bottom depth will display the top and bottom of the interval you logged. (E.g. if you logged up from 100m to 5m the start depth is 100m, stop depth 5m but the top depth is 5m and bottom depth 100m.) If you would like to indicate the logging direction in your auto file name you should use start and stop depth.
- Select a **Format**: Different data and time formats can be chosen for fields of the **Acquisition** item.

By clicking the **Add** button you will make the selected field part of your auto file name. The actual auto file name and an example can be seen in the **Format** text field and the **Sample** line above. You can add text (e.g. depth units) or separators into the **Format** text unit manually.

Replay

Previously recorded data can be replayed with or without data acquisition system connected. To replay a TFD file click the  button (should this button be inactive ensure that **Sampling** is turned **Off**). A file manager dialogue unit opens in which you can choose the file to be replayed (click the **Select** button), whether the embedded or an external tool configuration file should be used and define the depth interval to be replayed.

3.8 Browsers & processors panel

The **Browsers & processors panel** controls the starting and stopping of client processes, which consist of applications supporting on-screen data display, printing and data processing.

Figure 3.39 – Browsers & processors panel

The default selection of browser and processor windows that will start up when a tool is loaded is defined in the tool configuration file. If a browser or processor is listed but not running, click on it to select it and push the **Start** button. Detailed information about the different browser and processor windows will be given in Chapter 4 below.

3.9 Status panel

The Status panel displays LEDs indicating the status of various components of the logging system. Click the Details button to show a sketch of the system in a separate window (Figure 3.40).

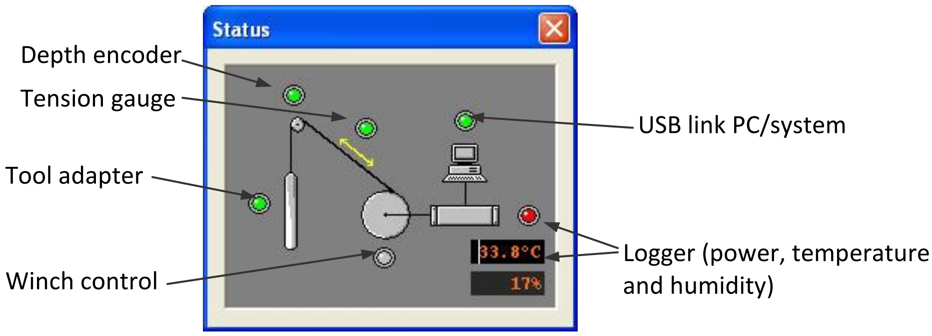


Figure 3.40 – Extended Status panel

If the corresponding components are available the LEDs show green for normal operation and red for error conditions.

4 Browser & Processor Window Reference

Once a tool has been selected in the Tool panel and loaded the system will provide access to the relevant **Browser** windows and data **Processors** specific to the tool type. The acquired data is provided in real time to these individual client windows (**Browsers** and **Processors**). By setting options within these client windows the user can control the layout for both onscreen data display and for hard-copy printout, calibrate tools such as calipers and other pulse type tools and edit and print customized log headers.
Available Browsers and Processors are listed in the **Browser & processors panel** in the dashboard.
Following are the most common Browsers and Processors. Some tools use unique Browsers and Processors which will be covered in chapters of the tool manuals devoted specifically to them.

4.1 MChCurve Browser

The **M**ulti **Ch**annel **Curve** Browser displays a scrolling graphical real-time representation of the logged data with respect to either time or depth (Figure 4.1). Toolbars at the right side of the window allows changing the vertical scale of the display.
In order for MChCurve or the Image display browsers to operate properly, at least one printer must be installed and set to default.

Figure 4.1 – MChCurve browser window

Toolbars at the top and right side of the window allow changing the vertical scale of the display, access to depth settings and print options:

 Time Mode Display;

Depth mode display with pre-defined depth scales;

 Open the depth settings dialog unit;

 Enables printing of the data display;

 Opens the **About** dialog unit.

File menu

Opening the **File** menu provides access to the following options:

Print: Enables real-time printing of the data display.

Print Setup: Displays the **Print Setup** dialog unit (Figure 4.2).

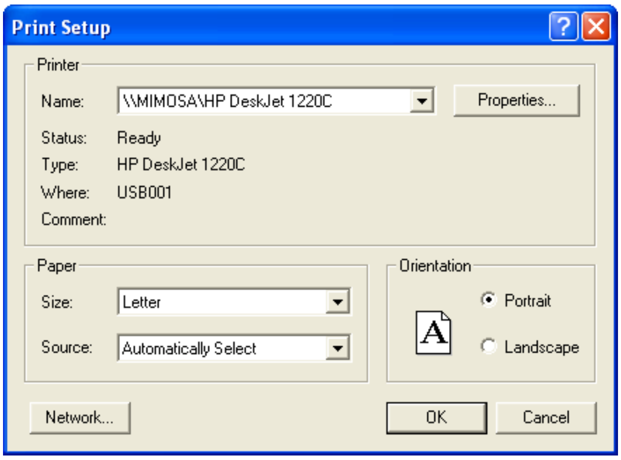


Figure 4.2 – Print Setup dialog unit

Select your Windows printer and set page size and orientation. Click on **Properties** to setup printer specific details.

Page Setup: Opens the **Page Setup** dialog unit (Figure 4.3). Select whether the full header as selected in the Acquisition panel will be printed (check **Print header**). A short header – consisting of curve titles and depth scale information – will be printed at top and/or bottom of the log if the corresponding option is checked.

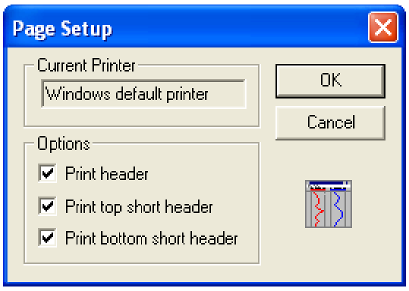


Figure 4.3 – Page Setup dialog unit

Exit: Terminates the MChCurve browser window. It can be restarted by choosing the MChCurve entry in the **Browsers & processors panel** and clicking the **Start** button.

Edit menu

The **Edit** menu provides access to the following options:

Depth Scale: Provides a short-cut to enable Time or Depth mode display and access to pre-defined depth scales.

Depth Settings: Displays the **Depth Settings** dialog unit (Figure 4.4). Alternatively you can open the settings dialog unit by double left clicking on the depth column title in the data display.

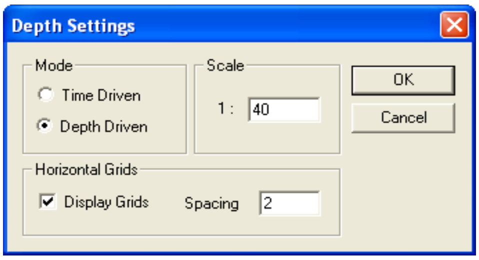


Figure 4.4 – Depth Settings dialog unit

Analog to selecting the display mode – **Time** or **Depth** - from the toolbar or short-cut menu, you can set the option by ticking the corresponding option in the **Mode** section.
Besides setting a scale value for the vertical dimension (depth) you can specify whether horizontal grid line are displayed across the log plot (check the **Display Grids** option) and at which frequency they will be displayed. If you enter a value 1 into the **Spacing** edit unit a grid line will be displayed every meter or feet depending on the system unit settings (LoggerSettings application).

Depth Column Position: The position and width of the depth column display can be defined by specifying the left and right limits in the **Depth Column Position** dialog unit (Figure 4.5). Taking into account that the entire width of the data display area of the MChCurve browser window corresponds to 100% enter the desired percentage values for the left and right limits of the depth column in the corresponding edit unites.

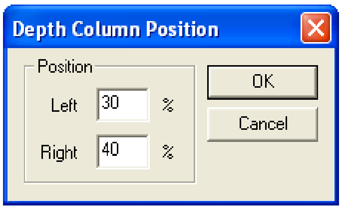


Figure 4.5 – Depth Column Position dialog unit

Log Settings: You can change the display settings for the curves shown in the MChCurve browser. From the menu select the channel title to open the corresponding **Log Settings** dialog unit. Alternatively you can open the settings dialog unit by double left clicking on the curve title in the data display.

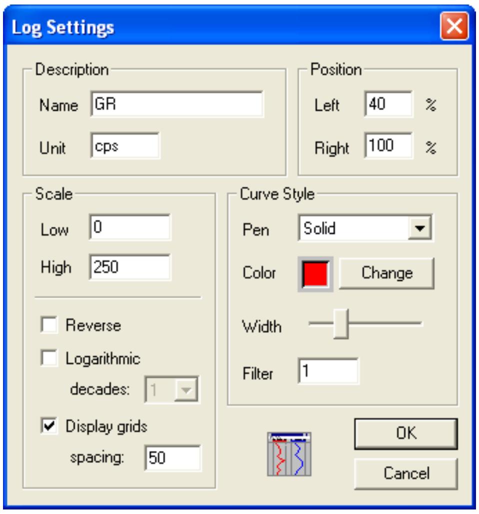


Figure 4.6 –Log Settings dialog unit

Besides defining the displayed curve title and unit you can change following settings:
Position: Enter a percentage value for the left and right track limits. Tracks may superimpose each other.
Scale Low / High: Enter the low and high scale value for your curve. If data values lay outside the scale limits the curve will be wrapped around.
To reverse the scale display and display the scale increasing from right to left check the **Reverse** button.
If you prefer a logarithmic scaling, check the corresponding **Logarithmic** option and specify the number of decades to be handled.
To display vertical grid lines check the **Display grids** option and enter the grid frequency.
The color, line style and width for each curve can be specified using the control provided in the **Curve Style** section.
Filter: An on-the-fly average filter for the displayed curve can be applied if a value other than 1 is entered into the **Filter** edit unit. E.g. if a value of 5 is entered each curve value displayed will be the average calculated over a window of five samples. Please note that the filter will only affect the data display and not the recorded data.

Log settings will have no influence on the data recorded and saved into a TFD file.

Show Logs: The **Display Logs** dialog unit lists all available channels. Place a check mark in front of the data channels that you would like to see in the MChCurve browser window.

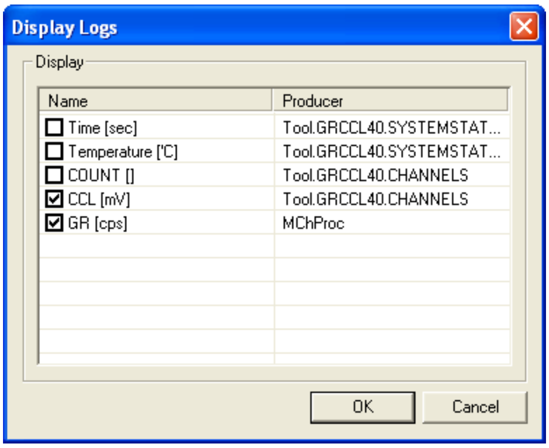


Figure 4.7 – Displayed logs selection

The entries in the **producer** column indicate the origin of the data channel, i.e. whether it was measured by the **Tool** or computed using **MChProc**.

View menu
The **View** menu allows enabling – disabling of the toolbars and positioning the splitter bar (separation between log title area and data display).

4.2 MChNum Browser

The **M**ulti **Ch**annel **Num**eric Browser window (Figure 4.8) displays the numeric value for each selected tool channel and allows calibration of data channels where applicable. It can also display calculated values computed in real-time with the MChProc processor and status information based on data received from the logging tool.

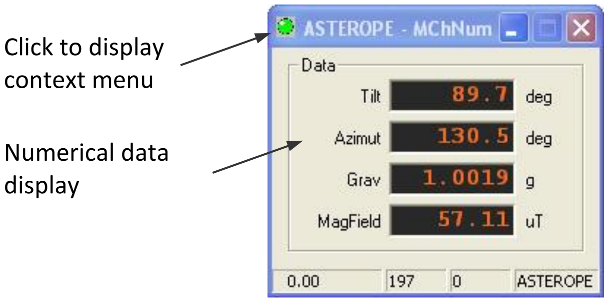


Figure 4.8 – MChNum browser window

Left clicking on the “green LED” icon in the left corner of the MChNum window title or a right click on the window title will open a context menu (Figure 4.9).

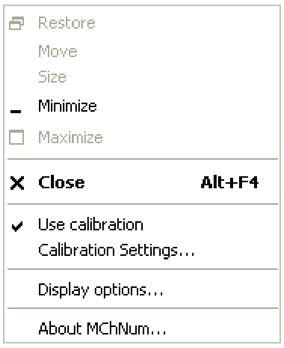


Figure 4.9 – MChNum browser context menu

Besides **Minimize**, **Maximize** and **Close** options to control the windows behavior you will find options for **Calibration** and the use of **Calibration** as well as **Display options** in this menu.

4.2.1 Display options

In order to compose the information displayed in the MChNum browser window select the **Display options...** entry from the context menu. A dialog unit as shown in Figure 4.10 opens.

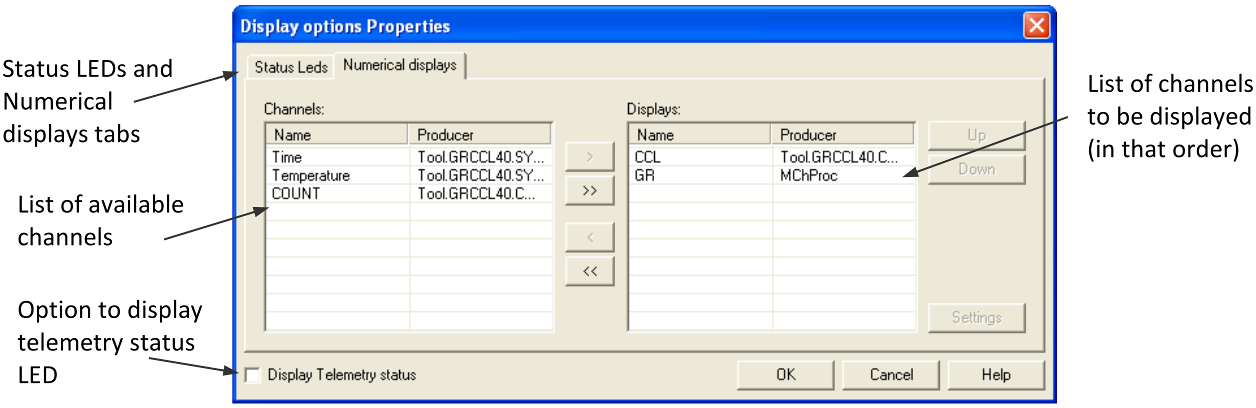


Figure 4.10 – MChNum browser context menu

Two tabs are provided to define the Status LEDs and Numerical displays being displayed in the MChNum browser window. Figure 4.11 outlines the difference between both display items.

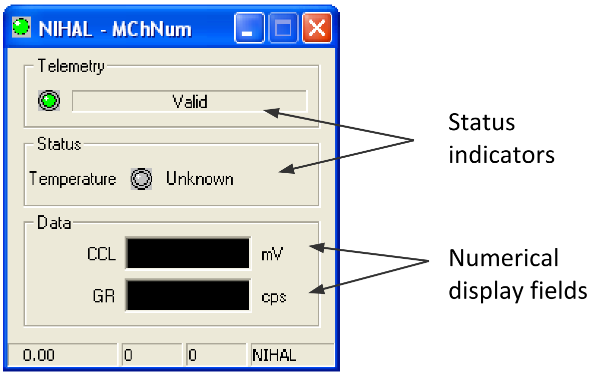


Figure 4.11 – MChNum browser with status LEDs and numerical display fields

Adding a numerical display

In order to add a new numerical display to the MChNum browser ensure the **Numerical displays** tab is activated and click on the channel that you would like to add in the **Channels** list. Push the **>** button to move the entry to the **Display** list (to move all channels click the **>>** button). To change the order of appearance select the entry you would like to move and click on the **Up** and **Down** buttons as appropriate.
Analog you can remove display channels using the **<** or **<<** buttons.

Adding status LEDs

Ensure the **Status LEDs** tab is activated. Add a channel to the **Display** list by selecting it in the **Channels** list and pushing the **>** button. In order to specify under which conditions a certain status will be displayed select the entry from the **Display** list and click the **Settings** button in the lower right corner of the dialog unit. The **LED Settings** dialog unit (Figure 4.12) opens.

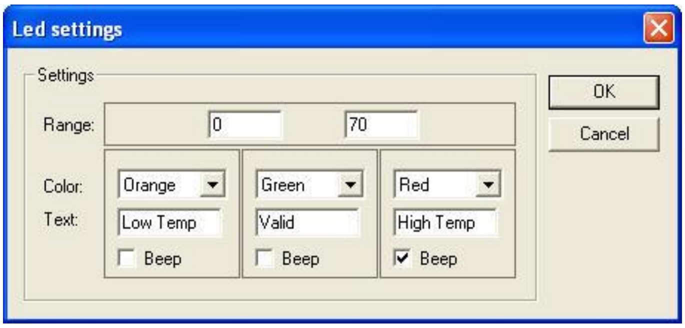


Figure 4.10 – MChNum browser context menu

In the **Range** fields enter the values for the low and high threshold (e.g. if the lowest operational temperature for your tool is 0°C and the highest operational temperature 70°C select a status LED for the on-board temperature channel and enter the range values 0 and 70). To define LED color and message text displayed for the cases “below low range value” (left group of controls), “between low and high range” (middle group of controls) and “above high range value” (right group of controls) use the corresponding controls. Check whether an acoustic signal (**Beep**) should appear. Click **OK** to close the dialog unit.

If you would like to see an LED indicating the telemetry status, simply check the corresponding option in the lower left corner of the **Display Options Properties** dialog unit (Figure 4.10).

4.2.2 Calibration Settings

The context menu of the MChNum browser (Figure 4.9) provides two options related to calibration. The **Use Calibration** option is normally turned on when logging. This results in the calibrations being applied to the MChNum display. If the user wishes to watch raw data being displayed, uncheck the **Use Calibration** option. Please not that raw data will be saved in the TFD file and calibration will be applied when importing the data into WellCAD. If recalibration is found to be necessary the data can be reloaded supplying a corrected tool configuration file.
Selecting the **Calibration Settings** option opens a dialog unit equipped with equal or similar controls and entry options as the one shown in Figure 4.11.

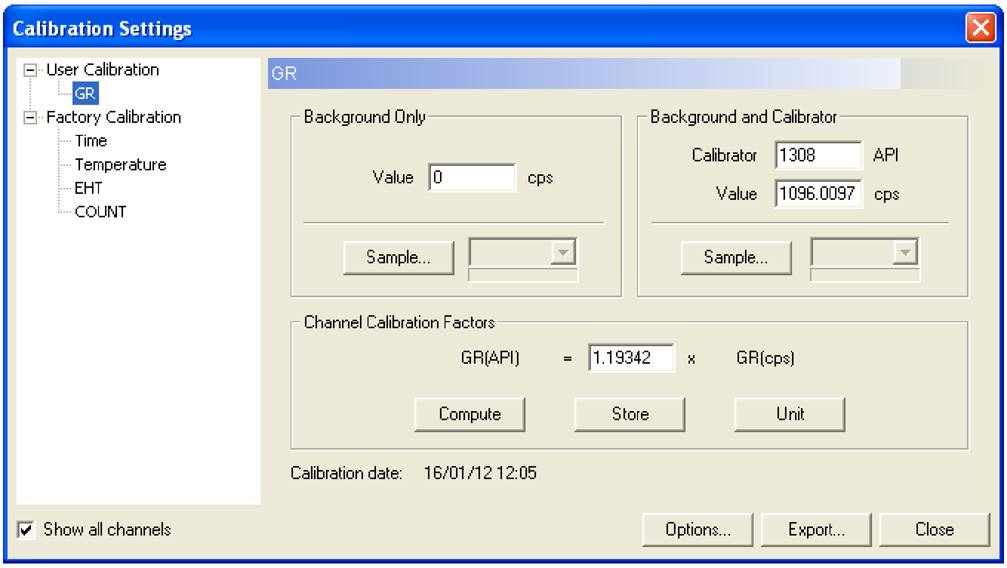


Figure 4.11 – Calibration Settings dialog unit for the QL40 GAM tool

Calibration procedures and dialog units are explained in detail in the corresponding tool manuals.
In general the calibration procedure is based on a linear regression between two reference points, such as the background radiation and radiation emitted by a calibration standard for a natural gamma ray tool, or the inner and outer rings of a caliper tool calibration jig.

Note that LoggerSuite offers also the option to perform a multi-point calibration (Figure 4.12). To activate the multipoint calibration the tool sub file might need some modifications. Contact ALT for more information.

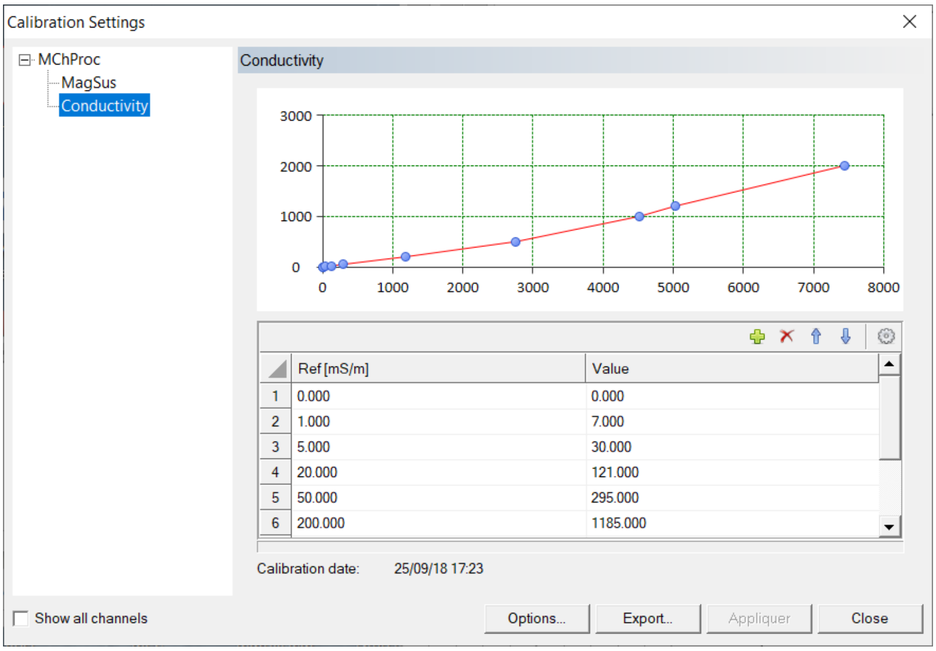


Figure 4.12 – Multi-point calibration example

4.3 MChProc

The **MChProc** Processor provides data format conversion and must be running for those tools requiring this function. It also provides the capability to calculate values using formulas beyond simple linear calibrations provided by MChNum. This processor will automatically start when initialized by the tool selection in the Tool panel. The user should make sure that it is running during calibration and logging. Do not turn off **MChProc**, or processed data will not be recorded. If it is listed in the Dashboard panel as a processor, it must be running. As different tools may or may not provide options to alter settings for the **MChProc** processor, please refer to the tool's manual for more details.

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LoggerSettings

Software Application Guide

Version 13.0

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Table of Contents

1 General Information

LoggerSettings is a standalone utility to manage your logging tools (i.e. tool configuration files) and configure the logger (OPAL, SCOUT PRO, SCOUT, MATRIX, ALTLOGGER, BBOX…) for a variety of software and hardware parameters.

The **LoggerSettings** application is installed as part of the **LoggerSuite**.

The application's user interface shows a tree control and property sheets with changing contents according to the selected option from the tree control.

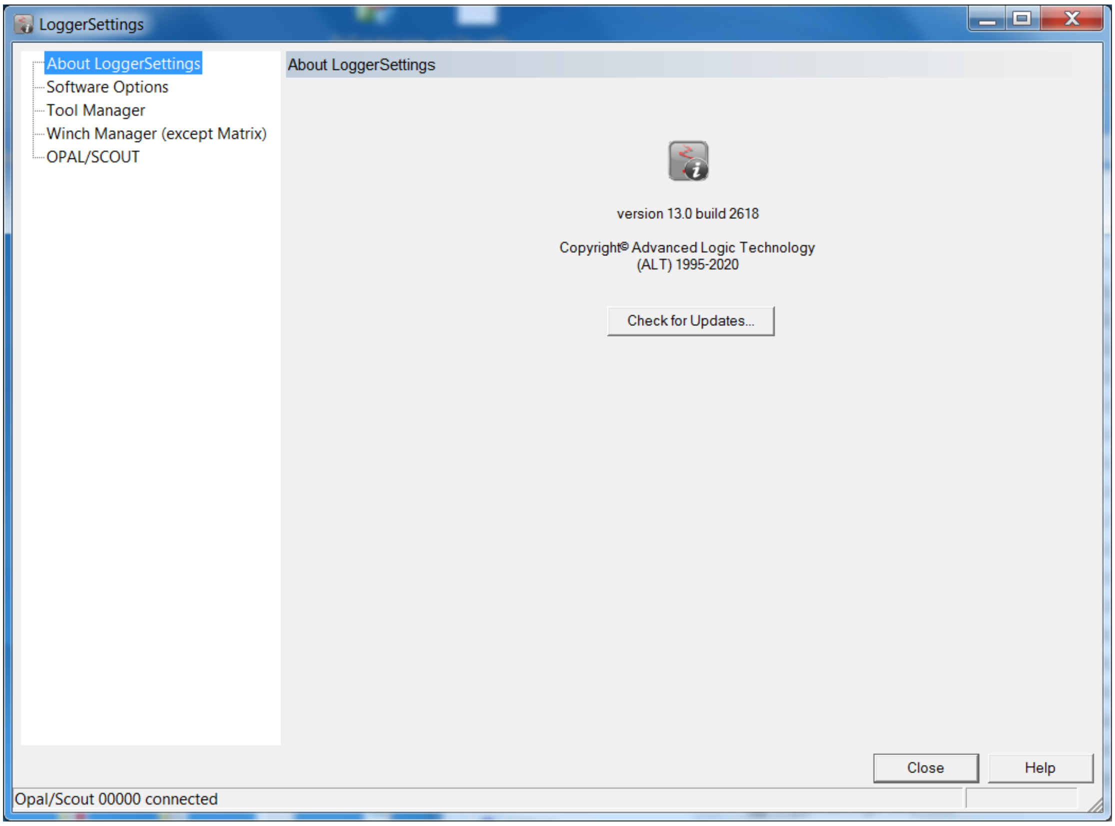


Figure 1-1

When starting the application the "About LoggerSettings" page showing the application version and build number will be displayed (Figure 1-1).
The application will detect automatically if a logger has been connected and updates the tree control with additional options as necessary. A logger can be connected at any time via a USB cable.

The "Check for Updates" option gives access to the latest release version of the software. An internet connection is required to have this functionality operational.

2 Software Options

In the Software Options page User can change the system units and presentation styles of the displays in the acquisition software’s dashboard (Figure 2-1):

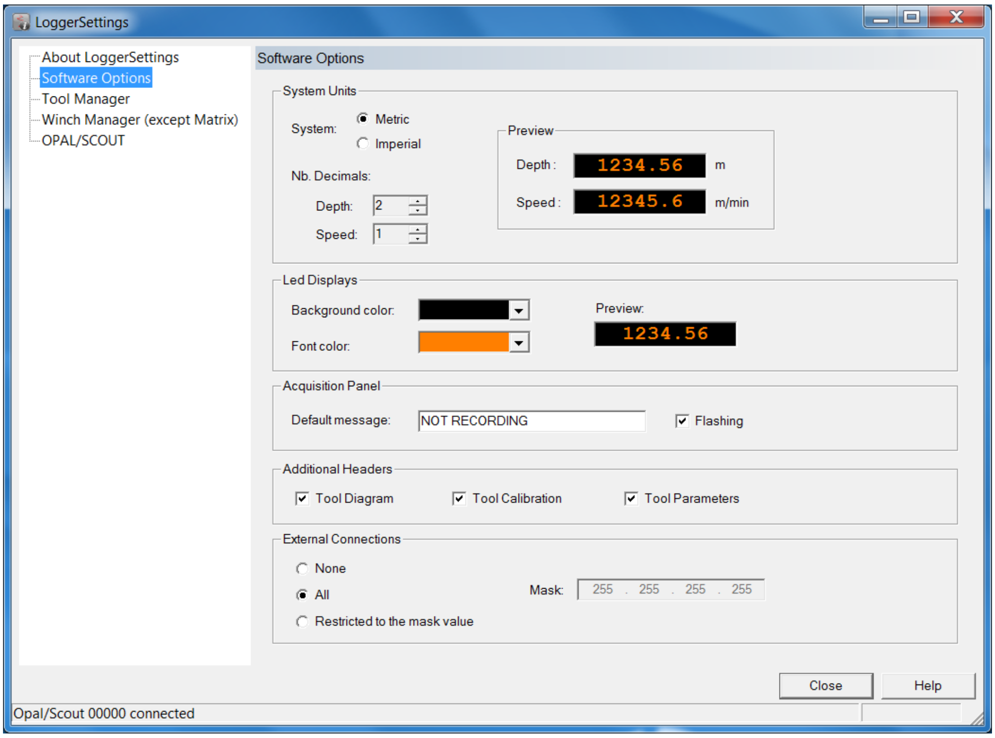


Figure 2-1 –

System Units:
Select Metric or Imperial units
Define the number of decimals for the depth and speed displays

LED Displays:
Select a new colour for background and text of the dashboard panel displays.

Figure 2-2 – Acquisition Software’s Dashboard Panel

Acquisition Panel:
Set the text of the default message that will be displayed in the display of the Acquisition panel. As an option you can chose to have the message flashing.

Additional headers:
Some default headers can be added automatically at file import into WellCAD software. By checking the corresponding boxes user has the option to add:

- a “Tool Diagram” - tool stack diagram highlighting the offset position of each measured channels
- a “Tool Calibration” table – table listing all sensor calibration factors
- “Tool parameters” – acoustic televiewer settings & commands used for the record including the full wave form preview

External Connections:
If you want to allow other computers to connect their browsers to your PC select either the **All** option or **Restrict** the access to a subnet by entering a corresponding address mask using the wildcard 255. E.g. an IP address of 123.456.789.**255** would allow access of computers having the first three blocks of digits 123.456.789 in their IP address.

3 Tool Manager

ALT/MSI logging systems use tool configuration files (*.TOL,*.TOOL, *.SUB and *.STACK) to control settings for each type of logging tool and tool mode. The configuration files and their associated files like calibrations, headers and WellCAD templates are managed from the Tool Manager page (Figure 3.1). **Users must use this page to import, export or remove configuration files**!

Note: Copying and pasting tool configurations between folders using Windows File Explorer should be avoided in order to guarantee correct operation.

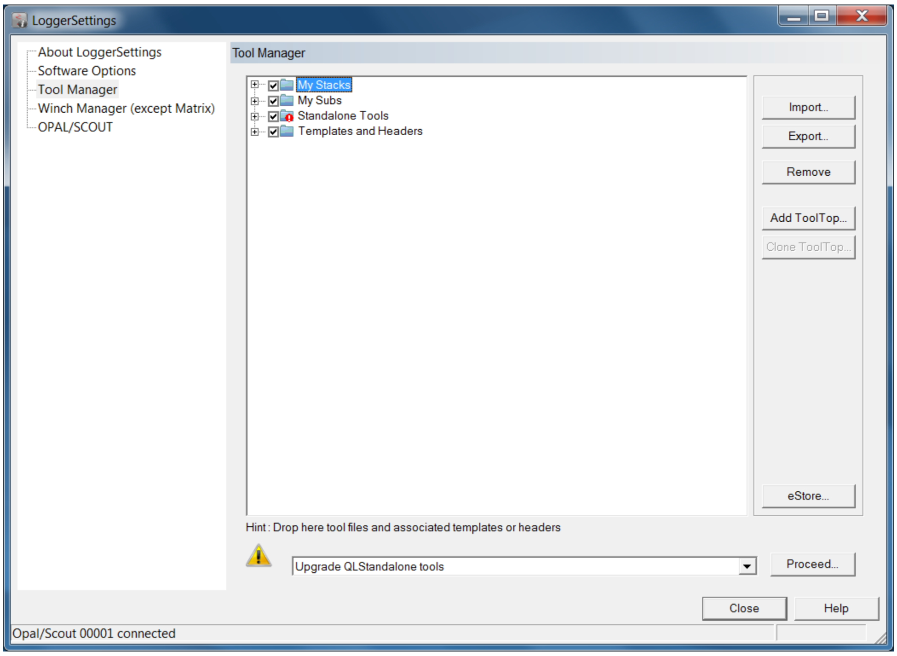


Figure 3-1 M r

The Tool Manager page displays a tree control showing the installed tool configurations. Three major groups can be identified:

My Stacks:
Contains all final tool stack configurations. Please note that a bottom sub with a tool top is already a tool stack.

My Subs:
All sub files you received from the tool vendor are stored here. Sub files contain only the configuration of an individual element (e.g. tool top, tool body, bottom plug, inline centralizer,...) incorporated in the final tool stack.

Standalone Tools:
Listed are all standalone tools (i.e. non stackable tools).

***Templates and Headers**:*
Lists all installed headers and layout templates (see paragraph 3.5).

For tools having a bitmap associated a preview of the tool sub / stack is displayed (Figure 3-2). When clicking on the **Details** (Figure 3-3) button a list with the final dimensions of a tool stack / sub is shown instead of the tool sketch.

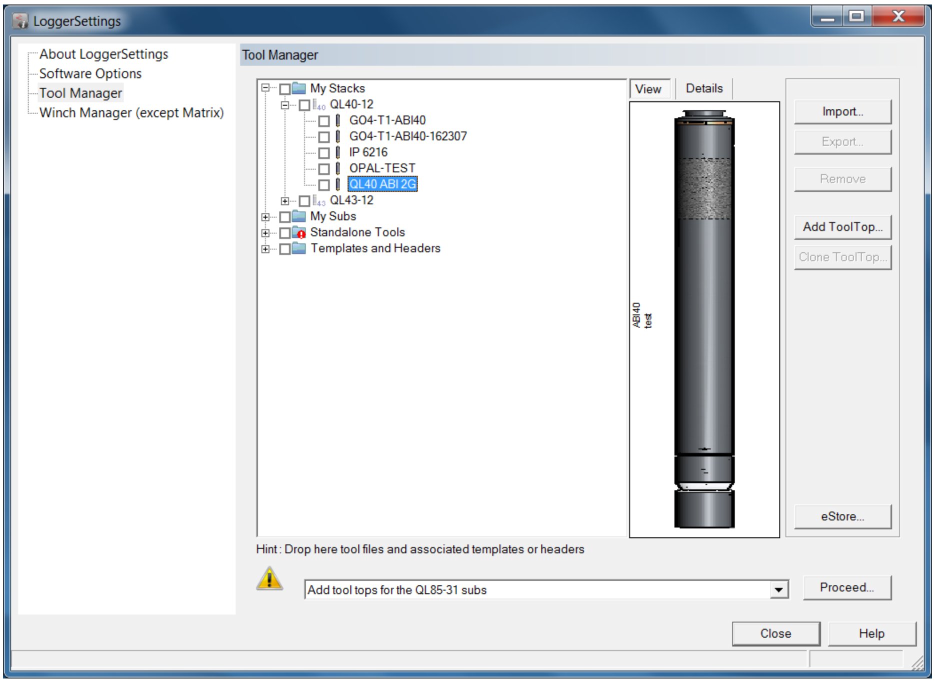


Figure 3-2

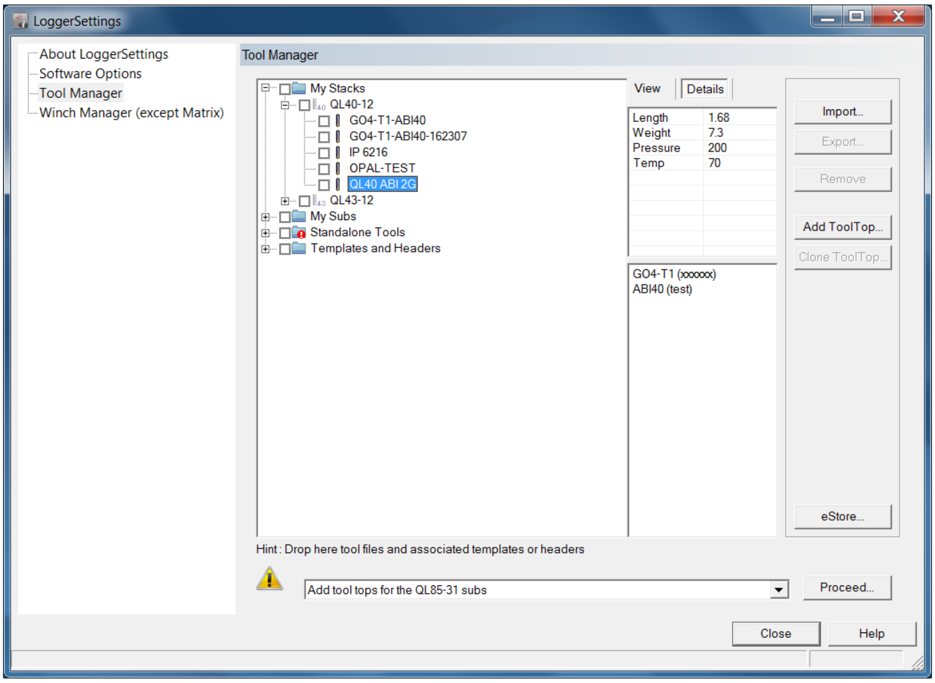


Figure 3-3

3.1 Importing and installing files

The tool configuration files supplied with the logging equipment can be installed in different ways:

- **Drag and drop the configuration files** on **“LoggerSettings” icon** visible on your computer’s desktop.
  Note that multiple tool configuration files can be installed all at once when they are grouped into a single folder. **Drag and drop the folder** containing the files on Logger Settings icon.
  or
- **Drag and drop** the configuration files into the **“Tool Manager” window**

- Alternatively click on the **Import** button (Figure 3-4) and use the file Open dialog box to browse for your configuration files (i.e. *.TOL, *.TOOL, *.SUB , *.STACK, *.WCH, *WDT, *.BMP files).

The LoggerSettings application recognizes the loaded files and installs them automatically in their designated locations displayed in the tree structure of the Tool Manager page (Figure 3-4).

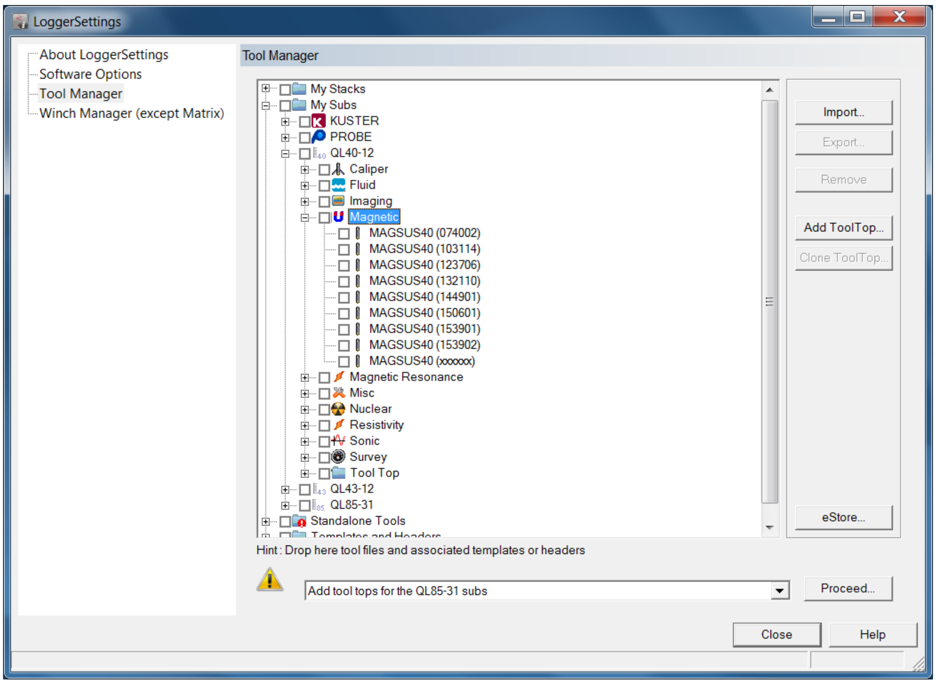


Figure 3-4

After successful installation of a configuration file a message box confirming the installation will be shown (Figure 3-5). If one or more configuration files could not be installed the message box shown in Figure 3-6 will be displayed.

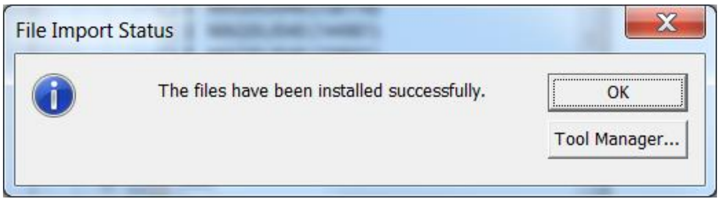


Figure 3-5

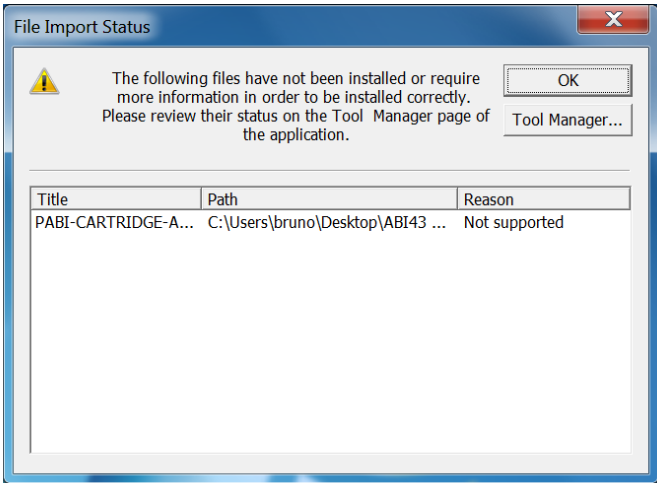


Figure 3-6

The application checks the validity of the imported files. A red icon in front of an entry in the tree control indicates that the configuration is invalid or must be updated (see also section 3.4). Yellow icons are shown for newly added items.

3.2 Exporting tools

In order to ease the transfer of tool configurations between different computers the Tool Manager page offers an Export option.

Select one or multiple tools (it is also possible to select an entire folder with a tool family) by clicking into the black square next to the tool name in the Tool Manager control (Figure 3-7). Click on the **Export...** button and use the Browse Folder dialog box to select or create the storage location for the tool configuration files to export. Any files associated with the current selection (e.g. calibrations, headers, templates,...) will be exported automatically and a designated folder will be created containing all components. You can drag the entire folder into the Tool manager window on another computer in order to install the tool configuration there.

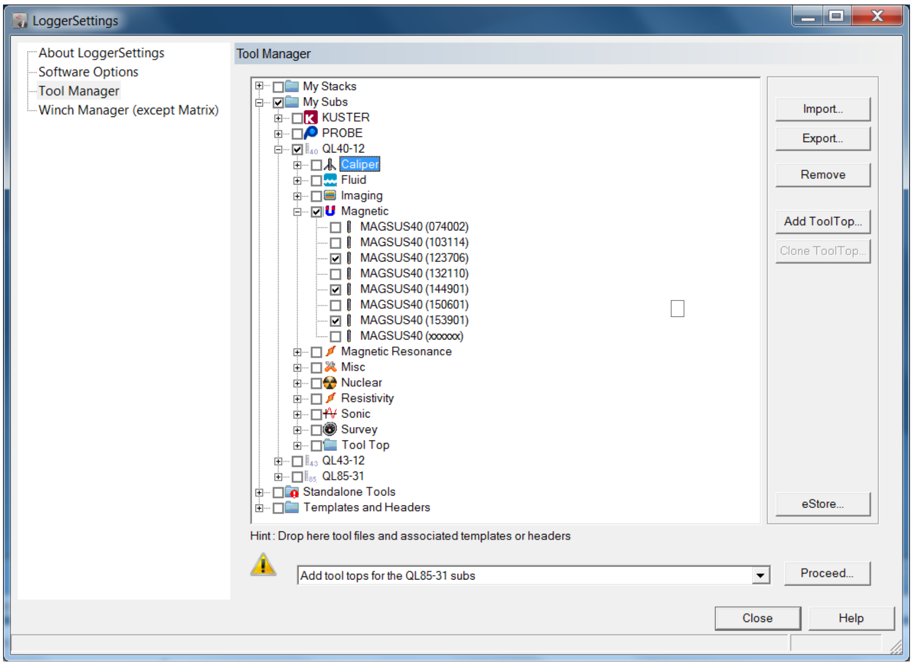


Figure 3-7

3.3 Removing tools

In order to remove tool configurations select the corresponding entry in the tree control on the Tool Manager page and click on the **Remove** button. A message box will be displayed requesting confirmation to remove and delete the selected configuration files.

Any removed tools will be moved into a subfolder named *Tools.Trash* located in application's folder (C:\Logger\Tool.Trash\).

3.4 Error Handling

If a red symbol with an exclamation mark is displayed in front of a tool configuration or directory (Figure 3-8) a problem occurred and some tool configurations might not be valid.

The drop down list located at the bottom of the Tool Manager window suggests different actions to remediate the tool configuration issues:

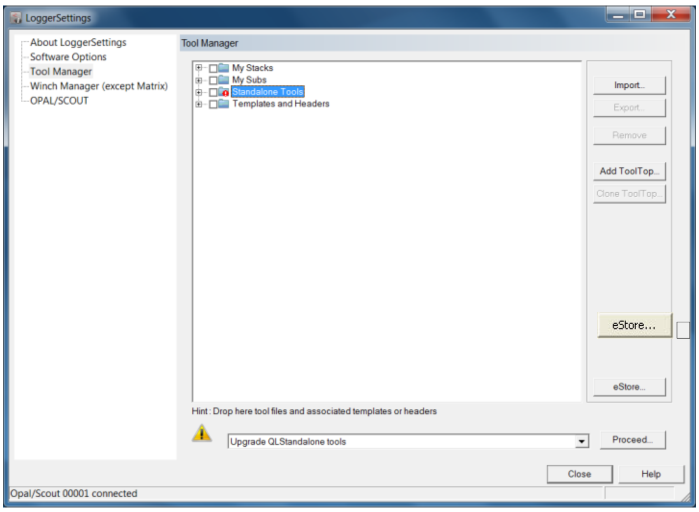


Figure 3-8 –

In this example QLStandalone tool configuration files are invalid and must be corrected. Click on **“Proceed”** for the next step.

From the **“Update QL-Standalone Tools”** dialog box (Figure 3-9), select from the drop down list the tool configuration file to update and then chose the tool top type to allocate to this specific tool. User must confirm the wiring of the tool top mounted physically on the tool as detailed in the tool top wiring section. Click on **“Update”** to confirm your tool top configuration.

Repeat the operation for all tool configuration files available from the drop down list.

Note: The acquisition system configures the power/coms and auxiliary lines based on the tool top wiring defined by the User. Improper settings may damage the tool or degrade the tool telemetry performance. Contact ALT in case of any doubt or question.

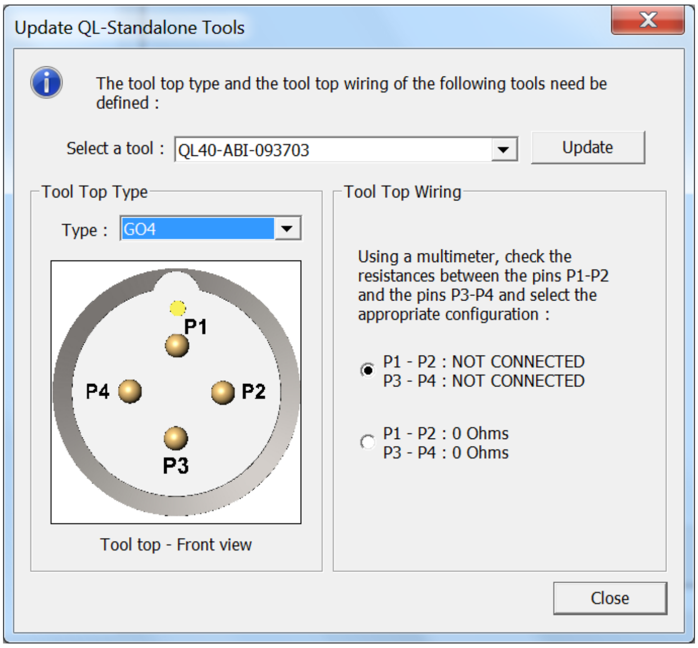


Figure 3-9

When no tool tops are defined for a family of QL-tools (Figure 3-10), the user will need to create the required tool top configurations. This can be done by selecting either **“Add Tool Tops for QLxx-xx Subs”- Proceed** or by clicking on the **“Add Tool Top”** button:

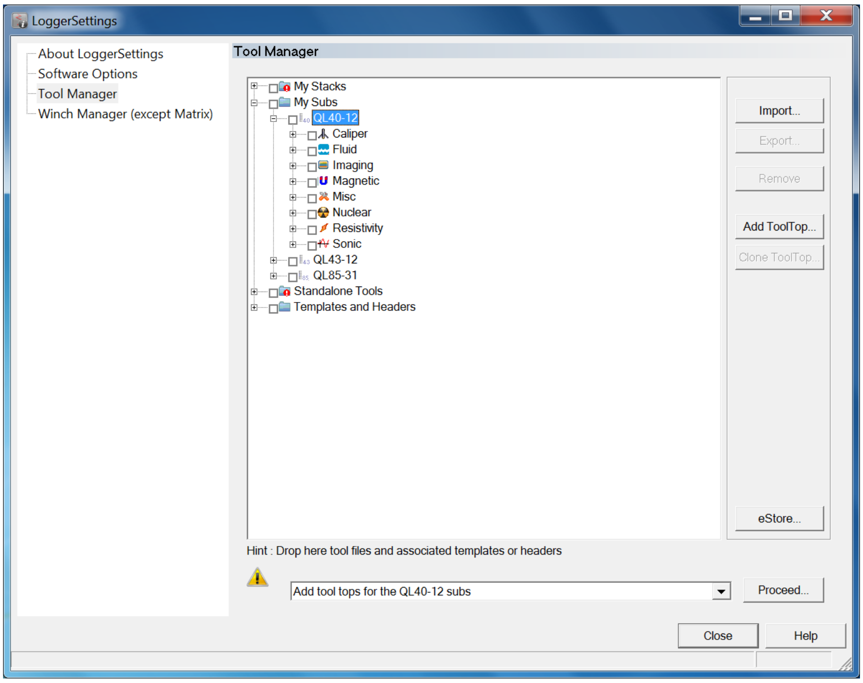


Figure 3-10 [illegible]

To create a new tool top (Figure 3-11):

- define a mechanical description for the tool joint top and bottom
- assign a serial number or a description to identify the new tool top
- define the tool top wiring mode[1]
- click on **OK** to confirm your settings and to create the new tool top

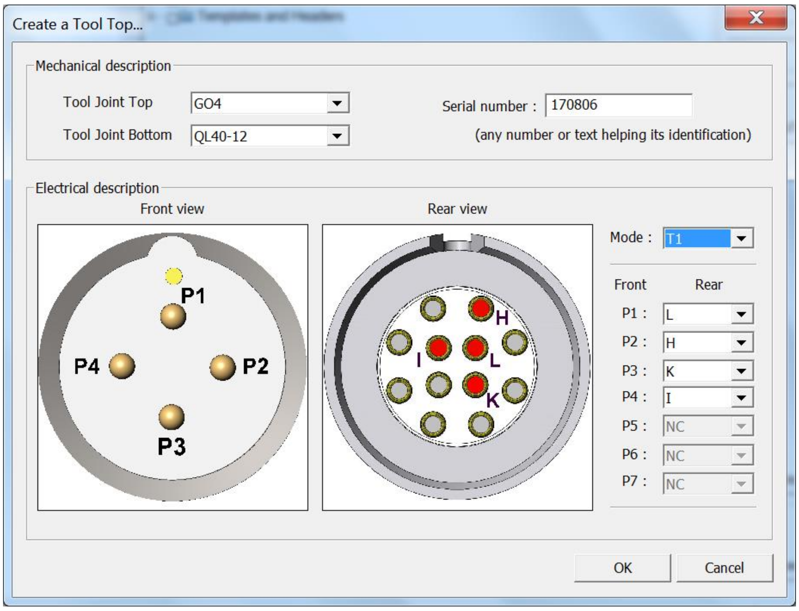


Figure 3-11 [illegible]

The newly created tool tops are now displayed in a **"Tool Top"** folder (Figure 3-12) and are highlighted with a yellow icon.

---

[1] [illegible]

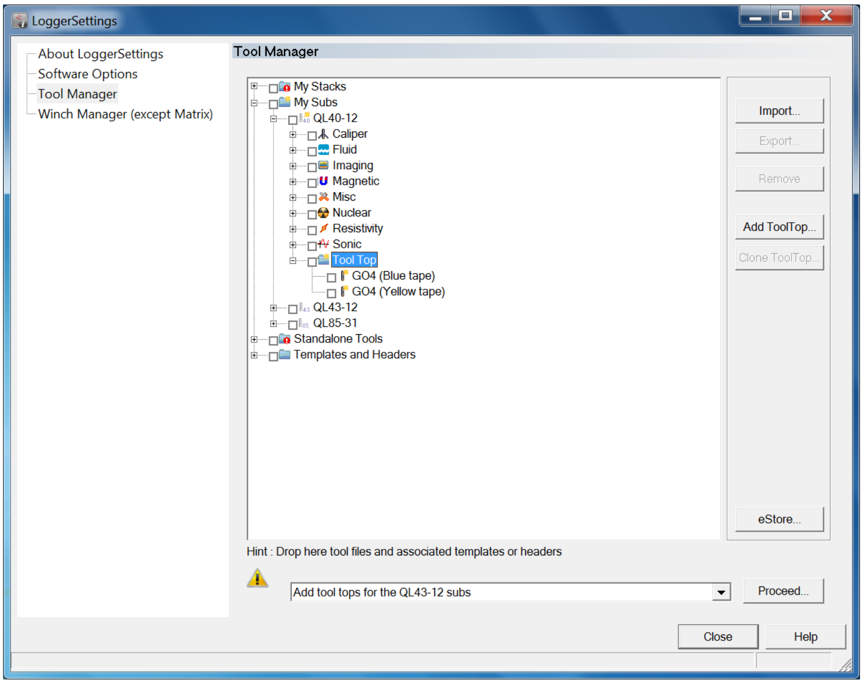


Figure 3-12

The **“Clone Tool Top”** button can be used to duplicate an existing tool top configuration. User will be asked to assign a reference number or a description for the duplicated tool top (Figure 3-13).

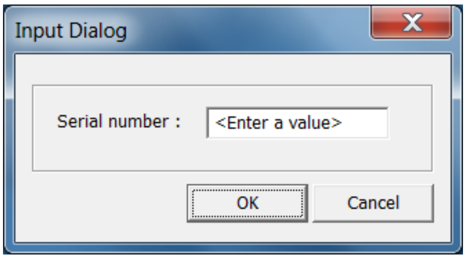


Figure 3-13

3.5 Templates and Headers

Header designs created with HeadCAD or Borehole Document Templates generated in WellCAD can be added and handled in the Tool manager window as well (Figure 3-14).

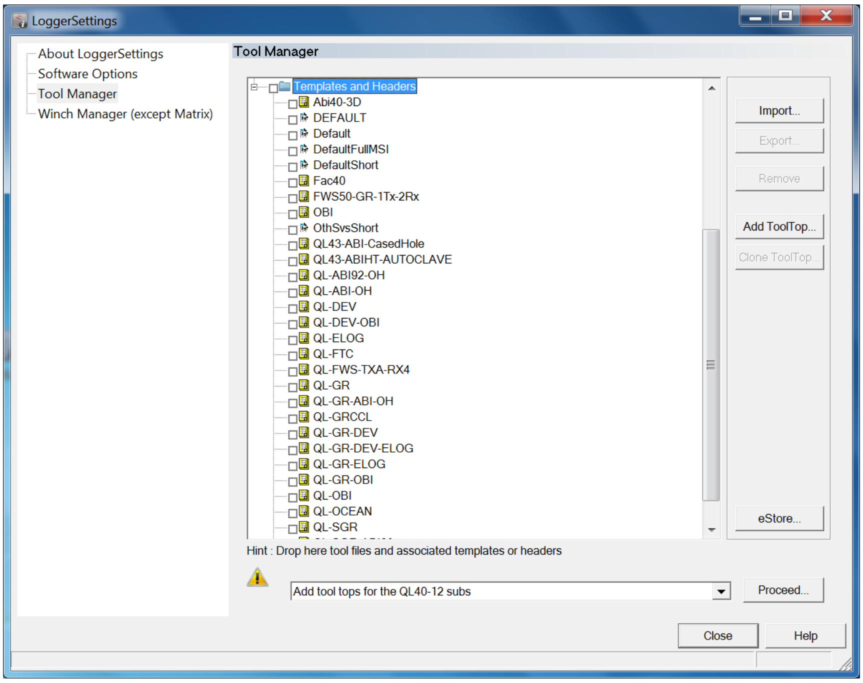


Figure 3-14

Click on the **Import** button or simply drag and drop the *.WCH or *.WDT files to install them in the Tool manager repository. If headers or templates are included in previously exported stack configuration folder (see paragraph 3.2) they will automatically be extracted and placed in the **Templates and Headers** group.
In order to edit a header design or layout template simply double left click on the corresponding icon in the tree control to start HeadCAD or WellCAD.
To apply a header or templates simply click the corresponding button in the Acquisition panel in the Logger dashboard or when configuring the tool stack in the Tool Stack Factory of the Logger.

3.6 The external data storage “eStore”

The main purpose of the LoggerSettings and the Tool Manager in particular is to support the user in organizing and manage his logging tool configurations. To avoid an overflow of the Tool Manager window with old or unused configuration files an external tool repository is available to remove elements from the current stock without losing them and the ability to easily retrieve them. To add data to the external tool repository use your Windows Explorer.
To access the external tool storage simply click the **eStore** button in the lower right of the Tool Manager window. (Figure 3.15)

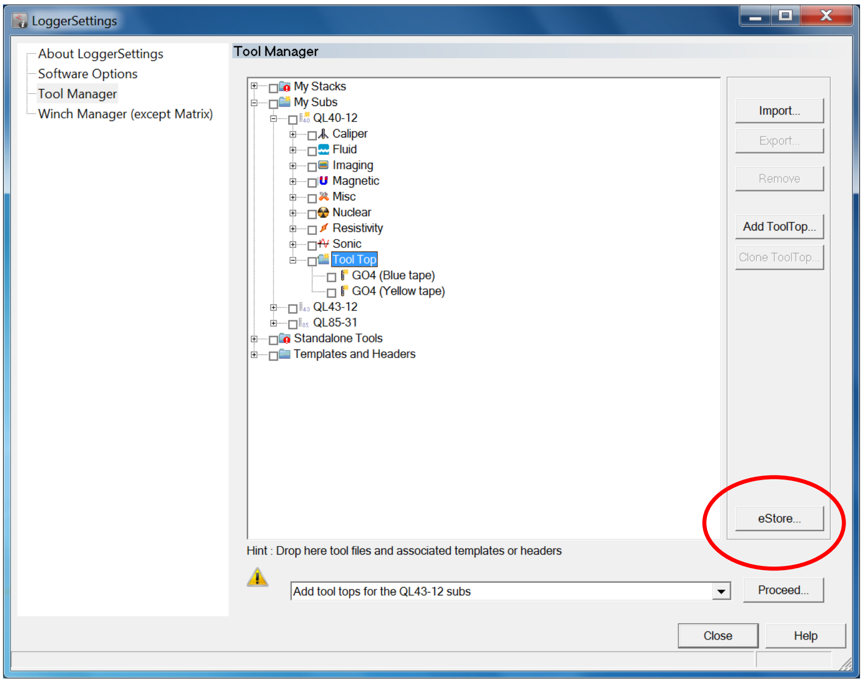


Figure 3-15 [illegible] **eStore** [illegible]

By default you will be directed to the …/Logger / Support / eStore folder under the installation path of the LoggerSuite software and the following dialog box will be displayed (Figure 3-16).

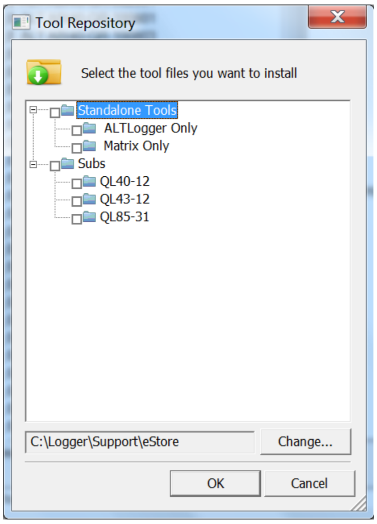


Figure 3-16 [illegible]

All QL subs and standalone tools found in the repository will be listed. The eStore does not keep tool stacks as they are custom built.
In order to add subs to the Tool Manager simply select the corresponding item or family of entries and click on OK.
Should you wish to access another external tool repository click the **Change** button and enter a local or network path into the corresponding dialog box (Figure 3-17).

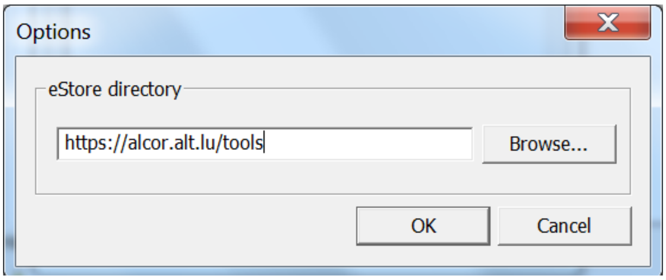
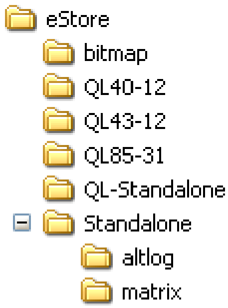


Figure 3-17

It is also possible to enter the (http/https) address of a network web server. In this case you may be prompted for a user name and password.

The **eStore** repository should have the following structure



where the folders :

- bitmap contains all tool bitmap files (*.bmp)
- QL40-12 contains all QL40-12 subs (*.sub)
- QL43-12 contains all QL43-12 subs (*.sub)
- QL85-31 contains all QL85-31 subs (*.sub)
- QL-Standalone contains subs and stack files for standalone tools (*.sub, *.stack)
- Standalone\altlog contains the tool files compatible with ALT loggers (USB PlugIn, Abox, BBox, Jazz)
- Standalone\matrix contains the tool files compatible with the Matrix logger.

3.7 Building customized groups

You can add custom groups under the Standalone Tools level of the tree control in the Tool manager window in order to organize tool configurations even further.

To add a new group:

1. Select the items that you would like to group from the list (Figure 3-18).

2. Right click on any of the selected items and select **New Group** from the displayed context menu.

3. A new group will be created. Single left click on the *New Group* title and enter a new name for your group. (Figure 3-19)

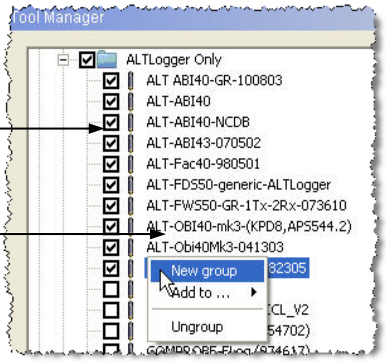


Figure 3-18

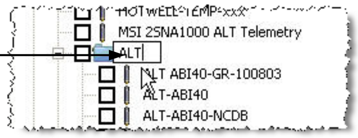


Figure 3-19

To add one or multiple items to an existing group simply select the corresponding item(s) and right click on it. Select **Add to...** from the displayed context menu.

In a similar way you can remove items from groups (select the item(s) within the group, right click on one of the selected entries and choose **Ungroup**) or suspend an entire group (select a group, right click and select **Ungroup**).

The same structure you setup in the Tool Manager will be available in the **Tool** panel of your Logger applications dashboard. (Figure 3-20)

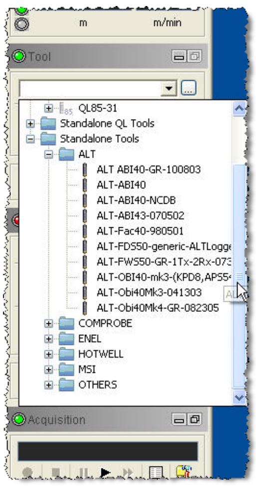


Figure 3-20

4 Winch Manager

In order to configure your logger the device must be connected to the computer.

4.1 *OPAL-SCOUT PRO-SCOUT-BBOX-ALTLOGGER*

The Winch Manager page allows the user to manage winch/logging truck hardware configurations (Figure 4-1).

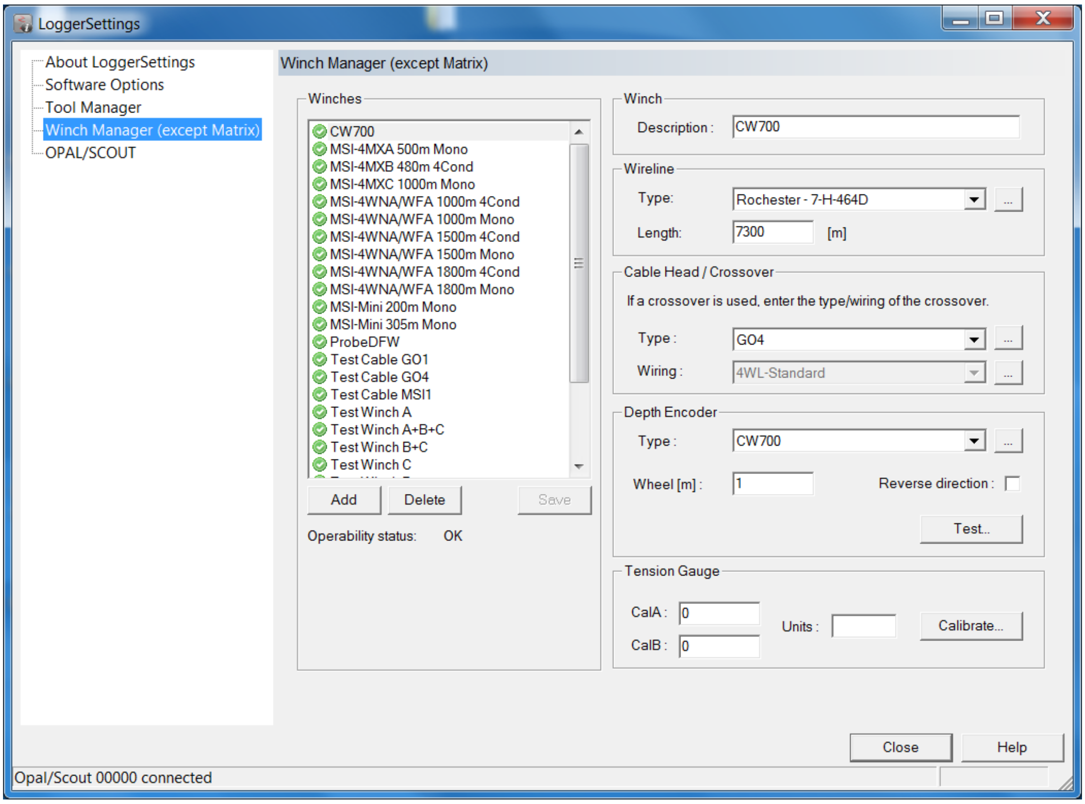


Figure 4-1 M r

To create a new winch configuration, click on **“Add”** button and fill the edit boxes on the right side of the page:

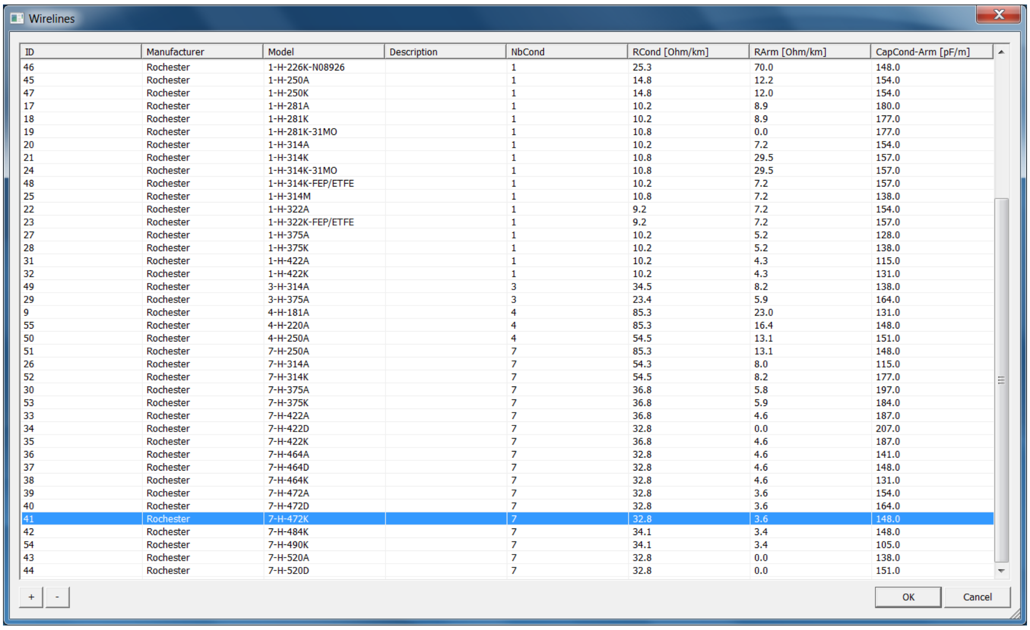
Winch:

- Give a description for your winch configuration

Wireline:

- Select the wireline type from the drop down list and enter the length.

  If your wireline is not listed click on the square symbol ... at the right to access to the wirelines table (Figure 4-2). The wirelines table summarizes the pre-defined wirelines and their physical properties. By clicking on + or – buttons user can add or remove a wireline description and properties.



Wirelines

ID	Manufacturer	Model	Description	NbCond	RCond [Ohm/km]	RArm [Ohm/km]	CapCond-Arm [pF/m]
46	Rochester	1-H-226K-N08926		1	25.3	70.0	148.0
45	Rochester	1-H-250A		1	14.8	12.2	154.0
47	Rochester	1-H-250K		1	14.8	12.0	154.0
17	Rochester	1-H-281A		1	10.2	8.9	180.0
18	Rochester	1-H-281K		1	10.2	8.9	177.0
19	Rochester	1-H-281K-31MO		1	10.8	0.0	177.0
20	Rochester	1-H-314A		1	10.2	7.2	154.0
21	Rochester	1-H-314K		1	10.8	29.5	157.0
24	Rochester	1-H-314K-31MO		1	10.8	29.5	157.0
48	Rochester	1-H-314K-FEP/ETFE		1	10.2	7.2	157.0
25	Rochester	1-H-314M		1	10.8	7.2	138.0
22	Rochester	1-H-322A		1	9.2	7.2	154.0
23	Rochester	1-H-322K-FEP/ETFE		1	9.2	7.2	157.0
27	Rochester	1-H-375A		1	10.2	5.2	128.0
28	Rochester	1-H-375K		1	10.2	5.2	138.0
31	Rochester	1-H-422A		1	10.2	4.3	115.0
32	Rochester	1-H-422K		1	10.2	4.3	131.0
49	Rochester	3-H-314A		3	34.5	8.2	138.0
29	Rochester	3-H-375A		3	23.4	5.9	164.0
9	Rochester	4-H-181A		4	85.3	23.0	131.0
55	Rochester	4-H-220A		4	85.3	16.4	148.0
50	Rochester	4-H-250A		4	54.5	13.1	151.0
51	Rochester	7-H-250A		7	85.3	13.1	148.0
26	Rochester	7-H-314A		7	54.3	8.0	115.0
52	Rochester	7-H-314K		7	54.5	8.2	177.0
30	Rochester	7-H-375A		7	36.8	5.8	197.0
53	Rochester	7-H-375K		7	36.8	5.9	184.0
33	Rochester	7-H-422A		7	36.8	4.6	187.0
34	Rochester	7-H-422D		7	32.8	0.0	207.0
35	Rochester	7-H-422K		7	36.8	4.6	187.0
36	Rochester	7-H-464A		7	32.8	4.6	141.0
37	Rochester	7-H-464D		7	32.8	4.6	148.0
38	Rochester	7-H-464K		7	32.8	4.6	131.0
39	Rochester	7-H-472A		7	32.8	3.6	154.0
40	Rochester	7-H-472D		7	32.8	3.6	164.0
41	Rochester	7-H-472K		7	32.8	3.6	148.0
42	Rochester	7-H-484K		7	34.1	3.4	148.0
54	Rochester	7-H-490K		7	34.1	3.4	105.0
43	Rochester	7-H-520A		7	32.8	0.0	138.0
44	Rochester	7-H-520D		7	32.8	0.0	151.0

+ - OK Cancel

Figure 4-2

Cable head:

- Select the cable head type from the drop down list
- Select a cable head wiring configuration. More information about cable head wiring and pin assignation used by the Logger can be found by clicking on the square symbol ... (Figure 4-3).

Warning: make sure that physical wiring of your cable head and pin assignation of the Logger match the wiring mode displayed in the "Wiring Diagram" page. Improper wiring of your set-up may damage the tool.

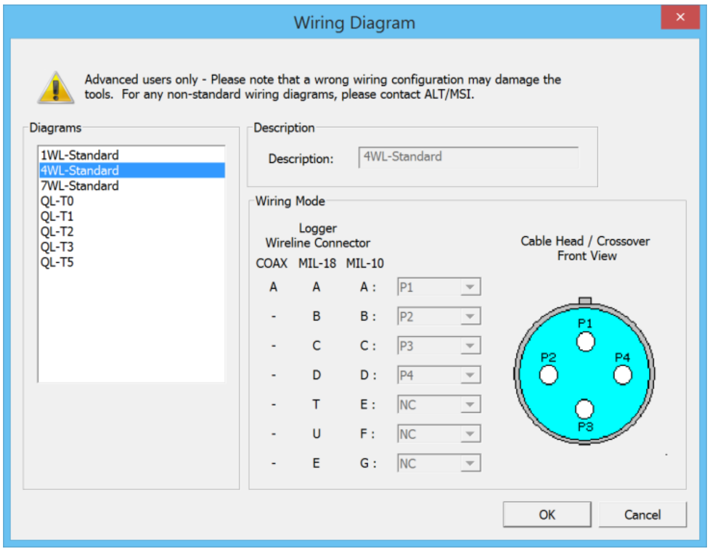


Figure 4-3

Depth encoder:

- Select from the list or create a new depth encoder configuration for your specific winch
- To create a new depth encoder configuration click on the square symbol ... . In the encoder page click on **"New"** to add a new device (Figures 4-4 & 4-5).

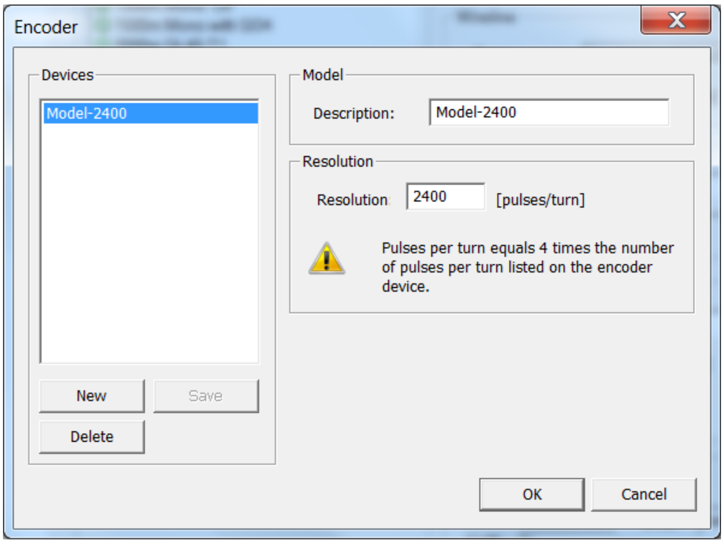


Figure 4-4 [illegible]

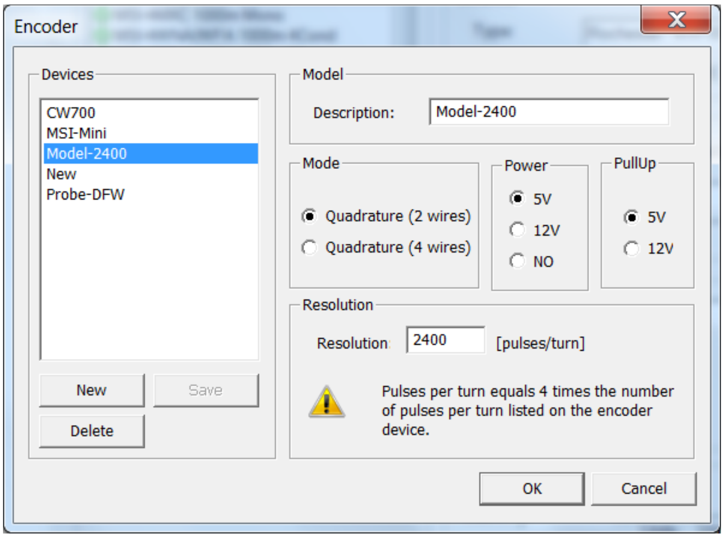


Figure 4-5 [illegible]

Give a **description** and define the **resolution (pulses/turn)** of your depth encoder to define a new device. This value must be an integer, that is it cannot have any decimal place values. This is the number of pulses from the encoder per wheel revolution. Quadrature encoders will be read by the system at four times their pulse per revolution number. For a 200 pulse per revolution encoder the system actually sees 800 pulses per revolution.
See also sections 6.3 Manual determination of Depth Encoder settings and 6.4 Standard Depth Encoder settings for winches from Mount Sopris Instruments.

For SCOUT PRO The depth encoder settings are defined through LoggerSettings application and must be configured to suit the depth encoder specifications.

	Description
Mode	Depth encoder wiring mode: *Quadrature (2 wires): two channel output encoder A , B* *Quadrature (4 wires): four channel output encoder A , B and inverted A- , B-*
Power	Power Voltage selection: *5 or 12V* *To Disable Power – select NO*
PullUP	Pull-up voltage selection: *5 or 12 V*

Click on **"Save"** button to store your new depth encoder configuration.

The **"Delete"** option offers the possibility to remove some unused depth encoder configurations.

- Once the depth encoder configuration is defined enter the **Wheel Circumference** in meters, this may be a non-integer number like 0.3333 or 1.23456.

- Press the **Test** button to check the depth reading.

- Press the **Reset** button to zero the depth. Pull cable from the winch to test the depth settings (Figure 4-6).

- Click on **Reverse Direction** if the depth is incremented in the wrong direction. Note that the depth should increase when the tool is going down and the reverse.

- In the **wheel** section user has the option to define the depth driving wheel circumference. To define the depth wheel circumference - if unknown - follow the instructions given below:

    1. Click on **Reset**
    2. Pull let's say 10m of cable
    3. Edit the length of the pulled cable (10m in this instance)
    4. Click on **Compute** to get the corresponding wheel circumference
    5. Click on **OK** to validate the depth direction and calibration

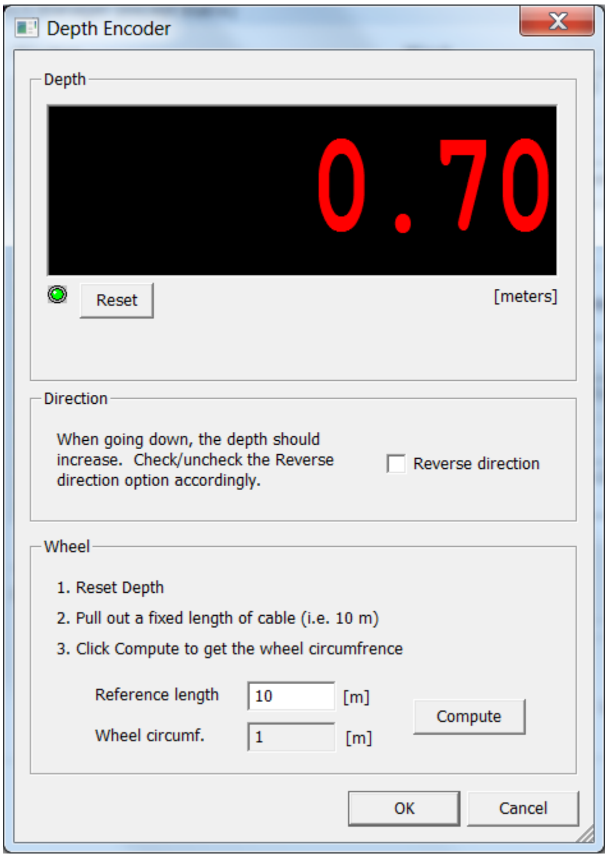


Figure 4-6

Tension Gauge:

If a tension device is connected to the Logger, calibration of the device can be accomplished in the Tension gauge section.

- Enter the units for the Tension display into the corresponding edit box

- Click on **"Calibrate"** to access to the tension calibration page (Figure 4-7)

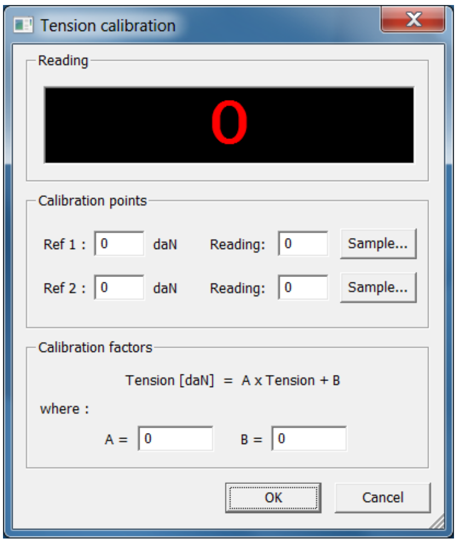


Figure 4-7

- Start the calibration of the Tension load cell by hanging the cable head without load over a cable sheave.
  Enter a value of 0 into the **Ref 1** edit box (Figure 4-7). Click on the **Sample** button to update the **Reading** box with a value measured by the system.
  Hang a load of known weight on the end of the cable and enter the weight (or tension value it causes) into the **Ref 2** edit box. Click on the corresponding **Sample** button to update the **Reading** box with a value measured by the system.

- Once the calibration is completed the system computes the calibration factors for the tension display.

4.2 MATRIX

When your computer detects the connected hardware, the Serial Number of your Matrix system and version numbers for System controller, Modem controller and PSU (Power Supply Unit) controller will be displayed (Figure 4-8).

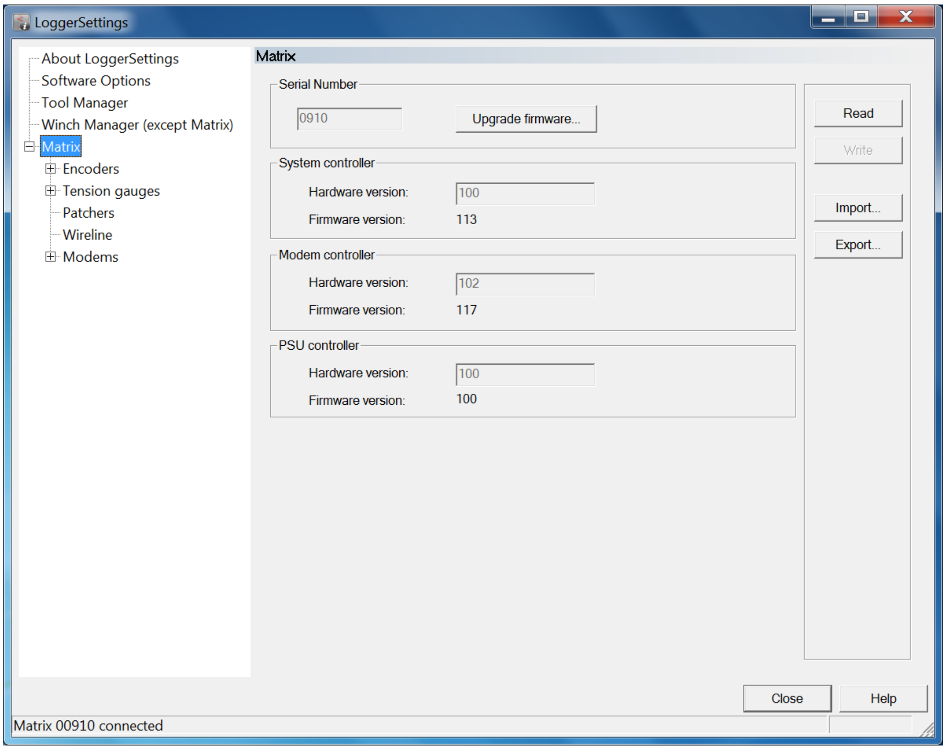


Figure 4-8

Click on the **+** icon in the tree control on the left pane of the dialog box to expand the tree for each topic.
Use the Read and Write buttons to retrieve and update the settings of the connected system. Click on Export to write the settings into a file or use the Import button to load a system configuration.

Depth Encoder:

Note: Do not connect your encoder until you are sure that the correct operating voltage has been set.

The Encoder page (Figure 4-9) provides information about the installed encoders. Up to two devices are supported. From the tree view select the encoder device for which you would like to change the settings.

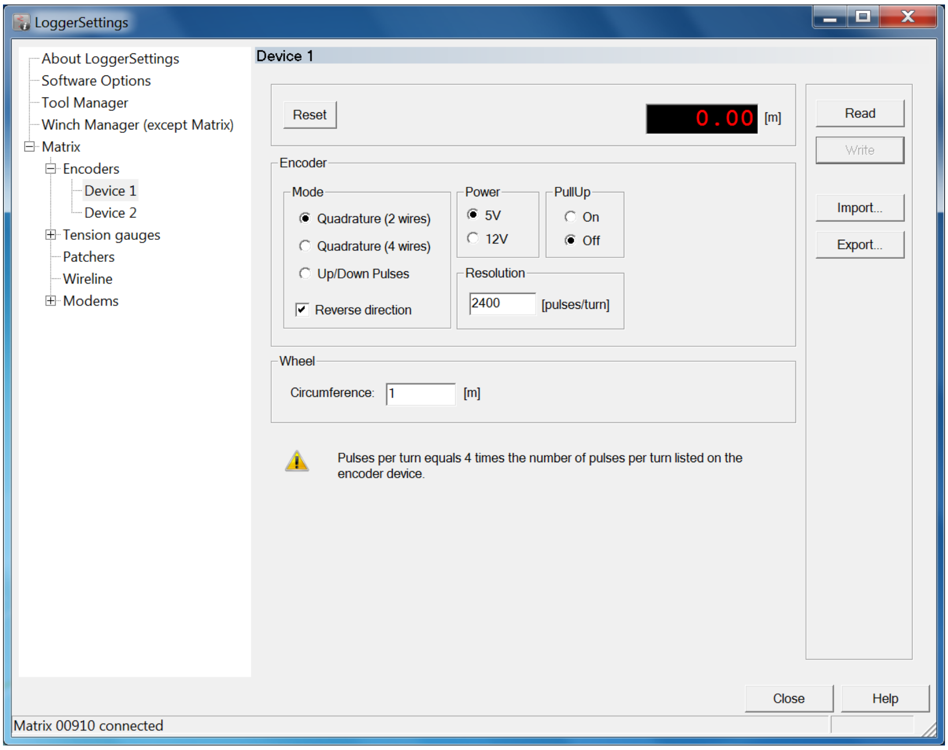


Figure 4-9 D d r

Click the **Read** button to load the stored settings from your system.

Mode
Three modes of encoders are supported:
Quadrature (2 wires) where there are A and B signal wires;
Quadrature (4 wires) where there are A, B, /A, and /B signal wires;
Up/Down Pulses where there are CW, CCW, /CW, and /CCW signal wires.

Reverse direction changes the counting direction without rewiring the encoder connections.

Power
The encoder power can be selected to be either 5V or 12V depending on the encoder type. ***Be sure this is set correctly or the encoder can be damaged.***

PullUp
This can be **On** to connect a pull-up resistor between Power and the signal line for those encoders requiring it or **Off**.

Resolution [pulses/turn]: This value must be an integer, that is it cannot have any decimal place values. Also, it cannot exceed 10,000. This is the number of pulses from the encoder per wheel revolution. Quadrature encoders will be read by the system at four times their pulse per revolution number. For a 200 pulse per revolution encoder the system sees actually 800 pulses per revolution.
See also sections 6.3 Manual determination of Depth Encoder settings and 6.4 Standard Depth Encoder settings for winches from Mount Sopris Instruments.

Wheel Circumference in meters, this may be a non-integer number like 0.3333 or 1.23456.

Test Reset: Press the button to zero the depth. Pull cable from the winch to test the settings.

Click **Write** when finished to transfer the new settings to the system.

Tension Gauge:

If a tension device is connected to the Matrix system, calibration of the device can be accomplished in the Tension gauge section. Up to two devices are supported and can be calibrated separately (Figure 4-10). From the tree view select the encoder device for which you would like to change the settings (Figure 4-11).

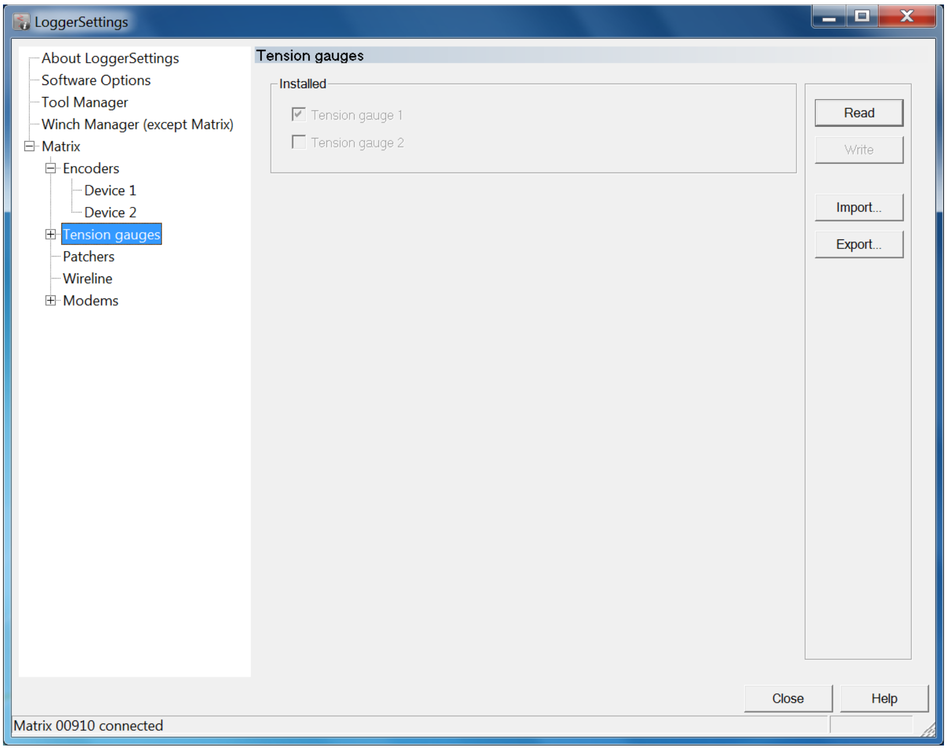


Figure 4-10

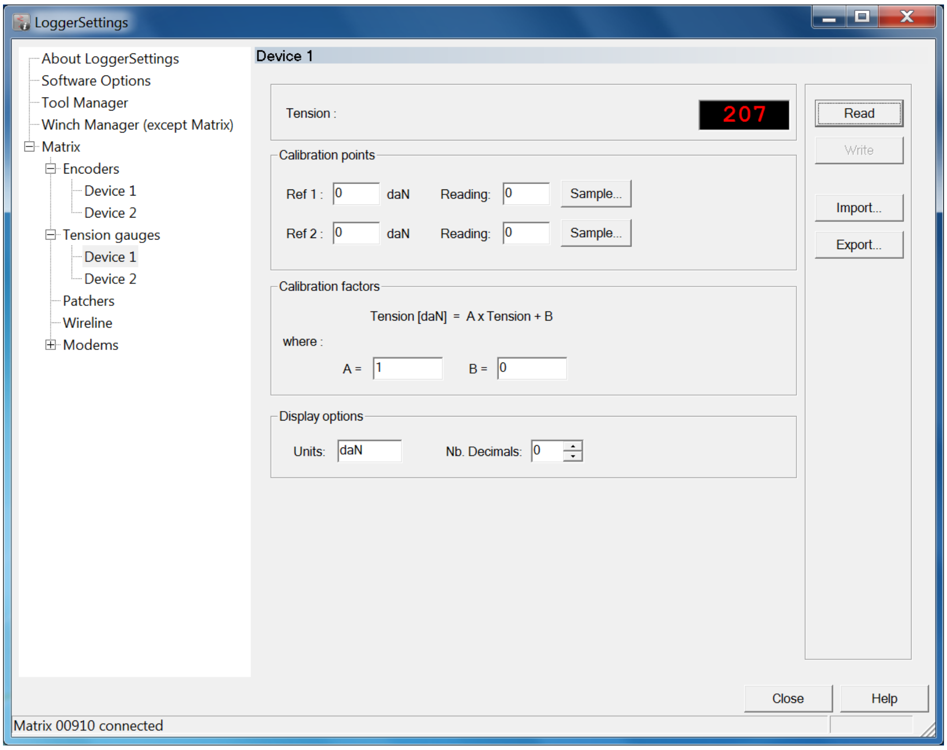


Figure 4-11

Connect Matrix to the logging winch.
Start the calibration of the Tension load cell by hanging the cable head without load over a cable sheave.
Enter a value of 0 into the **Ref 1** edit box (Figure 3.5). Click on the **Sample** button to update the **Reading** box with a value measured by the system.
Hang a load of known weight on the end of the cable and enter the weight (or tension value it causes) into the **Ref 2** edit box. Click on the corresponding **Sample** button to update the **Reading** box with a value measured by the system.
Click the **Write** button to update your system with these new calibration settings.
Reference units are displayed according to the System Units explained in section

Wireline:

Click the **Wireline** branch in the tree control on the left pane of the dialog box (Figure 4-12) to adjust the settings according to your cable characteristics.

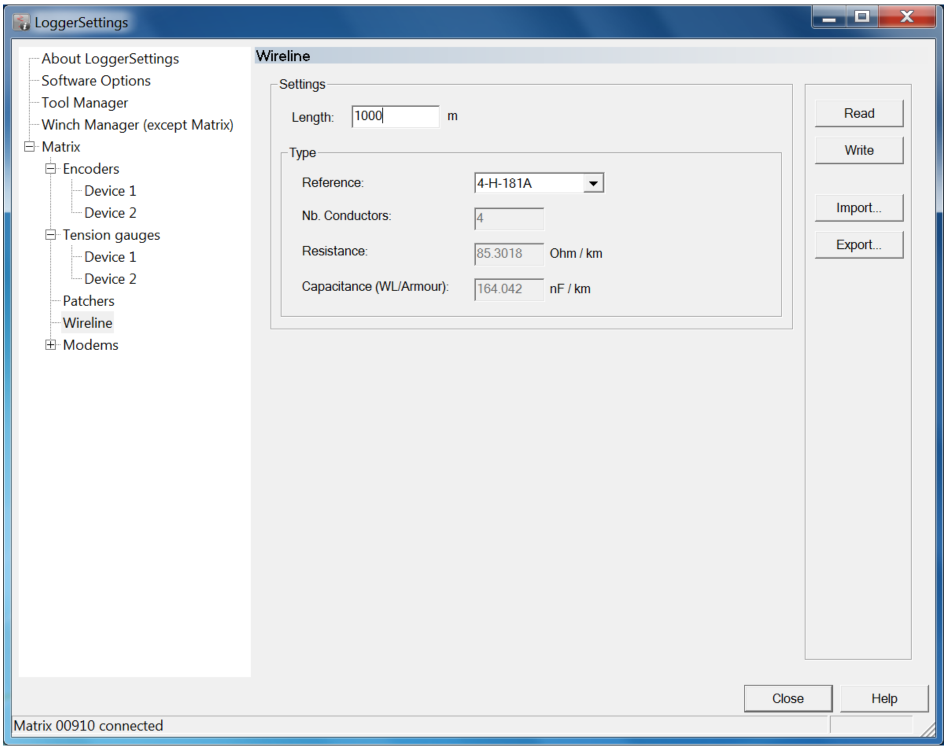


Figure 4-12

Length: Enter the Length of the wireline in meters or feet according to the system units selected.

Type

Reference: Select the correct wireline reference from the drop down list. Some standard Rochester cable types and corresponding references can be found in Table 1 below.

Description	Reference	Resistivity (Ohms/1000ft)
1/10” single conductor	1-H-100A	25.2
1/8” single conductor	1-H-125A	25.2
3/16” single conductor	1-H-181A	9.8
3/16” four conductor	4-H-181A	26
3/16” coax (Schlumberger)	1-H-100A	25.2
¼” coax video cable	1-H-181M	12.5

Table 1

For non-standard cables, select Unknown and fill the remaining fields. The resistance per unit length is the determining factor when using the Rochester Reference number.

- Nb. Conductors: Enter the number of conductors.
- Resistivity: Set the cable resistivity.
- Capacitance: Specify the cable capacitance.

Click **Write** when finished to transfer the new settings to the system.

Note: The wireline selection is used to calculate the voltage drop on the wireline and therefore the tool power supply voltage. This has no effect on the telemetry settings.

5 Upgrading Logger Firmware

If after upgrading the acquisition software the Logger firmware needs to be updated – the following dialog box will be automatically displayed when starting the application (Figure 5-1). Press "Upgrade" to proceed or "Not Now" to postpone the operation.

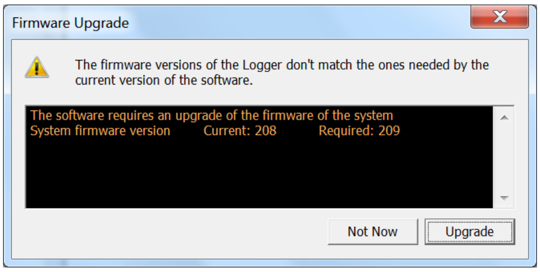


Figure 5-1

During the upgrade procedure the dialog box shown in Figure 5-2 will be displayed providing information on the upgrade status.

Note: Do not turn off the computer or logging system and do not disconnect any cable until the upgrade procedure is completely finished.

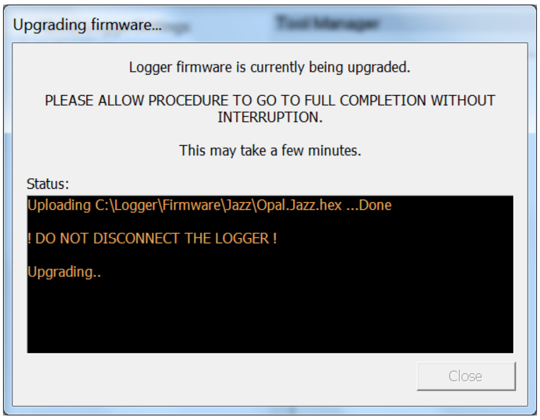


Figure 5-2

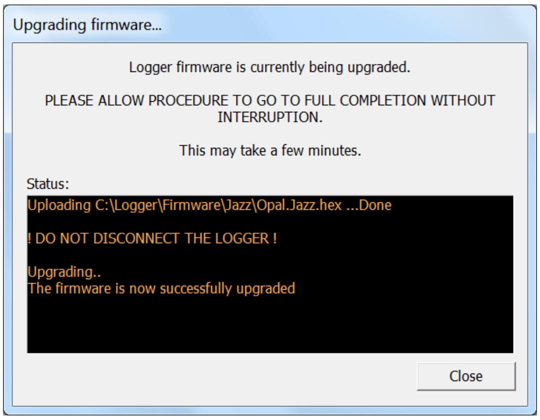


Figure 5-3

6 Appendix

6.1 Matrix Modems

To get an overview of the installed modems select the ALT, MSI or Third Party branches (Figure 6-1 to 6-3).
If it becomes necessary to change the installed modems either by adding a new one or removing an already installed one, it will be necessary to export the current configuration, send the exported file to your vendor (ALT or Mount Sopris Instruments) and install the updated file you will receive from your vendor. Please contact ALT or Mount Sopris Instruments for information about available modems.

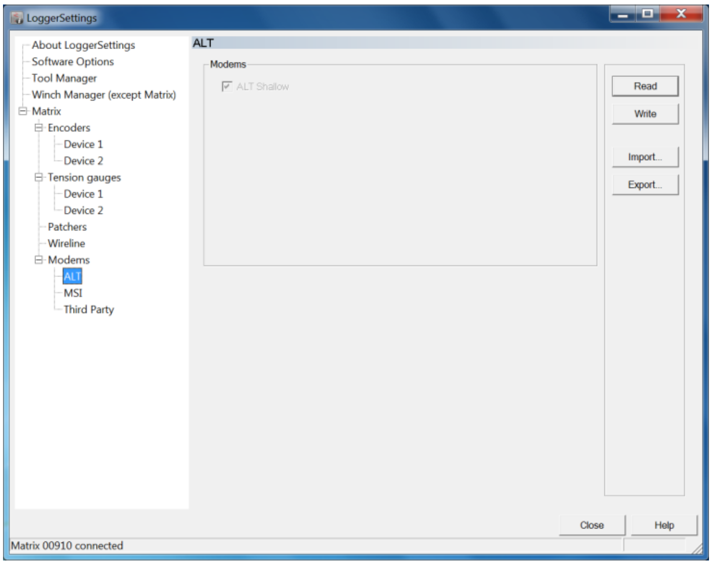


Figure 6-1 ALT Modems

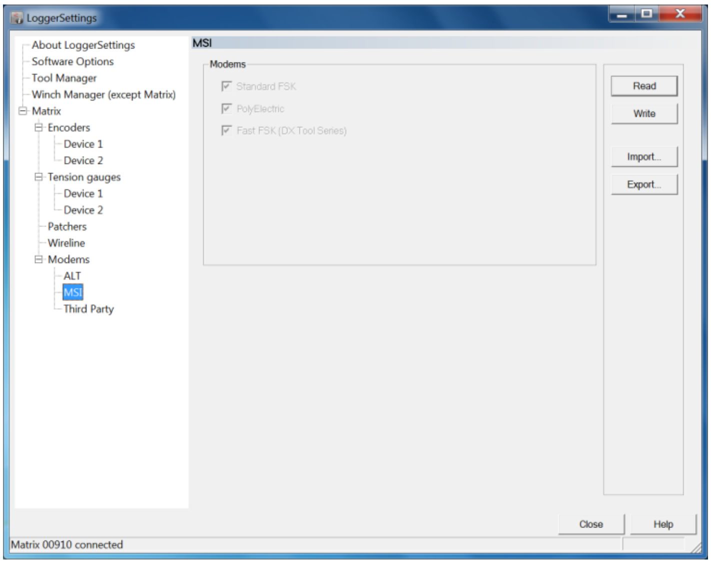


Figure 6-2 MSI Modems

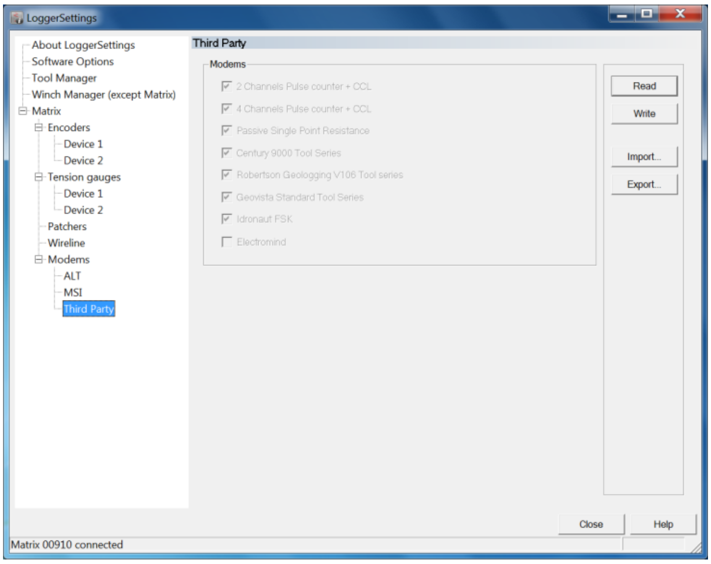


Figure 6-3 Third Party Modems [illegible]

6.2 Matrix Patchers

The Patchers page (Figure 6-4) displays the status of several hardware settings. No information can be edited here.

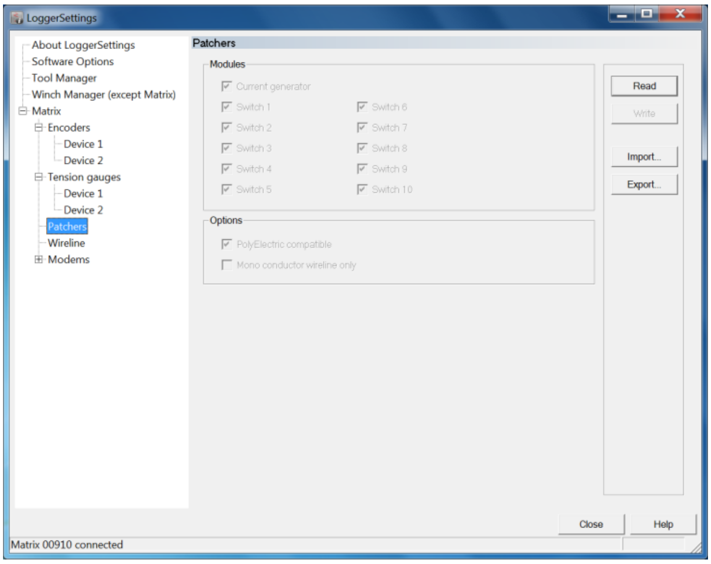


Figure 6-4 Matrix [illegible]

6.3 Standard Depth Encoder settings for winches from Mount Sopris Instruments

The settings below for the MX family winches yield an encoder resolution of 4 /2400 = 0.0016666 meters. This is because four transitions are detected (and counted) for each full pulse from Quadrature encoders.
The encoder sends 200 pulses per revolution. The Matrix records four (pulse transitions) times 200 (pulses) per revolution.
The wheel circumference is 1/3 meter. Therefore, three wheel revolutions results in an effective circumference of one meter. (Wheel Circumference divided by Integer Encoder pulses per turn).

For 4MXA-1000, 4MXB-1000, 4MXC-1000, 4WNA-1000:
Wheel Circumference In Meters = **1**
Resolution [pulses per turn] = **2400**
Mode = Quadrature (2 wires)
Power = 5V
PullUp = Off (default value in LoggerSettings is 5V)

For MW (Mini winch)
Wheel Circumference In Meters = **0.199492**
Resolution [pulses per turn] = **512**
Mode = Quadrature (2 wires)
Power = 5V
PullUp = Off (default value in LoggerSettings is 5V)

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APPENDIX C

Records of Geophysical Logging

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi
CC: George Schneider

Date / Shift: April-29-2021 - Shift 01
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.40	10.57-16.87	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
01-01	GAM2SFA	6752_6327	0.050	4.0	1.82	407.92	Down	1.82	-	00:31	02:29	IG_BH04_WP05_GAM2SFA_01-01.tfd	Stopped at 408 - Steel Wedge?
01-02	GAM2SFA	6752_6327	0.050	20.0	407.92	1.83	Up	-	1.83	02:31	02:53	IG_BH04_WP05_GAM2SFA_01-02.tfd	
01-03	GAM2SFA	6752_6327	0.050	10.0	1.82	395.40	Down	1.82	-	03:15	03:57	IG_BH04_WP05_GAM2SFA_01-03.tfd	
01-04	GAM2SFA	6752_6327	0.050	4.0	395.40	999.32	Down	-	-	03:59	06:31	IG_BH04_WP05_GAM2SFA_01-04.tfd	
01-05	GAM2SFA	6752_6327	0.050	20.0	999.32	975.44	Up	-	-	06:41	06:44	IG_BH04_WP05_GAM2SFA_01-05.tfd	
01-06	GAM2SFA	6752_6327	0.050	20.0	999.38	714.10	Up	-	-	06:55	07:22	IG_BH04_WP05_GAM2SFA_01-06.tfd	Main generator power failure

Client: NWMO
Location: Ignace – IG_BH04
Prepared by: OF

Job Number: 20253946-4050
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO:	Maria Sánchez-Rico Castejón		**Date / Shift:**	April-30-2021 – Shift 02
	Sarah Hirschorn		**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi			
CC:	George Schneider			
			Distributed By:	Email

Borehole data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.40	Variable	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
02-01	GAM2SFA	6752_6327	0.050	20.0	714.10	0.73	Up	-	0.73	7:44	8:27	IG_BH04_WP05_GAM2SFA_02-01.tfd	errors due to speed? slowed down to 15m/min at 250 m.
02-02	GAM2SFA	6752_6327	0.050	10.0	1.82	999.51	Down	1.82	-	8:40	10:32	IG_BH04_WP05_GAM2SFA_02-02.tfd	
02-03	GAM2SFA	6752_6327	0.050	20.0	999.51	1.87	Up	-	1.87	10:38	11:42	IG_BH04_WP05_GAM2SFA_02-03.tfd	
02-05	GAM2SFA	6752_6327	0.050	10.0	1.82	999.53	Down	1.82	-	12:30	14:23	IG_BH04_WP05_GAM2SFA_02-05.tfd	
02-11	GAM2SFA	6752_6327	0.050	10.0	50.01	999.58	Down	1.82	50	19:31	21:25	IG_BH04_WP05_GAM2SFA_02-11.tfd	Dynamic Logging
02-15	GAM2SFA	6752_6327	0.050	10.0	999.37	50.19	Up	-	50.19	00:29	02:00	IG_BH04_WP05_GAM2SFA_02-15.tfd	Electrical tape placed at 80 m for reference
02-17	GAM2SFA	6752_6327	0.050	10.0	50.00	768.88	Down	50	-	02:20	03:30	IG_BH04_WP05_GAM2SFA_02-17.tfd	Stopped due to errors when turning on pump at ~730 m
02-18	GAM2SFA	6752_6327	0.050	10.0	730.00	999.48	Down	-	-	03:44	04:10	IG_BH04_WP05_GAM2SFA_02-18.tfd	Completion of log 02-17
02-20	GAM2SFA	6752_6327	0.050	10.0	999.54	81.74	Up	-	81.47	06:30	7:57	IG_BH04_WP05_GAM2SFA_02-20.tfd	End zero to 80 mark.

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	OF	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20353946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi
CC: George Schneider

Date / Shift: May-1-2021 - Shift 03
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Borehole Data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.40	49-51	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
03-01	GAM2SFA	6752_6327	0.050	10.0	80.00	995.02	Down	80.00		08:00	09:46	IG_BH04_WP05_GAM2SFA_03-01.tfd	Pump is at 65m
03-02	GAM2SFA	6752_6327	0.050	20.0	995.02	81.16	Up		81.16	10:00	11:00	IG_BH04_WP05_GAM2SFA_03-02.tfd	
03-03	GAM2SFA	6752_6327	0.050	10.0	80.00	995.02	Down	80		11:03	12:53	IG_BH04_WP05_GAM2SFA_03-03.tfd	CO2 meter creates noise spikes
03-04	GAM2SFA	6752_6327	0.050	20.0	995.02	80.85	Up		80.85	12:55	13:47	IG_BH04_WP05_GAM2SFA_03-04.tfd	
03-05	GAM2SFA	6752_6327	0.050	10.0	80.00	995.04	Down	80		13:48	15:33	IG_BH04_WP05_GAM2SFA_03-05.tfd	
03-06	GAM2SFA	6752_6327	0.050	20.0	995.04	81.18	Up		81.18	15:35	16:21	IG_BH04_WP05_GAM2SFA_03-06.tfd	
03-07	GAM2SFA	6752_6327	0.050	10.0	80.00	995.05	Down	80		16:25	18:06	IG_BH04_WP05_GAM2SFA_03-07.tfd	
03-08	GAM2SFA	6752_6327	0.050	20.0	995.05	80.75	Up		80.75	18:10	18:57	IG_BH04_WP05_GAM2SFA_03-08.tfd	
03-09	GAM2SFA	6752_6327	0.050	10.0	80.00	995.02	Down	80		19:10	18:50	IG_BH04_WP05_GAM2SFA_03-09.tfd	
03-10	GAM2SFA	6752_6327	0.050	20.0	995.02	80.93	Up		80.93	20:52	21:39	IG_BH04_WP05_GAM2SFA_03-10.tfd	
03-11	GAM2SFA	6752_6327	0.050	10.0	80.00	999.31	Down	80		21:40	23:21	IG_BH04_WP05_GAM2SFA_03-11.tfd	
03-12	GAM2SFA	6752_6327	0.050	20.0	999.31	81.04	Up		81.04	23:25	00:11	IG_BH04_WP05_GAM2SFA_03-12.tfd	Pump is out of the hole
03-13	2PCA	5032	0.01	2.5	429.44	319.44	Up	1.87	2.12	03:03	03:45	IG_BH04_WP05_2PCA_03_13.tfd	Post cal checks performed

Client: NWMO
Location: Ignace – IG_BH04
Prepared by: OF

Job Number: 20353946-4050
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi
CC: George Schneider

Date / Shift: May-02-2021 – Shift 04
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Borehole data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.40	38.33	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
04-01	GAM2NEU	5602_6650	0.025	2.5	300.03	199.98	Up	2.35	2.29	13:10	13:57	IG_BH04_WP05_GAM2NEU_04-01.tfd	DGI - Repeat section
04-02	GAMDEN	5602_6366	0.025	2.5	300.18	199.23	Up	2.68	2.55	15:11	15:52	IG_BH04_WP05_GAMDEN_04-02.tfd	DGI - Repeat section
04-03	2PCA	5032	0.010	2.5	999.47	938.05	Up	1.71	-	18:28	18:54	IG_BH04_WP05_2PCA_04-03.tfd	Lost telemetry at end and had to restart log
04-04	2PCA	5033	0.010	2.5	945.00	2.63	Up	-	2.63	19:10	01:32	IG_BH04_WP05_2PCA_04-04.tfd	
04-05	GAMABI	6752_190404	0.0021	2.25	2.49	6.00	Down	2.49	2.49	02:24	02:29	IG_BH04_WP05_GAMABI_04-05.tfd	
04-06	GAMABI	6752_190404	0.0021	2.25	2.49	415.03	Down	2.49	2.75	02:32	05:46	IG_BH04_WP05_GAMABI_04-06.tfd	

Client: NWMO
Location: Ignace – IG_BH04
Prepared by: OF

Job Number: 20253946-4050
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi

CC: George Schneider

Date / Shift: May-03-2021 – Shift 05

Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.40	34.18	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
05-01	GAM2NEU	5602_6650	0.025	2.5	990.00	2.35	Up	2.35	1.67	9:42	16:18	IG_BH04_WP05_GAM2NEU_05-01.tfd	Full neutron log EOH through the casing
05-02	GAMABI	6752_190404	0.050	15.0	2.49	289.30	Down	2.49	2.49	16:51	17:15	IG_BH04_WP05_GAMABI_05-02.tfd	
05-03	ABI	201201	0.050	15.0	230.00	995.78	Down	1.47	-	18:39	19:35	IG_BH04_WP05_ABI_05-03.tfd	
05-04	ABI	201201	0.002	0.9	994.52	960.00	Up	-	-	19:59	20:51	IG_BH04_WP05_ABI_05-04.tfd	
05-05	ABI	201201	0.002	0.8	970.02	872.00	Up	-	-	21:06	23:26	IG_BH04_WP05_ABI_05-05.tfd	
05-06	ABI	201201	0.002	1.2	877.00	527.00	Up	-	-	23:28	04:06	IG_BH04_WP05_ABI_05-06.tfd	Ended due to bad wrap on winch
05-07	ABI	201201	0.002	1.5	532.03	359.97	Up	-	0.81	04:11	06:08	IG_BH04_WP05_ABI_05-07.tfd	

Client: NWMO

Location: Ignace – IG_BH04

Prepared by: OF

Job Number: 20253946-4050

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO:	Maria Sánchez-Rico Castejón		**Date / Shift:**	May-04-2021 – Shift 06
	Sarah Hirschorn		**Work Package:**	WP05 – Borehole Geophysical Logging
	Mostafa Khorshidi			
CC:	George Schneider			
			Distributed By:	Email

Borehole Data									
Depth Reference	**Stickup (m)**	**Water Level (m bgs)**	**Borehole Total Depth (m bgs)**	**Casing Depth (m bgs)**	**Casing Diameter (mm)**	**Inclination**	**BH Winch Offset from Borehole (m)**	**Open Hole Diameter (mm)**	**Comments**
Ground Surface	0.40	32.96	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
06-01	GAMDEN	6366	0.025	2.5	990.00	746.85	Up	2.68		8:57	10:35	IG_BH04_WP05_GAMDEN_06-01.tfd	Full neutron log EOH through the casing
06-02	GAMDEN	6366	0.025	2.5	751.98	2.09	Up		2.09	10:40	15:40	IG_BH04_WP05_GAMDEN_06-02.tfd	
06-03	2PGA2PIA	3493_3513	0.05	20.0	110.00	350.00	Down	2.12		17:03	17:17	IG_BH04_WP05_2PGA2PIA_06-03.tfd	
06-04	2PGA2PIA	3493_3513	0.05	4.0	350.00	450.08	Down			17:18	17:43	IG_BH04_WP05_2PGA2PIA_06-04.tfd	QA/QC Log
06-05	2PGA2PIA	3493_3513	0.05	20.0	450.08	999.52	Down			17:44	18:10	IG_BH04_WP05_2PGA2PIA_06-05.tfd	
06-06	2PGA2PIA	3493_3513	0.05	4.5	999.52	99.00	Up		2.29	18:11	21:41	IG_BH04_WP05_2PGA2PIA_06-06.tfd	Ended due to bad wrap on winch
06-07	GAM2SFA	5598_6327	0.050	4.0	1.66	700.00	Down	1.66		23:19	02:20	IG_BH04_WP05_GAM2SFA_06-07.tfd	
06-08	GAM2SFA	5598_6327	0.050	4.0	680.00	999.40	Down			02:24	03:47	IG_BH04_WP05_GAM2SFA_06-08.tfd	
06-09	GAM2SFA	5598_6327	0.050	4.0	999.45	1.39	Up			04:06		IG_BH04_WP05_GAM2SFA_06-09.tfd	Not completed at end of shift – continue logging on shift 7

Client:	NWMO	**Job Number:**	20253946-4050
Location:	Ignace – IG_BH04	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	OF	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi

CC: George Schneider

Date / Shift: May-05-2021 – Shift 07

Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.40	32.96	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
06-09	GAM2SFA	5598_6327	0.050	4.0	999.45	1.39	Up	1.66	1.39	04:06	11:00	IG_BH04_WP05_GAM2SFA_06-09.tfd	Completion of log from night shift
07-03	GAMHMI	5598_676	0.05	4.50	400.10	299.83	Up	3.20		12:12	12:30	IG_BH04_WP05_GAMHMI_07-03.tfd	QA/QC Log
07-05	GAMHMI	5598_676	0.05	4.50	999.21	95.01	Up		3.15	13:24	16:54	IG_BH04_WP05_GAMHMI_07-05.tfd	Main Run
07-07	2SNA	5598_676	0.0250	2.25	400.00	423.11	Down	1.57		18:13	18:26	IG_BH04_WP05_2SNA_07-07.tfd	QA/QC Log
07-08	2SNA	4116.00	0.0250	2.25	423.11	479.74	Down			19:16	19:40	IG_BH04_WP05_2SNA_07-08.tfd	QA/QC Log
07-09	2SNA	4116.00	0.0250	2.25	475.00	500.01	Down			19:46	19:57	IG_BH04_WP05_2SNA_07-09.tfd	QA/QC Log
07-10	2SNA	4116.00	0.0250	2.25	999.59	386.37	Up			20:19	00:58	IG_BH04_WP05_2SNA_07-10.tfd	Main Run
07-11	2NSA	4116.00	0.0250	2.25	392.02	-0.13	Up		-0.13	01:07	04:00	IG_BH04_WP05_2NSA_07-11.tfd	Main Run

Client: NWMO

Location: Ignace – IG_BH04

Prepared by: OF

Job Number: 20253946-4050

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi
CC: George Schneider

Date / Shift: May-06-2021 – Shift 08
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Borehole data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.56	30.67	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
08-01	FWS	210306	0.050	2.0	500.41	399.99	Up	2.75		08:17	09:06	IG_BH04_WP05_FWS_08-01.tfd	repeat run
08-02	FWS	210306	0.050	2.0	999.10	895.98	Up			10:59	11:52	IG_BH04_WP05_FWS_08-02.tfd	changed power supply due to main g maintanance
08-03	FWS	210306	0.050	2.0	915.09	883.63	Up			12:10	12:30	IG_BH04_WP05_FWS_08-03.tfd	bad power supply , >10%errors
08-04	FWS	210306	0.050	2.0	920.05	2.92	Up		2.92	12:40	20:16	IG_BH04_WP05_FWS_08-04.tfd	running off 3kw honda
08-05	GAMIP	5579	0.100	19.0	158.33	500.00	Down	10.85		21:09	21:32	IG_BH04_WP05_GAMIP_08-05.tfd	
08-06	GAMIP	5579	0.050	3.0	500.00	600.00	Down			21:34	22:09	IG_BH04_WP05_GAMIP_08-06.tfd	
08-07	GAMIP	5579	0.100	19.0	600.00	999.50	Down			22:10	22:35	IG_BH04_WP05_GAMIP_08-07.tfd	
08-08	GAMIP	5579	0.050	3.0	999.50	960.00	Up		5.36	23:40	23:55	IG_BH04_WP05_GAMIP_08-08.tfd	Power Failure, tool drop, pull tool and reset zero
08-09	GAMIP	5579	0.050	3.0	999.52	89.17	Up	10.85	10.8	02:33	08:00	IG_BH04_WP05_GAMIP_08-09.tfd	

Client: NWMO
Location: Ignace – IG_BH04
Prepared by: OF

Job Number: 20253946-4050
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi
CC: George Schneider

Date / Shift: May-08-2021 – Shift 9
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Borehole data									
Depth Reference	**Stickup (m)**	**Water Level (m bgs)**	**Borehole Total Depth (m bgs)**	**Casing Depth (m bgs)**	**Casing Diameter (mm)**	**Inclination**	**BH Winch Offset from Borehole (m)**	**Open Hole Diameter (mm)**	**Comments**
Ground Surface	0.56	30.67-38.58	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
10-2	GAMOBI	160403	0.016	4.0	522.02	379.09	Up	2.35		8:11	8:50	IG_BH04_WP05_GAMOBI_10-2.tfd	repeat of the section with errors
10-4	GAMOBI	160403	0.002	4.0	996.92	709.61	Up			9:52	11:11	IG_BH04_WP05_GAMOBI_10-4.tfd	repeat of the section with errors
10-5	GAMOBI	160403	0.002	4.0	620.00	520.70	Up			11:27	11:57	IG_BH04_WP05_GAMOBI_10-5.tfd	repeat of the section with errors
10-6	GAMOBI	160403	0.002	4.0	295.00	247.50	Up		2.30	12:19	12:31	IG_BH04_WP05_GAMOBI_10-6.tfd	repeat of the section with errors
10-7	GAMABI	5589_201 201	0.050	15.0	5.13	995.68	Down	2.49		13:20	14:38	IG_BH04_WP05_GAMABI_10-7.tfd	ABI down run
10-8	GAMABI	5589_201 201	0.002	2.0	994.99	742.10	Up			14:42	18:33	IG_BH04_WP05_GAMABI_10-8.tfd	good ABI and GR run
10-9	GAMABI	5589_201 201	0.002	2.0	755.00	692.85	Up			19:06	20:17	IG_BH04_WP05_GAMABI_10-9.tfd	
10-10	GAMABI	5589_201 202	0.002	2.0	696.00	30.93	Up		3.07	20:40	04:23	IG_BH04_WP05_GAMABI_10-10.tfd	
10-12	2SNA	4116	0.0250	2.25	200.00	89.33	Up	1.56	1.62	05:13	06:01	IG_BH04_WP05_2SNA_10-12.tfd	

Client: NWMO
Location: Ignace – IG_BH04
Prepared by: OF

Job Number: 20253946-4050
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-20253946-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Mostafa Khorshidi
CC: George Schneider

Date / Shift: May-08-2021 – Shift 10
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Borehole data									
Depth Reference	Stickup (m)	Water Level (m bgs)	Borehole Total Depth (m bgs)	Casing Depth (m bgs)	Casing Diameter (mm)	Inclination	BH Winch Offset from Borehole (m)	Open Hole Diameter (mm)	Comments
Ground Surface	0.56	30.67-38.58	1000.36	100.77	122	-70.0	5.00	96	

Run	Probe Name	Serial Number	Inc. (m)	Speed (m/min)	From (m)	To (m)	Run dir	Start zero	End zero	Start Time	End Time	File name	Comments
10-2	GAMOBI	160403	0.016	4.0	522.02	379.09	Up	2.35		8:11	8:50	IG_BH04_WP05_GAMOBI_10-2.tfd	repeat of the section with errors
10-4	GAMOBI	160403	0.002	4.0	996.92	709.61	Up			9:52	11:11	IG_BH04_WP05_GAMOBI_10-4.tfd	repeat of the section with errors
10-5	GAMOBI	160403	0.002	4.0	620.00	520.70	Up			11:27	11:57	IG_BH04_WP05_GAMOBI_10-5.tfd	repeat of the section with errors
10-6	GAMOBI	160403	0.002	4.0	295.00	247.50	Up		2.30	12:19	12:31	IG_BH04_WP05_GAMOBI_10-6.tfd	repeat of the section with errors
10-7	GAMABI	5589_201 201	0.050	15.0	5.13	995.68	Down	2.49		13:20	14:38	IG_BH04_WP05_GAMABI_10-7.tfd	ABI down run
10-8	GAMABI	5589_201 201	0.002	2.0	994.99	742.10	Up			14:42	18:33	IG_BH04_WP05_GAMABI_10-8.tfd	good ABI and GR run
10-9	GAMABI	5589_201 201	0.002	2.0	755.00	692.85	Up			19:06	20:17	IG_BH04_WP05_GAMABI_10-9.tfd	
10-10	GAMABI	5589_201 202	0.002	2.0	696.00	30.93	Up		3.07	20:40	04:23	IG_BH04_WP05_GAMABI_10-10.tfd	
10-12	2SNA	4116	0.0250	2.25	200.00	89.33	Up	1.56	1.62	05:13	06:01	IG_BH04_WP05_2SNA_10-12.tfd	

Client: NWMO
Location: Ignace – IG_BH04
Prepared by: OF

Job Number: 20253946-4050
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

PFL DAILYLOG

AREA	DRILLHOLE(S)	PERSON(S)
Ignace Area, Ontario, Canada	IG_BH04	Petri Heikkinen (PEHE) Jere Komulainen (JERK)
RESPONSIBLE AT THE SITE Petri Heikkinen	ORGANISATION/CLIENT Golder / NWMO	

ADDITIONAL INFORMATION	ORDERNUMBER / MEASUREMENT PROGRAM
Time zone UTC-5 unless otherwise stated.	

DATE (YYMMDD)	TIME		ACTIVITY	Operator Initials
	Start (hh:mm)	Stop (hh:mm)		
20210709			**Travel Toronto – Thunder Bay. Waiting a PCR-result.**	**PEHE**
20210710			**Waiting a PCR-result. Travel Thunder Bay – Ignace.**	**PEHE**
20210711	**6:30**	**7:30**	**From Ignace to the BH04.**	**PEHE**
	7:30	**8:30**	**Site introduction at the BH04 site.**	**PEHE**
	8:30	**15:30**	**Unpacking the PFL-trailer. Preparation for the measurements. I couldn't test electrically because of we couldn't plug open wires to power supply. Electrician will come tomorrow morning 9:00AM.**	**PEHE**
	13:40		**Water level in the borehole is unknown. 30 m long surface meter didn't reach water level. A packer uninstalled during a morning.**	**PEHE**
	15:30	**16:10**	**From BH04 to the Ignace.**	**PEHE**
20120712	**6:40**	**07:30**	**From Ignace to the BH04.**	**PEHE**
	07:30	**10:32**	**Preparation at the site.**	**PEHE**
	8:00		**Water level 30.21 m.**	**PEHE**
	10:32		**Electricity connected.**	**PEHE**
	10:32	**10:48**	**Installation for Dummy-logging.**	**PEHE**
	10:48	**12:15**	**Dummy logging downwards. Bottom of borehole 997.5 m (Cable length, not corrected).**	**PEHE**
	12:15	**14:00**	**Dummy logging upwards.**	**PEHE**

	14:14		Dummy logging did not pass the criteria. See the picture. 	PEHE
	14:14	14:37	Preparation for second dummy run.	PEHE
	14:37	16:02	Dummy logging downwards.	PEHE
	16:02	16:47	Dummy logging upwards. Dummy stopped at the depth 857 m (winch dept) because of tension limit. Dummy is moved downwards few meter and up again. Stopped again at the same depth. Third run went through the place. Dummy at the depth 710 m.	PEHE
	16:47	17:30	From BH04 to the Ignace.	PEHE
20120713	6:20	7:00	From Ignace to the BH04.	PEHE
	7:00	8:20	Dummy from 710 m to 0. Dummy logging passed the criteria. See the picture. 	PEHE

	8:20	9:25	Preparations and installation for flow measurements (L=5 m, dl=0.5 m).	PEHE
	9:25	9:52	Moving the probe to the depth 50 m. Installation for water level sensor.	PEHE
	9:35		Water level 29.19 m.	PEHE
	9:52	11:48	Moving the tool to the depth 990 m and during the movement EC-logging.	PEHE
	11:48	18:56	Flow logging (L=5.0m, dl=0.5 m) without pumping from 990 m upwards. Data processing.	PEHE
	18:56		Flow logging at the depth 800 m. Peter (Golder) will be on site to monitor measurement. Peter will inform Jere if something unexpected happens.	PEHE
	18:56	19:30	From BH04 to the Ignace.	PEHE
20120714	6:00	6:40	From Ignace to the BH04.	PEHE
	6:40		Measurements at the depth 427 m.	PEHE
	6:40	15:44	Data processing. Preparation for pumping.	PEHE
	15:44		Measurements without pumping ready at the depth 100 m.	PEHE
	15:44	17:00	Installation of pumping equipment.	PEHE
	17:00		Pumping started. Target drawdown 10 m.	PEHE
	17:00	17:10	Waiting for steady state with pumping. Drawdown of c. 12 m was achieved which is good.	PEHE
	17:10	18:18	Moving the probe from 90 m to 990 m. Steady state water level logging.	PEHE
	18:18		Stopping steady state water level logging.	PEHE
	18:18	18:25	Preparation for flow logging (L=5.0m, dl=0.5 m) with pumping:	PEHE
	18:24		Flow logging (L=5.0m, dl=0.5 m) with pumping from 990 m upwards. Measurement started.	PEHE
	18:53	19:34	From BH04 to the Ignace.	PEHE
	22:20	6:00	Remote connection between measurement computer and office in Finland works. Data processing and monitoring of measurement.	JERK
20120715	6:15	6:55	From Ignace to the BH04.	PEHE
	6:55		Flow logging (L=5.0m, dl=0.5 m) with pumping at the depth 672 m.	PEHE
	6:55	9:06	Data processing.	PEHE
	9:06		Pumping rate is below the lower limit of the meter. Pumping rate have to be measured with a vessel.	PEHE
	9:06		Pumping rate 1950 mL/3 min = 650 mL/min.	PEHE
	9:06	16:05	Monitoring the measurement and data processing.	PEHE
	16:05		Pumping rate 1400 mL/3 min = 467 mL/min.	PEHE
	16:21	17:00	From BH04 to the Ignace.	PEHE
	17:00	17:54	Data processing and monitoring remotely	PEHE
	17:54	18:30	From Ignace to the BH04.	PEHE
	18:30	19:00	Water level started to rise in borehole and pumping had to be adjusted.	PEHE
	22:30	00:08	Monitoring the measurement with remote connection.	JERK
	00:08		Measurement run reached lower end of casing pipe and stopped. This was expected as it happened also during the previous measurement run. Petri will continue in the morning and measure 10 m higher so that entire measurement section reaches casing pipe.	JERK
	00:08	06:00	Data processing at office in Finland.	JERK
20120716	6:17	6:55	From Ignace to the BH04.	PEHE
	6:55	7:18	Flow logging (L=5.0m, dl=0.5 m) with pumping from 108.5 m - 100 m. Data processing	PEHE

	7:19		Pumping stopped	PEHE
	7:18	8:21	Installation for Flow logging (L=0.5 m, dl=0.1m)	PEHE
	8:21		Pumping started.	PEHE
	8:24	9:34	Moving the tool to the depth 990 m and during the movement EC-logging.	PEHE
	9:58	14:37	Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 986 m upwards. Data processing.	PEHE
	15:20	16:21	Winch stopped a run. Reason is unknown at this moment. Overheat maybe. Solving a problem.	PEHE
	16:00		Pumping stopped.	PEHE
	16:21	17:00	From BH04 to the Ignace.	PEHE
20120717	7:00	7:40	From Ignace to the BH04.	PEHE
	7:00	11:24	Winch troubleshooting. New motor was changed.	PEHE
	11:24	11:45	Moving the probe from 164.5 m to 129 m	PEHE
	11:31		Pumping started.	PEHE
	11:45	13:32	Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 129 m to 108.7 m. Data processing.	PEHE
	13:32		Measurement run reached lower end of casing pipe and stopped. This was expected as it happened also during the previous measurement run.	PEHE
	13:32	14:37	Took a quite long time to get a probe to the casing pipe.	PEHE
	13:44		Pumping was stopped and lifted away because it was on the way when attempting to get probe pass the lower end of casing pipe.	PEHE
	14:37	14:50	Flow logging (L=0.5 m, dl=0.1m) without pumping preselected depths from 108.6 m to 106 m. Data processing.	PEHE
	14:50	15:30	Data processing.	PEHE
	15:30	16:10	From BH04 to the Ignace.	PEHE
	16:10	19:30	Data processing.	PEHE
20120718	6:20	6:55	From Ignace to the BH04.	PEHE
	6:55	7:30	Uninstallation for the flow sensor.	PEHE
	7:30	15:34	Cleaning, maintenance and packaging. The trailer was moved aside from the measuring point. Data processing.	PEHE
	15:34	16:16	From BH04 to the Ignace.	PEHE
20120719	6:20	6:55	From Ignace to the BH04.	PEHE
	6:55	17:04	Cleaning, maintenance and packaging. Data processing.	PEHE
	17:04	17:42	From BH04 to the Ignace.	PEHE

APPENDIX D

Probe. TOL Files

```
[Description]
ToolName             = MSI1-ABI_190404
DriverName           = TOOLSTACK
FamilyName           =

[Subs]
Sub1                 = QL40-12\QL40-MSI1-100.sub
Sub2                 = QL40-12\QL40-ABI2G-190404.sub

[WellCAD]
Template1            =

[Header]
HeaderForm           =

; channels ------------------------

[Tool.ABI40.SYSTEMSTATUS.System Status]
NumberFormat         = %3.0f
DisplayEnable        = no

[Tool.ABI40.SYSTEMSTATUS.Motor]
NumberFormat         = %3.0f
DisplayEnable        = no
QCLow                = 0.5
QCHigh               = 1.5
QCLowRangeColor      = 2
QCMedRangeColor      = 1
QCHighRangeColor     = 2
QCLowRangeText       = No Sync
QCMedRangeText       = OK
QCHighRangeText      = No Sync
QCLowRangeBeep       = no
QCMedRangeBeep       = no
QCHighRangeBeep      = no

[Tool.ABI40.SYSTEMSTATUS.Orientation]
NumberFormat         = %3.0f
DisplayEnable        = no
QCLow                = 0.5
QCHigh               = 1.5
QCLowRangeColor      = 2
QCMedRangeColor      = 1
QCHighRangeColor     = 2
QCLowRangeText       = OFFLINE
QCMedRangeText       = OK
QCHighRangeText      = OFFLINE
QCLowRangeBeep       = no
```

```
QCMedRangeBeep        = no
QCHighRangeBeep       = no

[Tool.ABI40.SYSTEMSTATUS.Motor Period]
NumberFormat          = %6.4f
DisplayEnable         = no

[Tool.ABI40.SYSTEMSTATUS.VTool]
FactoryCalibrationEnable = yes
NumberFormat          = %5.1f
DisplayEnable         = no

[Tool.ABI40.SYSTEMSTATUS.V12]
FactoryCalibrationEnable = yes
NumberFormat          = %5.2f
DisplayEnable         = no

[Tool.ABI40.TEMPERATURE.RThead]
FactoryCalibrationEnable = yes
NumberFormat          = %7.2f
DisplayEnable         = no

[Tool.ABI40.TEMPERATURE.T CPU]
FactoryCalibrationEnable = yes
NumberFormat          = %5.1f
DisplayEnable         = no

[Tool.ABI40.APS544.Roll]
NumberFormat          = %6.1f
DisplayEnable         = no

[Tool.ABI40.APS544.MRoll]
NumberFormat          = %6.1f
DisplayEnable         = no

[Tool.ABI40.APS544.Tilt]
NumberFormat          = %6.1f
Low                   = 0
High                  = 15
NbDecade              = 1
Mode                  = Linear
ReverseScale          = no
GridEnable            = yes
Grid                  = 2.5
Left                  = 70
Right                 = 100
PenStyle              = solid
PenWidth              = 2
```

```
PenColor              = ff
DisplayEnable         = yes

[Tool.ABI40.APS544.MagnField]
NumberFormat          = %6.2f
DisplayEnable         = no

[Tool.ABI40.APS544.Azimuth]
NumberFormat          = %6.1f
Low                   = 0
High                  = 360
NbDecade              = 1
Mode                  = Linear
ReverseScale          = no
GridEnable            = yes
Grid                  = 45
Left                  = 40
Right                 = 70
PenStyle              = solid
PenWidth              = 2
PenColor              = ff0000
DisplayEnable         = yes

[Tool.ABI40.APS544.Gravity]
NumberFormat          = %6.4f
DisplayEnable         = no

[Tool.ABI40.APS544.T APS]
NumberFormat          = %6.2f
Low                   = 0
High                  = 300
NbDecade              = 1
Mode                  = Linear
ReverseScale          = no
GridEnable            = no
Grid                  = 0
Left                  = 0
Right                 = 30
PenStyle              = solid
PenWidth              = 2
PenColor              = 8000
Filter                = 1
DisplayEnable         = yes

[Tool.ABI40.ECHO1.WndTime]
NumberFormat          = %6.2f
DisplayEnable         = no
```

```
[Tool.ABI40.ECHO1.WndAmpl]
NumberFormat          = %6.2f
DisplayEnable         = no

[Tool.ABI40.ECHO1.TravelTime]

[Tool.ABI40.ECHO1.Amplitude]

[Tool.ABI40.ECHO2.TravelTime2]

[Tool.ABI40.ECHO2.Amplitude2]

[Tool.ABI40.THICKNESS.ThicknessTTime]

[Tool.ABI40.THICKNESS.Score]

[MChProc.MotSpeed]
NumberFormat          = %4.1f
DisplayEnable         = no

[MChProc.T Head]
NumberFormat          = %7.2f
Low                   = 0
High                  = 300
NbDecade              = 1
Mode                  = Linear
ReverseScale          = no
GridEnable            = yes
Grid                  = 50
Left                  = 0
Right                 = 30
PenStyle              = solid
PenWidth              = 2
PenColor              = ff
Filter                = 1
DisplayEnable         = yes

[Logger.Speed]
DisplayEnable         = no

[Logger.Tension]
DisplayEnable         = no

[Logger.ToolPowerVoltage]
DisplayEnable         = no

[Logger.ToolPowerCurrent]
DisplayEnable         = no
```

```
; browsers and processors ---------

[MChProc]
XOffset             = 953
YSize               = 147
XSize               = 302
Minimized           = yes
YOffset             = 510

[MChNum]
NumDisplay1         = MChProc.MotSpeed
NbNumDisplay        = 8
NumDisplay2         = MChProc.T Head
NumDisplay3         = Tool.ABI40.TEMPERATURE.T CPU
NumDisplay4         = Tool.ABI40.SYSTEMSTATUS.VTool
NumDisplay5         = Tool.ABI40.APS544.Azimuth
NumDisplay6         = Tool.ABI40.APS544.Tilt
NumDisplay7         = Tool.ABI40.APS544.MagnField
NumDisplay8         = Tool.ABI40.APS544.Gravity
LedDisplay1         = Tool.ABI40.SYSTEMSTATUS.Motor
NbLedDisplay        = 2
LedDisplay2         = Tool.ABI40.SYSTEMSTATUS.Orientation
XOffset             = 582
YOffset             = 524
XSize               = 304
YSize               = 453
Minimized           = no

[AbiSurfaceImg]
DepthScale          = 100
GridSpacing         = 0.5
XOffset             = 1189
ForceTimeMode       = yes
YSize               = 1030
XSize               = 731
DepthSpacing        = 5
Minimized           = yes
YOffset             = 0
Grid                = yes

[AbiThicknessImg]
ScoreMax            = 5000
GridSpacing         = 1
DepthScale          = 200
XOffset             = 454
ScoreMin            = 0
ThicknessPalette    = 0,0,0,128,32,128,0,0,63,255,255,0
```

```
ForceTimeMode       = yes
ThicknessMin        = 2
ThicknessUnit       = mm
YSize               = 359
OrientTo            = nothing
XSize               = 567
CasingVelocity      = 5850
DepthSpacing        = 10
ScorePalette        = 0,0,0,128,32,128,0,0,63,255,255,0
ThicknessMax        = 14
Minimized           = yes
YOffset             = 381
Grid                = no

[AbiCaliper]
XOffset             = 576
YSize               = 584
High                = 120
XSize               = 614
Low                 = 0
CasingVelocity      = 5850
Minimized           = no
ToolOD              = 39
YOffset             = 0
Grid                = 10
Unit                = 1
FluidVelocity       = 1450

[MChCurve]
GridSpacing         = 0.5
DepthScale          = 100
XOffset             = 889
ForceTimeMode       = yes
YSize               = 571
DepthColLeft        = 0.3
XSize               = 1029
DepthSpacing        = 5
DepthColRight       = 0.4
Minimized           = yes
YOffset             = 592
Grid                = yes
```

```
[Description]
ToolName             = MSI1-FWS40-PLUG-40
DriverName           = TOOLSTACK
FamilyName           =

[Subs]
Sub1                 = QL40-12\QL40-MSI1-210516.sub
Sub2                 = QL40-12\QL40-FWSM-210306.sub
Sub3                 = QL40-12\QL40-PLUG.sub

[WellCAD]
Template1            =

[Header]
HeaderForm           =

; channels ------------------------

[FwsProc.RX1-1A - dt]
NumberFormat         = %g

[FwsProc.RX2-1A - dt]
NumberFormat         = %g

[FwsProc.RX3-1A - dt]
NumberFormat         = %g

[FwsProc.RX4-1A - dt]
NumberFormat         = %g

[FwsProc.TAmpl0]
NumberFormat         = %g

[FwsProc.Ampl0]
NumberFormat         = %g

[FwsProc.TAmplX]
NumberFormat         = %g

[FwsProc.AmplX]
NumberFormat         = %g

[MChProc.Slowness]
NumberFormat         = %0.f

; browsers and processors ---------

[FwsProc]
```

```
FirstArrivalProcessWave = 0
XSize                = 255
YSize                = 142
Minimized            = no
XOffset              = 226
YOffset              = 51
CementBondProcessWave = 0

[MChProc]
Minimized            = yes

[MChNum]
XSize                = 230
YSize                = 340
Minimized            = no
XOffset              = 227
YOffset              = 143
NumDisplay1          = FwsProc.RX1-1A - dt
NumDisplay2          = FwsProc.RX2-1A - dt
NumDisplay3          = FwsProc.RX3-1A - dt
NumDisplay4          = FwsProc.RX4-1A - dt
NumDisplay5          = FwsProc.TAmpl0
NumDisplay6          = FwsProc.Ampl0
NumDisplay7          = FwsProc.TAmplX
NumDisplay8          = FwsProc.AmplX
NumDisplay9          = MChProc.Slowness
NbNumDisplay         = 9

[FwsWave]
DisplayRx1           = yes
XSize                = 1089
DisplayRx2           = yes
DisplayTxA           = yes
YSize                = 824
DisplayRx3           = yes
DisplayTxB           = no
DisplayRx4           = yes
DisplayRx5           = no
DisplayRx6           = no
Minimized            = no
DisplayRx7           = no
XOffset              = 447
DisplayRx8           = no
YOffset              = 0
```

```
[Description]
ToolName             = MSI1-HMI453_6766
DriverName           = TOOLSTACK
FamilyName           =

[Subs]
Sub1                 = QL40-12\QL40-MSI1-MSI.sub
Sub2                 = QL40-12\QL40-HMI453-6766.sub

[WellCAD]
Template1            =

[Header]
HeaderForm           =

; channels ------------------------

[Tool.HMI453.SYSTEMSTATUS.Time]
DisplayEnable        = no
NumberFormat         = %8.3f

[Tool.HMI453.SYSTEMSTATUS.TCPU]
DisplayEnable        = no
NumberFormat         = %5.1f

[Tool.HMI453.CHANNELS.MSUS_COUNT]
NumberFormat         = %5.0f
DisplayEnable        = no

[Tool.HMI453.CHANNELS.COND_COUNT]
NumberFormat         = %5.0f
DisplayEnable        = no

[MChProc.MagSus]
NumberFormat         = %6.2f
DisplayEnable        = yes
Low                  = 0
High                 = 250
NbDecade             = 1
Mode                 = Linear
ReverseScale         = no
GridEnable           = yes
Grid                 = 50
Left                 = 40
Right                = 100
PenStyle             = solid
PenWidth             = 2
PenColor             = ff
```

```
DisplayedName        = MagSus
QCLow                = 0
QCHigh               = 0
QCLowRangeColor      = 2
QCMedRangeColor      = 1
QCHighRangeColor     = 2
QCLowRangeText       = Invalid
QCMedRangeText       = Valid
QCHighRangeText      = Invalid
QCLowRangeBeep       = no
QCMedRangeBeep       = no
QCHighRangeBeep      = no
Filter               = 1

[MChProc.Conductivity]
NumberFormat         = %6.2f
DisplayEnable        = yes
Low                  = 0
High                 = 250
NbDecade             = 1
Mode                 = Linear
ReverseScale         = no
GridEnable           = yes
Grid                 = 50
Left                 = 40
Right                = 100
PenStyle             = solid
PenWidth             = 2
PenColor             = ff0000
DisplayedName        = Conductivity
QCLow                = 0
QCHigh               = 0
QCLowRangeColor      = 2
QCMedRangeColor      = 1
QCHighRangeColor     = 2
QCLowRangeText       = Invalid
QCMedRangeText       = Valid
QCHighRangeText      = Invalid
QCLowRangeBeep       = no
QCMedRangeBeep       = no
QCHighRangeBeep      = no
Filter               = 1

[MChProc.Resistivity]
DisplayEnable        = yes
NumberFormat         = %6.2f
PenColor             = 0
PenStyle             = solid
```

```
PenWidth            = 2
Left                = 0
Right               = 30
Low                 = 0
High                = 200
GridEnable          = yes
Grid                = 20
NbDecade            = 1
ReverseScale        = no
Mode                = Linear
Filter              = 2

; browsers and processors ---------

[MChProc]
Minimized           = no
XOffset             = 773
YOffset             = 352
XSize               = 228
YSize               = 120

[MChNum]
XSize               = 230
YSize               = 172
Minimized           = no
XOffset             = 283
YOffset             = 156
NumDisplay1         = MChProc.MagSus
NumDisplay2         = MChProc.Conductivity
NumDisplay3         = MChProc.Resistivity
NbNumDisplay        = 3

[MChCurve]
XSize               = 665
ForceTimeMode       = yes
Grid                = yes
GridSpacing         = 0.5
YSize               = 840
DepthSpacing        = 5
DepthColRight       = 0.4
DepthScale          = 100
Minimized           = no
XOffset             = 230
YOffset             = -8
DepthColLeft        = 0.3
```

```
[Description]
ToolName             = MSI1-QLGR-ABI190404
DriverName           = TOOLSTACK
FamilyName           =

[Subs]
Sub1                 = QL40-12\QL40-MSI1-MSI.sub
Sub2                 = QL40-12\QL40-GR-6752.sub
Sub3                 = QL40-12\QL40-ABI2G-190404.sub

[WellCAD]
Template1            =

[Header]
HeaderForm           =

; channels ------------------------

[Tool.GR.SYSTEMSTATUS.Time]
NumberFormat         = %8.3f
DisplayEnable        = no

[Tool.GR.SYSTEMSTATUS.TCPU]
NumberFormat         = %5.1f
DisplayEnable        = no

[Tool.GR.CHANNELS.EHT]
NumberFormat         = %5.0f
DisplayEnable        = no

[Tool.GR.CHANNELS.COUNT]
NumberFormat         = %5.0f
DisplayEnable        = no

[MChProc.GR]
NumberFormat         = %6.2f
DisplayEnable        = yes
Low                  = 0
High                 = 250
NbDecade             = 1
Mode                 = Linear
ReverseScale         = no
GridEnable           = yes
Grid                 = 50
Left                 = 0
Right                = 30
PenStyle             = solid
PenWidth             = 2
```

```
PenColor             = ff

[Tool.ABI40.SYSTEMSTATUS.System Status]
NumberFormat         = %3.0f
DisplayEnable        = no

[Tool.ABI40.SYSTEMSTATUS.Motor]
NumberFormat         = %3.0f
DisplayEnable        = no
QCLow                = 0.5
QCHigh               = 1.5
QCLowRangeColor      = 2
QCMedRangeColor      = 1
QCHighRangeColor     = 2
QCLowRangeText       = No Sync
QCMedRangeText       = OK
QCHighRangeText      = No Sync
QCLowRangeBeep       = no
QCMedRangeBeep       = no
QCHighRangeBeep      = no

[Tool.ABI40.SYSTEMSTATUS.Orientation]
NumberFormat         = %3.0f
DisplayEnable        = no
QCLow                = 0.5
QCHigh               = 1.5
QCLowRangeColor      = 2
QCMedRangeColor      = 1
QCHighRangeColor     = 2
QCLowRangeText       = OFFLINE
QCMedRangeText       = OK
QCHighRangeText      = OFFLINE
QCLowRangeBeep       = no
QCMedRangeBeep       = no
QCHighRangeBeep      = no

[Tool.ABI40.SYSTEMSTATUS.Motor Period]
NumberFormat         = %6.4f
DisplayEnable        = no

[Tool.ABI40.SYSTEMSTATUS.VTool]
FactoryCalibrationEnable = yes
NumberFormat         = %5.1f
DisplayEnable        = no

[Tool.ABI40.SYSTEMSTATUS.V12]
FactoryCalibrationEnable = yes
NumberFormat         = %5.2f
```

```
DisplayEnable        = no

[Tool.ABI40.TEMPERATURE.RThead]
FactoryCalibrationEnable = yes
NumberFormat         = %7.2f
DisplayEnable        = no

[Tool.ABI40.TEMPERATURE.T CPU]
FactoryCalibrationEnable = yes
NumberFormat         = %5.1f
DisplayEnable        = no

[Tool.ABI40.APS544.Roll]
NumberFormat         = %6.1f
DisplayEnable        = no

[Tool.ABI40.APS544.MRoll]
NumberFormat         = %6.1f
DisplayEnable        = no

[Tool.ABI40.APS544.Tilt]
NumberFormat         = %6.1f
Low                  = 0
High                 = 15
NbDecade             = 1
Mode                 = Linear
ReverseScale         = no
GridEnable           = yes
Grid                 = 2.5
Left                 = 70
Right                = 100
PenStyle             = solid
PenWidth             = 2
PenColor             = ff
DisplayEnable        = yes

[Tool.ABI40.APS544.MagnField]
NumberFormat         = %6.2f
DisplayEnable        = no

[Tool.ABI40.APS544.Azimuth]
NumberFormat         = %6.1f
Low                  = 0
High                 = 360
NbDecade             = 1
Mode                 = Linear
ReverseScale         = no
GridEnable           = yes
```

```
Grid                 = 45
Left                 = 40
Right                = 70
PenStyle             = solid
PenWidth             = 2
PenColor             = ff0000
DisplayEnable        = yes

[Tool.ABI40.APS544.Gravity]
NumberFormat         = %6.4f
DisplayEnable        = no

[Tool.ABI40.APS544.T APS]
NumberFormat         = %6.2f
Low                  = 0
High                 = 300
NbDecade             = 1
Mode                 = Linear
ReverseScale         = no
GridEnable           = no
Grid                 = 0
Left                 = 0
Right                = 30
PenStyle             = solid
PenWidth             = 2
PenColor             = 8000
Filter               = 1
DisplayEnable        = yes

[Tool.ABI40.ECHO1.WndTime]
NumberFormat         = %6.2f
DisplayEnable        = no

[Tool.ABI40.ECHO1.WndAmpl]
NumberFormat         = %6.2f
DisplayEnable        = no

[Tool.ABI40.ECHO1.TravelTime]

[Tool.ABI40.ECHO1.Amplitude]

[Tool.ABI40.ECHO2.TravelTime2]

[Tool.ABI40.ECHO2.Amplitude2]

[Tool.ABI40.THICKNESS.ThicknessTTime]

[Tool.ABI40.THICKNESS.Score]
```

```
[MChProc.MotSpeed]
NumberFormat         = %4.1f
DisplayEnable        = no

[MChProc.T Head]
NumberFormat         = %7.2f
Low                  = 0
High                 = 300
NbDecade             = 1
Mode                 = Linear
ReverseScale         = no
GridEnable           = yes
Grid                 = 50
Left                 = 0
Right                = 30
PenStyle             = solid
PenWidth             = 2
PenColor             = ff
Filter               = 1
DisplayEnable        = yes

; browsers and processors ---------

[MChProc]
XSize                = 302
YSize                = 147
Minimized            = yes
XOffset              = 953
YOffset              = 510

[MChCurve]
XSize                = 1029
ForceTimeMode        = yes
Grid                 = yes
GridSpacing          = 0.5
YSize                = 571
DepthSpacing         = 5
DepthColRight        = 0.4
DepthScale           = 100
Minimized            = yes
XOffset              = 889
YOffset              = 592
DepthColLeft         = 0.3

[MChNum]
XSize                = 230
YSize                = 407
```

```
Minimized            = no
XOffset              = 271
YOffset              = 204
LedDisplay1          = Tool.ABI40.SYSTEMSTATUS.Motor
LedDisplay2          = Tool.ABI40.SYSTEMSTATUS.Orientation
NbLedDisplay         = 2
NumDisplay1          = MChProc.GR
NumDisplay2          = MChProc.MotSpeed
NumDisplay3          = MChProc.T Head
NumDisplay4          = Tool.ABI40.TEMPERATURE.T CPU
NumDisplay5          = Tool.ABI40.SYSTEMSTATUS.VTool
NumDisplay6          = Tool.ABI40.APS544.Azimuth
NumDisplay7          = Tool.ABI40.APS544.Tilt
NumDisplay8          = Tool.ABI40.APS544.MagnField
NumDisplay9          = Tool.ABI40.APS544.Gravity
NbNumDisplay         = 9

[AbiSurfaceImg]
XSize                = 731
ForceTimeMode        = yes
Grid                 = yes
GridSpacing          = 0.5
YSize                = 824
DepthSpacing         = 5
DepthScale           = 100
Minimized            = no
XOffset              = 805
YOffset              = 0

[AbiThicknessImg]
GridSpacing          = 1
Grid                 = no
ForceTimeMode        = yes
XSize                = 567
ThicknessMin         = 2
ThicknessUnit        = mm
DepthSpacing         = 10
YSize                = 359
ThicknessPalette     = 0,0,0,128,32,128,0,0,63,255,255,0
ThicknessMax         = 14
DepthScale           = 200
Minimized            = yes
OrientTo             = nothing
XOffset              = 454
YOffset              = 381
ScorePalette         = 0,0,0,128,32,128,0,0,63,255,255,0
ScoreMin             = 0
ScoreMax             = 5000
```

```
CasingVelocity       = 5850

[AbiCaliper]
High                 = 300
Unit                 = usec
FluidVelocity        = 1450
XSize                = 440
Grid                 = 50
YSize                = 390
Minimized            = no
XOffset              = 255
YOffset              = 1
ToolOD               = 39
Low                  = 0
CasingVelocity       = 5850
```

```
[Description]
ToolName = MSI1-GAM_FTC_6327
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,MSI1,1,
Sub2 = Nuclear,GR,6752,MULTICH
Sub3 = Fluid,FTC,6327,MULTICH

[Default]
TimeSamplingRate=500
DepthSamplingRate=0.05

[MultiCh]
NbCh =17
ToolLength = 1.897

[ToolId]
GR = 16
FTC = 25

[GR.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[FTC.ModuleId]
SYSTEMSTATUS = 1
ELOG = 5
TEMPERATURE = 2

; MSI1 channels ------------------------

; GR channels ------------------------

[Ch1]
Name=Time
Producer=Tool.GR.SYSTEMSTATUS
ChShift=0.965
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch2]
Name=TCPU
```

Producer=Tool.GR.SYSTEMSTATUS
ChShift=0.99
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch3]
Name=EHT
Producer=Tool.GR.CHANNELS
ChShift=0.965
Unit=Volts
Offset=0
DataType=word
CalA=-3.95513
CalB=0
CalibrationEnable=yes
NumberFormat=%5.0f
DisplayEnable=no
Reference1=0
Reference2=-1093
CalDate=29/04/21 18:44

[Ch4]
Name=COUNT
Producer=Tool.GR.CHANNELS
ChShift=0.96
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch5]
Name=GR
Producer=MChProc
Formula={ch4}/{ch1}
ChShift=0.965
Unit=cps
CalA=1
CalB=0

```
CalibrationEnable=yes
CalibrationType=GR
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff

; FTC channels ------------------------

[Ch6]
Name=Time
Producer=Tool.FTC.SYSTEMSTATUS
Unit=sec
ChShift=0
DataType=DWord
Offset=0
CalA=0.001
CalB=0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch7]
Name=Temperature
Producer=Tool.FTC.SYSTEMSTATUS
Unit='C
ChShift=0.063
DataType=Word
Offset=4
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no
Reference1=1
Reference2=0
CalDate=25/01/16 10:53
```

[Ch8]
Name=Vinj
Producer=Tool.FTC.ELOG
Unit=V
ChShift=0
DataType=long
Offset=0
CalA=1.16491e-006
CalB=-0.0139841
CalibrationEnable=yes
NumberFormat=%8.3f
DisplayEnable=no
DisplayedName=Vinj
Low=0
High=15
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=ff
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1
Reference1=9.258
Reference2=0
CalDate=09/02/17 14:26

[Ch9]
Name=Iinj
Producer=Tool.FTC.ELOG
Unit=mA
ChShift=0
DataType=long
Offset=4

```
CalA=7.51732e-006
CalB=-0.000768271
CalibrationEnable=yes
NumberFormat=%8.1f
DisplayEnable=no
DisplayedName=Iinj
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=80ff
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1
Reference1=89.9
Reference2=0
CalDate=09/02/17 12:37

[Ch10]
Name=DV1
Producer=Tool.FTC.ELOG
Unit=V
ChShift=0
DataType=long
Offset=16
CalA=5.49207e-007
CalB=-0.000161385
CalibrationEnable=yes
NumberFormat=%8.3f
DisplayEnable=no
DisplayedName=DV1
Low=0
```

```
High=1
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=8000
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1
Reference1=3.105
Reference2=0
CalDate=09/02/17 12:37

[Ch11]
Name=DV2
Producer=Tool.FTC.ELOG
Unit=V
ChShift=0
DataType=long
Offset=8
CalA=5.45127e-007
CalB=-3.67688e-005
CalibrationEnable=yes
NumberFormat=%8.3f
DisplayEnable=no
DisplayedName=DV2
Low=0
High=1
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
```

```
Right=30
PenStyle=solid
PenWidth=1
PenColor=ff0000
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1
Reference1=3.094
Reference2=0
CalDate=09/02/17 12:37

[Ch12]
Name=Temp
Producer=Tool.FTC.ELOG
Unit='C
ChShift=0
DataType=long
Offset=12
CalA=0.00329627
CalB=-230.75
Reference1=8
Reference2=36
CalDate=29/04/21 18:44
CalibrationEnable=yes
NumberFormat=%8.2f
DisplayEnable=yes
DisplayedName=Temp
Low=10
High=20
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=1
Left=35
Right=67.5
PenStyle=solid
PenWidth=2
PenColor=ff
```

```
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1

[Ch13]
Name=Cond
Producer=MChProc
Unit=uS/cm
ChShift=0.063
CalA=1.56809
CalB=-2.39163
Reference1=57
Reference2=29500
CalDate=29/04/21 18:27
CalibrationEnable=yes
NumberFormat=%8.1f
DisplayEnable=no
Formula=(148.526*{ch9})/({ch10}+{ch11})
DisplayedName=Cond
Low=0
High=10000
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=ff8000
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
```

```
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1

[Ch14]
Name=Cond25C
Producer=MChProc
Unit=uS/cm
ChShift=0.063
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%8.1f
Formula=46.5*{ch13}/({ch12}+21.5)
DisplayedName=Cond25C
Low=0
High=10000
NbDecade=3
Mode=Logarythmic
ReverseScale=no
GridEnable=yes
Grid=0
Left=67.5
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff8000
DisplayEnable=yes
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1
Reference1=1
Reference2=0
CalDate=25/01/16 10:53

; MSI1 channels calibrations ------------------------

; GR channels calibrations ------------------------
```

```
; FTC channels calibrations ------------------------

[Process]
Process1 = Processor,Start,mch\MChProc.exe
Process2 = Browser,Start,mch\MChCurve.exe
Process3 = Browser,Start,mch\MChNum.exe

[MChProc]
Minimized=yes

[MChCurve]
DepthScale=100
GridSpacing=0.5
XOffset=650
ForceTimeMode=no
YSize=977
DepthColLeft=0.3
XSize=848
DepthSpacing=5
DepthColRight=0.35
Minimized=no
YOffset=0
Grid=yes

[MChNum]
NumDisplay1=Ch5
NbNumDisplay=7
NumDisplay2=Ch8
NumDisplay3=Ch9
NumDisplay4=Ch10
NumDisplay5=Ch11
NumDisplay6=Ch12
NumDisplay7=Ch13
XOffset=658
YOffset=268
XSize=341
YSize=410
Minimized=no
```

```
[Description]
ToolName = NWMO-GO4-GRA-QL40 SNN
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,GO4,173205,
Sub2 = Nuclear,GRA,5602,MULTICH
Sub3 = Nuclear,QL40 SNN,6650_71-1-409G,MULTICH

[Default]
TimeSamplingRate=500
DepthSamplingRate=0.0025

[MultiCh]
NbCh =16
ToolLength = 2.587

[ToolId]
GRA = 16
QL40 SNN = 28

[GRA.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[QL40 SNN.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

; GO4 channels ------------------------

; GRA channels ------------------------

[Ch1]
Name=Time
Producer=Tool.GRA.SYSTEMSTATUS
ChShift=1.685
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch2]
Name=TCPU
Producer=Tool.GRA.SYSTEMSTATUS
```

```
ChShift=1.71
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch3]
Name=EHT
Producer=Tool.GRA.CHANNELS
ChShift=1.685
Unit=Volts
Offset=0
DataType=word
CalA=-4.14414
CalB=0
CalibrationEnable=yes
NumberFormat=%5.0f
DisplayEnable=no
Reference1=0
Reference2=-1127
CalDate=03/10/12 07:58

[Ch4]
Name=COUNT
Producer=Tool.GRA.CHANNELS
ChShift=1.68
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch5]
Name=GR
Producer=MChProc
Formula={ch4}/{ch1}
ChShift=1.685
Unit=CPS
CalA=1
CalB=0
CalibrationEnable=yes
```

```
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=0
Reference2=1
CalDate=23/03/12 15:52

; QL40 SNN channels ------------------------

[Ch6]
Name=Time
Producer=Tool.QL40 SNN.SYSTEMSTATUS
ChShift=0.171
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch7]
Name=TCPU
Producer=Tool.QL40 SNN.SYSTEMSTATUS
ChShift=0.21
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch8]
Name=SSN CNT
```

Producer=Tool.QL40 SNN.CHANNELS
ChShift=0.27
Unit=
Offset=0
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch9]
Name=LSN CNT
Producer=Tool.QL40 SNN.CHANNELS
ChShift=0.7
Unit=
Offset=4
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch10]
Name=SSN
Producer=MChProc
Formula={ch8}/{ch6}
ChShift=0.16
Unit=CPS
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=200

```
Reference2=1000
CalDate=22/05/19 09:04

[Ch11]
Name=LSN
Producer=MChProc
Formula={ch9}/{ch6}
ChShift=0.37
Unit=CPS
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=40
Reference2=200
CalDate=22/05/19 09:04

[Ch12]
Name=SSN_POR
Producer=MChProc
Formula=19.98223157*Exp(-0.000315937*{ch10}*Log(10))*100
ChShift=0.16
Unit=
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
```

Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=40
Reference2=200
CalDate=22/05/19 09:04

[Ch13]
Name=LSN_POR
Producer=MChProc
Formula=1.058210915*Exp(-0.001957069*{ch11}*Log(10))*100
ChShift=0.37
Unit=
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=40
Reference2=200
CalDate=22/05/19 09:04

```
[Description]
ToolName = NWMO-GO4-GRA-DEN
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,GO4,173205,
Sub2 = Nuclear,GRA,5602,MULTICH
Sub3 = Nuclear,DEN,6366_Q1246,MULTICH

[Default]
TimeSamplingRate=1000
DepthSamplingRate=0.05

[MultiCh]
NbCh =23
ToolLength = 2.922

[ToolId]
GRA = 16
DEN = 27

[GRA.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[DEN.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

; GO4 channels ------------------------

; GRA channels ------------------------

[Ch1]
Name=Time
Producer=Tool.GRA.SYSTEMSTATUS
ChShift=2.02
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch2]
Name=TCPU
Producer=Tool.GRA.SYSTEMSTATUS
```

```
ChShift=2.045
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch3]
Name=EHT
Producer=Tool.GRA.CHANNELS
ChShift=2.02
Unit=Volts
Offset=0
DataType=word
CalA=-4.14414
CalB=0
CalibrationEnable=yes
NumberFormat=%5.0f
DisplayEnable=no
Reference1=0
Reference2=-1127
CalDate=03/10/12 07:58

[Ch4]
Name=COUNT
Producer=Tool.GRA.CHANNELS
ChShift=2.015
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch5]
Name=GR
Producer=MChProc
Formula={ch4}/{ch1}
ChShift=2.02
Unit=CPS
CalA=1
CalB=0
CalibrationEnable=yes
```

```
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=0
Reference2=1
CalDate=23/03/12 15:52

; DEN channels ------------------------

[Ch6]
Name=Time
Producer=Tool.DEN.SYSTEMSTATUS
ChShift=0
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch7]
Name=TCPU
Producer=Tool.DEN.SYSTEMSTATUS
ChShift=0
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch8]
Name=MOT
```

```
Producer=Tool.DEN.SYSTEMSTATUS
ChShift=0
Unit=
Offset=6
DataType=byte
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no
QCLow=1.5
QCHigh=2.5
QCLowRangeColor=5
QCMedRangeColor=5
QCHighRangeColor=3
QCLowRangeText=OPENING
QCMedRangeText=CLOSING
QCHighRangeText=IDLE
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch9]
Name=HV
Producer=Tool.DEN.CHANNELS
ChShift=0
Unit=Volts
Offset=0
DataType=WORD
CalA=4.87465
CalB=1.53203
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch10]
Name=SSDCNT
Producer=Tool.DEN.CHANNELS
ChShift=0.171
Unit=counts
Offset=2
DataType=DWORD
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no
```

```
[Ch11]
Name=LSDCNT
Producer=Tool.DEN.CHANNELS
ChShift=0.246
Unit=counts
Offset=6
DataType=DWORD
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch12]
Name=CALCNT
Producer=Tool.DEN.CHANNELS
ChShift=0.437
Unit=counts
Offset=10
DataType=DWORD
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch13]
Name=CALCPS
Producer=MChProc
Formula={ch12}/{ch6}
ChShift=0
Unit=cps
CalibrationEnable=no
CalibrationType=
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

[Ch14]
Name=CAL
Producer=MChProc
Formula=(-1.2E-09*{ch13}*{ch13}+0.000804*{ch13}+2.66215849)
ChShift=0.437
Unit=cm
CalA=0.974155
CalB=-3.96451
CalibrationEnable=yes
```

```
Reference1=10.16
Reference2=25.4
CalDate=11/06/18 16:04
NumberFormat=%6.1f
DisplayEnable=yes
PenColor=0
PenStyle=solid
PenWidth=2
Left=0
Right=20
Low=0
High=50
GridEnable=yes
Grid=5
NbDecade=1
ReverseScale=no
Mode=Linear

[Ch15]
Name=SSDCPS
Producer=MChProc
Formula={ch10}/{ch6}
ChShift=0.171
Unit=cps
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=yes

[Ch16]
Name=RHOSSD
Producer=MChProc
Formula=if({ch15}>0,ln({ch15}),0)
ChShift=0.171
Unit=g/cc
CalibrationEnable=yes
CalA=-1.5717
CalB=15.759
Reference1=1.26
Reference2=2.6
NumberFormat=%6.2f
DisplayEnable=yes
PenColor=ff8000
PenStyle=solid
PenWidth=2
Left=40
Right=70
```

```
Low=1
High=3
GridEnable=no
Grid=10
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1
CalDate=11/06/18 16:04

[Ch17]
Name=LSDCPS
Producer=MChProc
Formula={ch11}/{ch6}
ChShift=0.246
Unit=cps
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=yes

[Ch18]
Name=RHOLSD
Producer=MChProc
Formula=if({ch17}>0,ln({ch17}),0)
ChShift=0.246
Unit=g/cc
CalibrationEnable=yes
CalA=-0.4659
CalB=5.1428
Reference1=1.26
Reference2=2.6
NumberFormat=%6.2f
DisplayEnable=yes
PenColor=ff
PenStyle=solid
PenWidth=3
Left=40
Right=70
Low=1
High=3
GridEnable=yes
Grid=0.2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=8
```

```
CalDate=11/06/18 16:04

[Ch19]
Name=RHOB
Producer=MChProc
Formula=((0.77 * {ch18}) +(0.228 * {ch16}))
ChShift=0.1575
Unit=g/cc
CalibrationEnable=no
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
DisplayEnable=yes
PenColor=40ff00
PenStyle=solid
PenWidth=4
Left=70
Right=100
Low=1
High=3
GridEnable=no
Grid=0.2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1

[Ch20]
Name=DRHO
Producer=MChProc
Formula={ch19}-{ch18}
ChShift=0.1575
Unit=g/cc
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

; GO4 channels calibrations ------------------------

; GRA channels calibrations ------------------------

; DEN channels calibrations ------------------------

[Process]
```

```
Process1 = Processor,Start,mch\MChProc.exe
Process2 = Browser,Start,mch\MChCurve.exe
Process3 = Browser,Start,mch\MChNum.exe

[MChProc]
Minimized=yes

[MChCurve]
DepthScale=100
GridSpacing=0.5
XOffset=733
ForceTimeMode=yes
YSize=664
DepthColLeft=0.3
XSize=811
DepthSpacing=5
DepthColRight=0.40
Minimized=no
YOffset=58
Grid=yes

[MChNum]
NumDisplay1=Ch5
NbNumDisplay=4
NumDisplay2=Ch14
NumDisplay3=Ch19
NumDisplay4=Ch20
LedDisplay1=Ch8
NbLedDisplay=1
XOffset=582
YOffset=445
XSize=304
YSize=300
Minimized=no
```

```
[Description]
ToolName=2PCA Caliper S/N: 2649
DriverName=MULTICH

;5-12-06 auto voltage,recip.ch, patcher ind. pls x
;6-23 caliper LED x
;5-30-07 no Dc channel pls x
;1-17-08 std adapter config pls hdw test
;7-01-08 created from 2caa pls
;7-11-08 verified 4mxa tel set pls
;7-23-08 review and approve jrs
;5-05-09 operating and cal voltage rev pls
; ***********************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
;Process5=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

; ***********************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=500
DepthSamplingRate=0.05

; ***********************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=50
Current=250
ToolTopNominalVoltage=54
ToolTopNominalCurrent=80
AutoAdjust=yes
VoltMeterYellow=50
VoltMeterGreen=70
VoltMeterRed=100
AmpMeterYellow=25
AmpMeterGreen=85
```

```
AmpMeterRed=100

[Patcher]
;negative voltage
Coupler=inductive
PowerZero=WL1
TPos=WLArm

; ****************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=2
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Gain=X1
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=15872
NegativePulseDiscriminatorLevel=-16256

[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
```

```
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=32767
NegativePulseDiscriminatorLevel=-2944

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=32767
NegativePulseDiscriminatorLevel=-2816


; ***************************************************************
; Caliper
;
[Caliper]
Caliper=yes
WarnBeforePowerOn=yes
OpenVoltage=60
OpenCurrent=250
OpenTime=90
RestorePowerWhenCaliperOpen=yes
CloseVoltage=60
CloseCurrent=250
CloseTime=90
RestorePowerWhenCaliperClosed=no

[CaliperOpenPatcher]
;negative voltage
Coupler=inductive
PowerZero=WL1
TPos=WLArm

[CaliperClosePatcher]
;positive power
Coupler=inductive
TNeg=WL1
```

```
PowerZero=WLArm


; ************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=5
NbRawCh=4
NbProcessedCh=1
ToolLength=1.95


[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=yes
CalibrationEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
```

```
NumberFormat=%5.3f
DisplayedName=Time
Low=0
High=1
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=0
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.count
Producer=Tool
ChShift=0.273
Unit=counts
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
```

```
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Caliper
Producer=MChProc
ChShift=0.55
Unit=cm
DataType=double
CalA=0.00911242
CalB=-14.9211
Reference1=10.2
Reference2=15.2
NumberFormat=%6.2f
PenColor=ff
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
High=15
GridEnable=yes
Grid=2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
CalDate=11/03/21 13:18
QCLow=1
QCHigh=150
QCInRangeColor=1
QCOutRangeColor=2
QCInRangeText=Open
QCOutRangeText=Red = Opening
DisplayedName=Caliper
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Red = Opening
QCMedRangeText=Open
QCHighRangeText=Red = Opening
QCLowRangeBeep=no
QCMedRangeBeep=no
```

```
QCHighRangeBeep=no

; ****************************************************************
; Data browsers default settings
;

[MChNum]
NbLedDisplay=1
LedDisplay1=Ch5
XOffset=464
YOffset=334
XSize=304
YSize=234
Minimized=no
NbNumDisplay=2
NumDisplay1=Ch5
NumDisplay2=Ch2

[MChCurve]
XOffset=285
YOffset=0
XSize=857
YSize=1026
Minimized=no
DepthScale=1000
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
DepthColLeft=0.3
DepthColRight=0.40


[RecDebug]
XOffset=229
YOffset=251
XSize=609
YSize=555
Minimized=no

[MChProc]
XOffset=1005
YOffset=283
XSize=302
YSize=145
Minimized=no
```

```
[Description]
ToolName=2PCA-F Caliper S/N: 4354
DriverName=MULTICH

;5-12-06 auto voltage,recip.ch, patcher ind. pls x
;6-23 caliper LED x
;5-30-07 no Dc channel pls x
;1-17-08 std adapter config pls hdw test
;7-01-08 created from 2caa pls
;7-11-08 verified 4mxa tel set pls
;7-23-08 review and approve jrs
;5-05-09 operating and cal voltage rev pls
; ************************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
;Process5=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

; ************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=500
DepthSamplingRate=0.05

; ************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=50
Current=250
ToolTopNominalVoltage=54
ToolTopNominalCurrent=80
AutoAdjust=yes
VoltMeterYellow=50
VoltMeterGreen=70
VoltMeterRed=100
AmpMeterYellow=25
AmpMeterGreen=85
```

```
AmpMeterRed=100

[Patcher]
;negative voltage
Coupler=inductive
PowerZero=WL1
TPos=WLArm

; ************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Gain=X1
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=15872
NegativePulseDiscriminatorLevel=-16256

[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
```

```
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=32767
NegativePulseDiscriminatorLevel=-2944

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=15871
NegativePulseDiscriminatorLevel=-2816


; ***************************************************************
; Caliper
;
[Caliper]
Caliper=yes
WarnBeforePowerOn=yes
OpenVoltage=60
OpenCurrent=250
OpenTime=90
RestorePowerWhenCaliperOpen=yes
CloseVoltage=60
CloseCurrent=250
CloseTime=90
RestorePowerWhenCaliperClosed=no

[CaliperOpenPatcher]
;negative voltage
Coupler=inductive
PowerZero=WL1
TPos=WLArm

[CaliperClosePatcher]
;positive power
Coupler=inductive
TNeg=WL1
```

```
PowerZero=WLArm


; ***************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=5
NbRawCh=4
NbProcessedCh=1
ToolLength=1.95


[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
```

```
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.count
Producer=Tool
ChShift=0.273
Unit=counts
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Caliper
Producer=MChProc
ChShift=0.55
Unit=cm
DataType=double
CalA=0.00888666
CalB=-26.3051
Reference1=10.2
Reference2=15.2
NumberFormat=%6.2f
PenColor=ff
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=5
```

```
High=15
GridEnable=yes
Grid=4
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
CalDate=16/03/21 08:55
QCLow=1
QCHigh=150
QCInRangeColor=1
QCOutRangeColor=2
QCInRangeText=Open
QCOutRangeText=Red = Opening
DisplayedName=Caliper
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Red = Opening
QCMedRangeText=Open
QCHighRangeText=Red = Opening
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

; **************************************************************
; Data browsers default settings
;

[MChNum]
NbLedDisplay=1
LedDisplay1=Ch5
XOffset=351
YOffset=595
XSize=304
YSize=201
Minimized=no
NumDisplay1=Ch5
NbNumDisplay=1

[MChCurve]
XOffset=1018
YOffset=4
XSize=893
YSize=1026
Minimized=no
DepthScale=500
ForceTimeMode=yes
```

```
DepthSpacing=50
Grid=yes
GridSpacing=5
DepthColLeft=0.3
DepthColRight=0.40


[RecDebug]
XOffset=229
YOffset=251
XSize=609
YSize=555
Minimized=no

[MChProc]
XOffset=368
YOffset=816
XSize=302
YSize=145
Minimized=no
```

```
[Description]
ToolName=2PCA-F Caliper S/N: 5032
DriverName=MULTICH

;5-12-06 auto voltage,recip.ch, patcher ind. pls x
;6-23 caliper LED x
;5-30-07 no Dc channel pls x
;1-17-08 std adapter config pls hdw test
;7-01-08 created from 2caa pls
;7-11-08 verified 4mxa tel set pls
;7-23-08 review and approve jrs
;5-05-09 operating and cal voltage rev pls
; ************************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
;Process5=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

; ************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=500
DepthSamplingRate=0.05

; ************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=50
Current=250
ToolTopNominalVoltage=54
ToolTopNominalCurrent=80
AutoAdjust=yes
VoltMeterYellow=50
VoltMeterGreen=70
VoltMeterRed=100
AmpMeterYellow=25
AmpMeterGreen=85
```

```
AmpMeterRed=100

[Patcher]
;negative voltage
Coupler=inductive
PowerZero=WL1
TPos=WLArm

; ***********************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Gain=X1
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=15872
NegativePulseDiscriminatorLevel=-16256

[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
```

```
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=32767
NegativePulseDiscriminatorLevel=-2944

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=15871
NegativePulseDiscriminatorLevel=-2816


; **************************************************************
; Caliper
;
[Caliper]
Caliper=yes
WarnBeforePowerOn=yes
OpenVoltage=60
OpenCurrent=250
OpenTime=90
RestorePowerWhenCaliperOpen=yes
CloseVoltage=60
CloseCurrent=250
CloseTime=90
RestorePowerWhenCaliperClosed=no

[CaliperOpenPatcher]
;negative voltage
Coupler=inductive
PowerZero=WL1
TPos=WLArm

[CaliperClosePatcher]
;positive power
Coupler=inductive
TNeg=WL1
```

```
PowerZero=WLArm


; ***************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=5
NbRawCh=4
NbProcessedCh=1
ToolLength=1.95


[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
```

```
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.count
Producer=Tool
ChShift=0.273
Unit=counts
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Caliper
Producer=MChProc
ChShift=0.55
Unit=cm
DataType=double
CalA=0.00890299
CalB=-27.0752
Reference1=10.2
Reference2=15.2
NumberFormat=%6.2f
PenColor=0
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
```

```
High=40
GridEnable=yes
Grid=4
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
CalDate=11/03/21 12:37
QCLow=1
QCHigh=150
QCInRangeColor=1
QCOutRangeColor=2
QCInRangeText=Open
QCOutRangeText=Red = Opening
DisplayedName=Caliper
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Red = Opening
QCMedRangeText=Open
QCHighRangeText=Red = Opening
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

; ***************************************************************
; Data browsers default settings
;

[MChNum]
NbLedDisplay=1
LedDisplay1=Ch5
XOffset=319
YOffset=98
XSize=304
YSize=201
Minimized=no
NumDisplay1=Ch5
NbNumDisplay=1

[MChCurve]
XOffset=296
YOffset=0
XSize=698
YSize=1026
Minimized=yes
DepthScale=100
ForceTimeMode=yes
```

```
DepthSpacing=10
Grid=yes
GridSpacing=1
DepthColLeft=0.3
DepthColRight=0.40


[RecDebug]
XOffset=229
YOffset=251
XSize=609
YSize=555
Minimized=no

[MChProc]
XOffset=317
YOffset=323
XSize=302
YSize=145
Minimized=no
```

```
[Description]
ToolName=2PGA Gamma S/N: 2622
DriverName=MULTICH

;
;4-26-06 auto voltage, recip ch, patcher ind pls x
;11-01-06  telemetry settingsn pls
;5-30-07 no recip, CalibrationEnable= update pls
;1-17-08 std adapter config pls
;2-01-08 scales no dtc pls hdw test
;3-13-08 change back to recip to eliminate saturation in high cps situations  jrs
;7-14-08 verify mini,4mxa,4mxc tel set pls
;8-040-8 review and approve jrs
**************************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
;Process5=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=500
DepthSamplingRate=0.025


; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=75
Current=250
ToolTopNominalVoltage=68
ToolTopNominalCurrent=41
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=80
VoltMeterRed=100
```

```
AmpMeterYellow=30
AmpMeterGreen=60
AmpMeterRed=100

[Patcher]
Coupler=Inductive
PowerZero=WLArm
TNeg=WL1

; ****************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=no
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=no

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Description=
Gain=X1
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=3200
NegativePulseDiscriminatorLevel=-5700
```

```
[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=2688
NegativePulseDiscriminatorLevel=-896

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=7808
NegativePulseDiscriminatorLevel=-4597

; ************************************************************
; Caliper
;
[Caliper]
Caliper=no

; ************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=5
NbRawCh=4
NbProcessedCh=1
ToolLength=0.79

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
```

```
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f
DisplayedName=GAM - Time
Low=0
High=1
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff0080
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
```

```
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
Filter=1

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%6.2f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Natrual Gamma
Producer=MChProc
ChShift=0.135
Unit=cps
Offset=15
DataType=double
CalA=1
CalB=0
NumberFormat=%6.2f
Low=0
High=200
NbDecade=1
Mode=Linear
ReverseScale=no
```

```
GridEnable=yes
Grid=10
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff0080
Filter=3
DisplayedName=Gamma
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
;DisplayedName=GR


; ************************************************************
; Data browsers default settings
;

[RecDebug]
XOffset=1
YOffset=147
XSize=810
YSize=689
Minimized=yes

[MChNum]
XOffset=310
YOffset=217
XSize=304
YSize=141
Minimized=no
NbNumDisplay=1
NumDisplay1=Ch5


[MChCurve]
DepthScale=1000
ForceTimeMode=yes
DepthSpacing=50
```

```
Grid=yes
GridSpacing=5
DepthColLeft=0.3
DepthColRight=0.4
XOffset=613
YOffset=2
XSize=834
YSize=975
Minimized=no

[MChProc]
XOffset=308
YOffset=371
XSize=302
YSize=145
Minimized=no
```

```
[Description]
ToolName=2PIA 0-100ms for Matrix
DriverName=MULTICH

;4-28-06 auto voltage,recip.ch patcher ind. pls x
;6-05-07 no DC ch ps
[Process]
Process1=mch\MchProc.exe
Process2=mch\Mchnum.exe
Process3=mch\MchCurve.exe
;Process5=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart


[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

[Default]
TimeSamplingRate=1000
DepthSamplingRate=.05

[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=no
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=no

[ToolAdapterConfig0]
Name=Winch 305M 1/10" single
Gain=X2
```

```
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=2175
NegativePulseDiscriminatorLevel=-768

[ToolAdapterConfig1]
Name=Winch 500M 1/8" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5376
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig2]
Name=Winch 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=3584
NegativePulseDiscriminatorLevel=-16256

[PowerSupply]
Voltage=65
Current=250
ToolTopNominalVoltage=75
ToolTopNominalCurrent=60
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=80
VoltMeterRed=150
AmpMeterYellow=25
AmpMeterGreen=50
AmpMeterRed=80

[Patcher]
;Negative Voltage
Coupler=inductive
```

```
TPos=WLArm
PowerZero=WL1


[Caliper]
Caliper=no
CaliperWaitTime=0

[MultiCh]
NbCh=6
NbRawCh=4
NbProcessedCh=2
ToolLength=1.73
TimeAvailable=no
TimeDataType=word
EnableSpeedCh=yes

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=M/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3
Reference1=1
Reference2=0
CalDate=05/12/05 12:37

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=Time
```

Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Cond
Producer=MCHProc
ChShift=0.70
Unit=mS
Offset=
DataType=double
CalA=0.0328332
CalB=-412.661
Reference1=0

```
Reference2=93
NumberFormat=%6.2f
PenColor=ff
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
High=100
GridEnable=yes
Grid=10
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
DisplayedName=Cond
CalDate=12/01/06 14:41

[Ch6]
DisplayEnable=yes
CalibrationEnable=no
Formula=1 / {Ch5} * 1000
Name=Ind Res
Producer=MCHProc
ChShift=0.70
Unit=Ohm-m
Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
PenColor=a00000
PenStyle=solid
PenWidth=2
Left=0
Right=30
Low=0
High=50
GridEnable=yes
Grid=10
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
DisplayedName=Ind Res
```

```
[MChNum]
Minimized=no
XOffset=502
YOffset=14
XSize=230
YSize=134
NumDisplay1=Ch5
NumDisplay2=Ch6
NbNumDisplay=2


[MChCurve]
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
XOffset=219
YOffset=136
XSize=797
YSize=631
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4

[MSIProc]
XOffset=218
YOffset=202
XSize=228
YSize=115
Minimized=no

[RecDebug]
XOffset=0
YOffset=0
XSize=570
YSize=514
Minimized=yes


[MChProc]
XOffset=0
YOffset=0
XSize=228
YSize=122
Minimized=yes
```

```
[Description]
ToolName=2PIA 0-1000ms for Matrix
DriverName=MULTICH

;4-27-06 auto voltage,recip.ch patcher ind. pls x
;11-01-06 telmetry update ps
;6-05-07 no DC ch update PS

[Process]
Process1=mch\MchProc.exe
Process2=mch\Mchnum.exe
Process3=mch\MchCurve.exe
;Process5=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

[Default]
TimeSamplingRate=1000
DepthSamplingRate=.05

[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=2
Gain=x0
PositivePulseEnable=yes
NegativePulseEnable=no
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=no


[ToolAdapterConfig0]
```

```
Name=Winch 305M 1/10" single
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5632
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig1]
Name=Winch 500M 1/10" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5504
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig2]
Name=Winch 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=3712
NegativePulseDiscriminatorLevel=-16256


[PowerSupply]
Voltage=75
Current=250
ToolTopNominalVoltage=75
ToolTopNominalCurrent=60
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=80
VoltMeterRed=150
AmpMeterYellow=25
AmpMeterGreen=50
AmpMeterRed=80
```

```
[Patcher]
;Positive Voltage
Coupler=inductive
PowerZero=WLArm
TNeg=WL1

[Caliper]
Caliper=no
CaliperWaitTime=0

[MultiCh]
NbCh=6
NbRawCh=4
NbProcessedCh=2
ToolLength=1.73
TimeAvailable=no
TimeDataType=word
EnableSpeedCh=yes

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=M/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3
Reference1=1
Reference2=0
CalDate=05/12/05 12:37

[Ch2]
DisplayEnable=no
```

```
CalibrationEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Cond
Producer=MCHProc
ChShift=0.70
Unit=mS
Offset=
DataType=double
CalA=0.262149
```

```
CalB=-3027.15
Reference1=0
Reference2=458
NumberFormat=%6.2f
PenColor=ff
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
High=1000
GridEnable=yes
Grid=100
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
CalDate=12/01/06 14:38
DisplayedName=Cond


[Ch6]
DisplayEnable=yes
CalibrationEnable=no
Formula=1 / {Ch5} * 1000
Name=Ind Res
Producer=MCHProc
ChShift=0.70
Unit=Ohm-m
Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
PenColor=a00000
PenStyle=solid
PenWidth=2
Left=0
Right=30
Low=0
High=50
GridEnable=yes
Grid=5
NbDecade=1
ReverseScale=no
Mode=Linear
```

```
Filter=2
;DisplayedName=Ind Res

[MChNum]
Minimized=no
XOffset=413
YOffset=23
XSize=230
YSize=134
NumDisplay1=Ch5
NumDisplay2=Ch6
NbNumDisplay=2


[MChCurve]
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
XOffset=219
YOffset=167
XSize=724
YSize=581
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4

[MSIProc]
XOffset=218
YOffset=202
XSize=228
YSize=115
Minimized=no

[RecDebug]
XOffset=0
YOffset=0
XSize=570
YSize=514
Minimized=yes

[MChProc]
XOffset=0
YOffset=0
XSize=228
YSize=122
Minimized=no
```

```
[Description]
ToolName=2PIA 0-10000ms for Matrix  *** Set switch in tool! ***
DriverName=MULTICH

;5-17-06 auto voltage,recip.ch patcher ind., ch7 correction pls
;11-01-06 telemtry update ps
;6-05-07 no DC ch update pls

[Process]
Process1=mch\MchProc.exe
Process2=mch\Mchnum.exe
Process3=mch\MchCurve.exe
;Process5=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

[Default]
TimeSamplingRate=1000
DepthSamplingRate=.05

[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=2
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=no
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=no

[ToolAdapterConfig0]
Name=Winch 305M 1/8" single
```

```
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=2176
NegativePulseDiscriminatorLevel=-768

[ToolAdapterConfig1]
Name=Winch 500M 1/8" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5376
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig2]
Name=Winch 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=2176
NegativePulseDiscriminatorLevel=-768

[PowerSupply]
Voltage=75
Current=250
ToolTopNominalVoltage=75
ToolTopNominalCurrent=60
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=80
VoltMeterRed=150
AmpMeterYellow=25
AmpMeterGreen=50
AmpMeterRed=80

[Patcher]
;Negative Voltage
```

```
Coupler=inductive
TPos=WLArm
PowerZero=WL1

[Caliper]
Caliper=no
CaliperWaitTime=0

[MultiCh]
NbCh=6
NbRawCh=4
NbProcessedCh=2
ToolLength=1.73
TimeAvailable=no
TimeDataType=word
EnableSpeedCh=yes

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=M/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3
Reference1=1
Reference2=0
CalDate=05/12/05 12:37

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=Time
```

```
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Cond
Producer=MCHProc
ChShift=0.70
Unit=mS
Offset=
DataType=double
CalA=4.00722
CalB=-51560.9
Reference1=0
```

```
Reference2=10000
NumberFormat=%6.2f
PenColor=400040
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
High=10000
GridEnable=yes
Grid=1000
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
CalDate=05/12/05 17:21

[Ch6]
DisplayEnable=yes
CalibrationEnable=no
Formula=1 / {Ch5} * 1000
Name=Ind Res
Producer=MCHProc
ChShift=0.70
Unit=Ohm-m
Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
PenColor=a00000
PenStyle=solid
PenWidth=2
Left=0
Right=30
Low=0
High=50
GridEnable=yes
Grid=5
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2

[MChNum]
Minimized=no
```

```
XOffset=411
YOffset=137
XSize=230
YSize=134
NumDisplay1=Ch5
NumDisplay2=Ch6
NbNumDisplay=2


[MChCurve]
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
XOffset=219
YOffset=33
XSize=580
YSize=581
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4

[MSIProc]
XOffset=218
YOffset=202
XSize=228
YSize=115
Minimized=no

[RecDebug]
XOffset=0
YOffset=0
XSize=570
YSize=514
Minimized=yes
```

```
[Description]
ToolName=2PIA Conductivity S/N: 2618 (0-1000ms)
DriverName=MULTICH

;4-27-06 auto voltage,recip.ch patcher ind. pls x
;11-01-06 telmetry update ps
;6-05-07 no DC ch update PS

[Process]
Process1=mch\MchProc.exe
Process2=mch\Mchnum.exe
Process3=mch\MchCurve.exe
;Process5=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

[Default]
TimeSamplingRate=1000
DepthSamplingRate=.05

[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=2
Gain=x0
PositivePulseEnable=yes
NegativePulseEnable=no
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=no


[ToolAdapterConfig0]
```

```
Name=Winch 305M 1/10" single
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5632
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig1]
Name=Winch 500M 1/10" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5504
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig2]
Name=Winch 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=3712
NegativePulseDiscriminatorLevel=-16256


[PowerSupply]
Voltage=75
Current=250
ToolTopNominalVoltage=75
ToolTopNominalCurrent=60
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=80
VoltMeterRed=150
AmpMeterYellow=25
AmpMeterGreen=50
AmpMeterRed=80
```

```
[Patcher]
;Positive Voltage
Coupler=inductive
PowerZero=WLArm
TNeg=WL1

[Caliper]
Caliper=no
CaliperWaitTime=0

[MultiCh]
NbCh=6
NbRawCh=4
NbProcessedCh=2
ToolLength=1.73
TimeAvailable=no
TimeDataType=word
EnableSpeedCh=yes

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=COND - Speed
Producer=Logger
ChShift=0
Unit=M/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3
Reference1=1
Reference2=0
CalDate=05/12/05 12:37

[Ch2]
DisplayEnable=no
```

```
CalibrationEnable=no
Name=COND - Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=COND - Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=COND - Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Apparent Conductivity
Producer=MCHProc
ChShift=0.72
Unit=mS/m
Offset=
DataType=double
CalA=0.609971
```

```
CalB=-7855.48
Reference1=0
Reference2=1752
NumberFormat=%6.2f
PenColor=ff
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=-100
High=2000
GridEnable=yes
Grid=100
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
CalDate=11/03/21 15:46
DisplayedName=Apparent Conductivity
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no


[Ch6]
DisplayEnable=yes
CalibrationEnable=no
Formula=1 / {Ch5} * 1000
Name=COND - Ind Res
Producer=MCHProc
ChShift=0.7
Unit=Ohm-m
Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
PenColor=a00000
```

PenStyle=solid
PenWidth=2
Left=0
Right=30
Low=-100
High=100
GridEnable=yes
Grid=5
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
DisplayedName=COND - Ind Res
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
;DisplayedName=COND - Ind Res

[MChNum]
Minimized=no
XOffset=296
YOffset=330
XSize=304
YSize=174
NumDisplay1=Ch5
NumDisplay2=Ch6
NbNumDisplay=2

[MChCurve]
DepthScale=1000
ForceTimeMode=yes
DepthSpacing=0.025
Grid=yes
GridSpacing=0.0025
XOffset=579
YOffset=0
XSize=1047
YSize=1000
Minimized=no

```
DepthColLeft=0.3
DepthColRight=0.4

[MSIProc]
XOffset=218
YOffset=202
XSize=228
YSize=115
Minimized=no

[RecDebug]
XOffset=0
YOffset=0
XSize=570
YSize=514
Minimized=yes

[MChProc]
XOffset=295
YOffset=148
XSize=302
YSize=145
Minimized=no
```

```
[Description]
ToolName=2PIA + 2PGA 0-100ms, Gamma for Matrix
DriverName=MULTICH

;5-09-06 auto voltage,recip.ch patcher ind. pls x
;11-01-06 telmetry update ps
;6-05-07 no recip, DC ch update pls
;2-08-08 std adapter config pls
;8-04-08 review and approve jrs
;10-29-08 changed Gamma - Induction ch logic divisor to test for 65535 count, fixed
Ind disc.  pls

;**************************************************************
; Data browsers
;
[Process]
Process1=mch\MchProc.exe
Process2=mch\Mchnum.exe
Process3=mch\MchCurve.exe
;Process5=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

[Default]
TimeSamplingRate=1000
DepthSamplingRate=.05
TimeSamplingRateMin=100
TimeSamplingRateMax=2000

[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
```

```
DefaultConfig=1
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=ini Winch 200-300M 1/8,1/10" single
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=3072
NegativePulseDiscriminatorLevel=-3328

[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=6143
NegativePulseDiscriminatorLevel=-5376

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=4864
NegativePulseDiscriminatorLevel=-4520

[PowerSupply]
Voltage=85.5
Current=250
ToolTopNominalVoltage=82
ToolTopNominalCurrent=70
AutoAdjust=yes
```

```
VoltMeterLabel=50
VoltMeterYellow=60
VoltMeterGreen=100
VoltMeterRed=120
AmpMeterLabel=50
AmpMeterYellow=60
AmpMeterGreen=90
AmpMeterRed=100

[Patcher]
;Negative Voltage
Coupler=inductive
TPos=WLArm
PowerZero=WL1


[Caliper]
Caliper=no
CaliperWaitTime=0

[MultiCh]
NbCh=9
NbRawCh=6
NbProcessedCh=3
ToolLength=2.36
TimeAvailable=no
TimeDataType=word
EnableSpeedCh=yes

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=M/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
```

```
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3
Reference1=1
Reference2=0
CalDate=05/12/05 12:37

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.count
Producer=Tool
ChShift=0
Unit=count
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch5]
```

```
DisplayEnable=no
CalibrationEnable=no
Name=Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch6]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch7]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch3} > 65534, ({Ch3}-1)/{Ch5},{Ch3}/{Ch2})
;Formula=if({Ch5} > 0, ({Ch3}-1)/{Ch5},0)
Name=Cond
Producer=MCHProc
ChShift=0.7
Unit=mS
Offset=
DataType=double
CalA=0.0372671
CalB=-479.516
Reference1=0
Reference2=93
NumberFormat=%6.2f
PenColor=400040
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
High=100
```

```
GridEnable=yes
Grid=5
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
DisplayedName=Cond
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch8]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 65534, ({Ch4}-1)/{Ch6},{Ch4}/{Ch2})
;Formula=if({Ch2} > 0, ({Ch4})/{Ch2},0)
Name=Gamma
Producer=MCHProc
ChShift=1.695
Unit=cps
;Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=100
NumberFormat=%6.2f
PenColor=4000
PenStyle=solid
PenWidth=2
Left=0
Right=30
Low=0
High=200
GridEnable=yes
Grid=20
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=3
```

```
[Ch9]
DisplayEnable=yes
CalibrationEnable=no
Formula=1 / {Ch7} * 1000
Name=Ind Res
Producer=MCHProc
ChShift=0.70
Unit=ohm-m
;Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
PenColor=ff8000
PenStyle=dash
PenWidth=2
Left=0
Right=30
Low=0
High=20
GridEnable=no
Grid=10
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1

[MChNum]
Minimized=no
XOffset=850
YOffset=39
XSize=230
YSize=162
NumDisplay1=Ch7
NumDisplay2=Ch8
NumDisplay3=Ch9
NbNumDisplay=3
NumDisplay4=Ch3
NumDisplay5=Ch4


[MChCurve]
DepthScale=200
ForceTimeMode=yes
DepthSpacing=20
```

```
Grid=yes
GridSpacing=2
XOffset=226
YOffset=64
XSize=580
YSize=581
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4
[MSIProc]
XOffset=218
YOffset=202
XSize=228
YSize=115
Minimized=no

[RecDebug]
XOffset=0
YOffset=0
XSize=570
YSize=514
Minimized=yes
```

```
[Description]
ToolName=2PIA + 2PGA 0-1000ms, Gamma for Matrix
DriverName=MULTICH

;5-09-06 auto voltage,recip.ch patcher ind. pls x
;11-01-06 telemetry update ps
;6-05-07 no recip, DC ch update pls
;2-08-08 std adapter config pls
;10-29-08 changed Gamma - Induction ch logic divisor to test for 65535 count, fixed
Ind disc.  pls
; *************************************************************
; Data browsers
;
[Process]
Process1=mch\MchProc.exe
Process2=mch\Mchnum.exe
Process3=mch\MchCurve.exe
;Process5=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

[Default]
TimeSamplingRate=1000
DepthSamplingRate=.05
TimeSamplingRateMin=100
TimeSamplingRateMax=2000

[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
```

```
PositivePulseEnable=yes
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=8704
NegativePulseDiscriminatorLevel=-10112

[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=1664
NegativePulseDiscriminatorLevel=-2304

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=4864
NegativePulseDiscriminatorLevel=-4480

[PowerSupply]
Voltage=83.5
Current=250
ToolTopNominalVoltage=82
ToolTopNominalCurrent=75
AutoAdjust=yes
VoltMeterLabel=50
VoltMeterYellow=60
```

```
VoltMeterGreen=100
VoltMeterRed=120
AmpMeterLabel=50
AmpMeterYellow=60
AmpMeterGreen=90
AmpMeterRed=100

[Patcher]
;Positive Voltage
Coupler=inductive
PowerZero=WLArm
TNeg=WL1

[Caliper]
Caliper=no
CaliperWaitTime=0

[MultiCh]
NbCh=9
NbRawCh=6
NbProcessedCh=3
ToolLength=2.36
TimeAvailable=no
TimeDataType=word
EnableSpeedCh=yes

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=M/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
```

```
Filter=3
Reference1=1
Reference2=0
CalDate=05/12/05 12:37

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.count
Producer=Tool
ChShift=0
Unit=count
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch5]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.dt
```

```
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch6]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch7]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch3} > 65534, ({Ch3}-1)/{Ch5},{Ch3}/{Ch2})
Name=Cond
Producer=MCHProc
ChShift=0.7
Unit=mS
;Offset=
DataType=double
CalA=0.358082
CalB=-4601.8
Reference1=0
Reference2=463
NumberFormat=%6.2f
PenColor=400040
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
High=1000
GridEnable=yes
Grid=50
NbDecade=1
ReverseScale=no
```

```
Mode=Linear
Filter=2
DisplayedName=Cond
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
CalDate=23/03/21 10:41

[Ch8]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 65534, ({Ch4}-1)/{Ch6},{Ch4}/{Ch2})
Name=Gamma
Producer=MCHProc
ChShift=1.695
Unit=cps
;Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=100
NumberFormat=%6.2f
PenColor=4000
PenStyle=solid
PenWidth=2
Left=0
Right=30
Low=0
High=200
GridEnable=yes
Grid=20
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=3

[Ch9]
DisplayEnable=yes
CalibrationEnable=no
```

```
Formula=1 / {Ch7} * 1000
Name=Ind Res
Producer=MCHProc
ChShift=0.70
Unit=ohm-m
;Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
PenColor=ff8000
PenStyle=dash
PenWidth=2
Left=0
Right=30
Low=0
High=20
GridEnable=no
Grid=10
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1

[MChNum]
Minimized=no
XOffset=331
YOffset=93
XSize=304
YSize=240
NumDisplay1=Ch7
NumDisplay2=Ch8
NumDisplay3=Ch3
NbNumDisplay=4
NumDisplay4=Ch4


[MChCurve]
DepthScale=200
ForceTimeMode=yes
DepthSpacing=20
Grid=yes
GridSpacing=2
XOffset=646
YOffset=16
XSize=1251
```

```
YSize=1004
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4

[MSIProc]
XOffset=218
YOffset=202
XSize=228
YSize=115
Minimized=no

[RecDebug]
XOffset=0
YOffset=0
XSize=570
YSize=514
Minimized=yes

[MChProc]
XOffset=299
YOffset=809
XSize=302
YSize=145
Minimized=yes
```

```
[Description]
ToolName=2SNA-S Spectral Gamma S/N: 4116
DriverName=2SNA1000S

;
;5-09-06 patcher Cin=WLArm pls x
;6-05-07 CalibrationEnable= update pls

; **************************************************************
; Data browsers
;
[Process]
Process1=sna1000s\sna1000sproc.exe
Process2=sna1000s\sna1000spectra.exe
Process3=mch\mchnum.exe
Process4=mch\mchcurve.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,Start
; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRateMin=1000
TimeSamplingRate=1000
TimeSamplingRateMax=5000
DepthSamplingRate=0.1
SpectrumSize=512

; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=121
Current=200
ToolTopNominalVoltage=105
ToolTopNominalCurrent=125
AutoAdjust=yes
VoltMeterYellow=105
VoltMeterGreen=135
VoltMeterRed=150
AmpMeterYellow=60
AmpMeterGreen=170
AmpMeterRed=200
```

```
[Patcher]
Coupler=Capacitive
PowerFilter=WL1
PowerZero=WLArm
CIn=WLArm
COut=WL1

; **************************************************************
; Tool telemetry protocol
;
[Protocol]
NbOfProtocol=1
SerialMode=Asynchronous
LengthMode=VariableWord
LengthAddress=0
LengthMultiplier=1
LengthOffset=0
LengthMax=2200
ChecksumMode=none
TimeOut1=800
TimeOut2=200
SamplingCmdLength=1
SamplingCmd=255

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=MSIFFSK
NbConfig=1
DefaultConfig=0
DataBits=8
StopBits=1
Parity=even

[ToolAdapterConfig0]
Name=Winch 500M 1/8" single
Description=
TxAmplitude=14804


; **************************************************************
; Caliper
;
[Caliper]
Caliper=no
```

```
; ****************************************************************
; Tool channels description & calibration
;

[SNA1000S]
Multiplier=3000
Offset=0
IFG=no

[MultiCh]
NbCh=13
NbRawCh=13
NbProcessedCh=0
ToolLength=1.81

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0.0
Unit=m/min
NumberFormat=%6.2f
PenColor=0
PenStyle=solid
PenWidth=1
Left=0
Right=30
Low=0
High=10
GridEnable=yes
Grid=2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1
DisplayedName=Speed

[Ch2]
DisplayEnable=yes
CalibrationEnable=no
Name=SP
Producer=Tool
ChShift=0.13
Unit=mV
Offset=32
DataType=mgxiifloat
Low=-100
```

High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=20
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=0
Filter=1
DisplayedName=SP

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Temp
Producer=Tool
ChShift=0.58
Unit=degC
Offset=62
DataType=mgxiifloat

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=HV
Producer=Tool
ChShift=0.58
Unit=Volts
Offset=74
DataType=mgxiifloat

[Ch5]
DisplayEnable=no
CalibrationEnable=no
Name=Resistance
Producer=SNA1000SProc
ChShift=0.13
Unit=Ohms
CalA=1
CalB=0
NumberFormat=%5.1f
Reference1=1
Reference2=0
CalDate=13/10/05 04:25

```
[Ch6]
DisplayEnable=yes
CalibrationEnable=yes
Name=GR total
DisplayName=Total Gamma
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=200
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=20
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=1
DisplayedName=GR total

[Ch7]
DisplayEnable=yes
CalibrationEnable=no
Name=K
DisplayName=K
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=2
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=0.2
Left=40
Right=100
PenStyle=solid
PenWidth=2
```

```
PenColor=ff
Filter=1
DisplayedName=K
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch8]
DisplayEnable=yes
CalibrationEnable=no
Name=U
DisplayName=U
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=2
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff0000
Filter=1
DisplayedName=U
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
```

QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch9]
DisplayEnable=yes
CalibrationEnable=no
Name=Th
DisplayName=Th
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=2
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff00
Filter=1
DisplayedName=Th
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch10]
DisplayEnable=no
CalibrationEnable=no
Name=Ch4
DisplayName=
Producer=SNA1000SProc
ChShift=0.58

```
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch11]
DisplayEnable=no
CalibrationEnable=no
Name=Ch5
DisplayName=
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch12]
DisplayEnable=no
CalibrationEnable=no
Name=Voltage
Producer=Tool
ChShift=0.58
Offset=8
DataType=mgxiifloat
Unit=mV
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch13]
DisplayEnable=no
CalibrationEnable=no
Name=Current
Producer=Tool
ChShift=0.13
Offset=20
DataType=mgxiifloat
Unit=mA
CalA=1
CalB=0
NumberFormat=%5.0f


; ****************************************************************
; Data browsers default settings
;
```

```
[SNA1000SProc]
IFG=no
EnableStackAutoReset=yes
StackSize=100
Ch1Name=K
Ch1Lo=1360
Ch1Hi=1560
Ch1Color=ffc8c8
Ch2Name=U
Ch2Lo=1660
Ch2Hi=1860
Ch2Color=c8ffc8
Ch3Name=Th
Ch3Lo=2520
Ch3Hi=2720
Ch3Color=c8c8ff
Ch4Name=Csi
Ch4Lo=600
Ch4Hi=770
Ch4Color=ffc8ff
Ch5Name=Ch5
Ch5Lo=0
Ch5Hi=0
Ch5Color=c8ffff
Ch1Display=yes
Ch2Display=yes
Ch3Display=yes
Ch4Display=no
Ch5Display=no
XOffset=336
YOffset=20
XSize=302
YSize=221
Minimized=no

[SNA1000Spectra]
CountLow=0.1
CountHigh=20
CountScaleAuto=yes
LinearCountScale=no
DisplayRawSpectrum=no
DisplayStackedSpectrum=yes
DisplayEnergyWindows=no
CountGrid=10
DisplayCountGrid=no
XOffset=271
YOffset=281
XSize=843
```

```
YSize=459
Minimized=no

[MChNum]
NbNumDisplay=10
NumDisplay1=Ch3
NumDisplay2=Ch4
NumDisplay3=Ch2
NumDisplay4=Ch5
NumDisplay5=Ch6
NumDisplay6=Ch7
NumDisplay7=Ch8
NumDisplay8=Ch9
NumDisplay9=Ch12
NumDisplay10=Ch13
XOffset=345
YOffset=250
XSize=304
YSize=438
Minimized=no

[MChCurve]
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
XOffset=790
YOffset=7
XSize=576
YSize=699
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4

[RecDebug]
XOffset=206
YOffset=216
XSize=786
YSize=689
Minimized=no
```

```
[Description]
ToolName = MSI_BR_GR5598-IP5579-PL
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,MSI1,MSI-1,
Sub2 = Resistivity,BRIDLE,,
Sub3 = Nuclear,GRA,5598,MULTICH
Sub4 = Resistivity,IP,5579,IP
Sub5 = Misc,PLUG,,

[Default]
ReleaseTime=0
TimeSamplingRate=1000
InjectionTime=50
DepthSamplingRate=0.05

[MultiCh]
NbCh =81
ToolLength = 11.086

[ToolId]
GRA = 16
IP = 22

[GRA.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[IP.ModuleId]
SYSTEMSTATUS = 1
ELOG = 5
IPLIN = 7
IPLOG = 8
IPFW16 = 10
IPFW64 = 11

; MSI1 channels ------------------------

; BRIDLE channels ------------------------

; GRA channels ------------------------

[Ch1]
Name=Time
Producer=Tool.GRA.SYSTEMSTATUS
ChShift=2.269
Unit=sec
Offset=0
```

DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch2]
Name=TCPU
Producer=Tool.GRA.SYSTEMSTATUS
ChShift=2.294
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch3]
Name=EHT
Producer=Tool.GRA.CHANNELS
ChShift=2.269
Unit=Volts
Offset=0
DataType=word
CalA=-3.24249
CalB=0
CalibrationEnable=yes
NumberFormat=%5.0f
DisplayEnable=no
Reference1=0
Reference2=-1285
CalDate=06/05/21 16:50

[Ch4]
Name=COUNT
Producer=Tool.GRA.CHANNELS
ChShift=2.264
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

```
[Ch5]
Name=GR
Producer=MChProc
Formula={ch4}/{ch1}
ChShift=2.269
Unit=CPS
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=0
Reference2=1
CalDate=23/03/12 15:52

; IP channels ------------------------

[Ch6]
Name=Time
DisplayedName=Time
Producer=Tool.IP.SYSTEMSTATUS
Unit=sec
ChShift=0.19
DataType=DWord
Offset=0
CalA=0.001
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%.3f

[Ch7]
Name=TCPU
DisplayedName=TCPU
Producer=Tool.IP.SYSTEMSTATUS
```

Unit='C
ChShift=0.19
DataType=word
Offset=4
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%5.1f

[Ch8]
Name=VSP
DisplayedName=VSP
Producer=Tool.IP.ELOG
Unit=mV
ChShift=1.879
DataType=long
Offset=0
CalA=0.603015
CalB=-8.44221
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%8.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=8000
Grid=20
Left=0
Right=30
ReverseScale=no
GridEnable=no
PenWidth=2
NbDecade=1
Low=-200
Reference1=0
Reference2=120
CalDate=08/03/17 10:39

[Ch9]
Name=VSPR
DisplayedName=VSPR
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.252
DataType=long
Offset=4
CalA=1.21022e-006

```
CalB=-0.227609
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%8.3f
PenStyle=solid
High=20
Mode=Linear
PenColor=ff0000
Grid=0
Left=0
PenWidth=2
ReverseScale=no
GridEnable=no
Right=30
NbDecade=1
Low=0
Reference1=15.734
Reference2=0.574
CalDate=08/03/17 10:39

[Ch10]
Name=I
DisplayedName=I
Producer=Tool.IP.ELOG
Unit=mA
ChShift=0.252
DataType=long
Offset=8
CalA=5.87176e-005
CalB=-0.00517009
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%8.1f
PenStyle=solid
High=600
Mode=Linear
PenColor=ff
Grid=0
Left=0
Right=30
PenWidth=2
ReverseScale=no
GridEnable=no
NbDecade=1
Low=0
Reference1=490
Reference2=0
CalDate=08/03/17 10:39
```

```
[Ch11]
Name=V16
DisplayedName=V16
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.456
DataType=long
Offset=12
CalA=1.19869e-006
CalB=-0.0678421
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%8.3f
Reference1=2.775
Reference2=0.114
CalDate=08/03/17 10:39

[Ch12]
Name=V64
DisplayedName=V64
Producer=Tool.IP.ELOG
Unit=V
ChShift=1.064
DataType=long
Offset=16
CalA=1.29334e-006
CalB=-0.0753723
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%8.3f
Reference1=0.671
Reference2=0.041
CalDate=08/03/17 10:39

[Ch13]
Name=V8
DisplayedName=V8
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.354
DataType=long
Offset=20
CalA=1.21499e-006
CalB=-0.0913257
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%8.3f
```

```
Reference1=5.93
Reference2=0.203
CalDate=08/03/17 10:39

[Ch14]
Name=V32
DisplayedName=V32
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.657
DataType=long
Offset=24
CalA=1.25467e-006
CalB=-0.0705678
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%8.3f
Reference1=1.343
Reference2=0.0655
CalDate=08/03/17 10:39

[Ch15]
Name=Vinj16
DisplayedName=Vinj16
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=4
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch16]
Name=NbWinlin
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.19
DataType=byte
Offset=12
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f
```

```
[Ch17]
Name=Tlin.1
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=Long
Offset=13
CalA=0.0001
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch18]
Name=WLin16.1
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=17
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch19]
Name=Tlin.2
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=25
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch20]
Name=WLin16.2
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=29
CalA=1.0
CalB=0.0
```

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch21]
Name=Tlin.3
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=37
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch22]
Name=WLin16.3
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=41
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch23]
Name=Tlin.4
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=49
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch24]
Name=WLin16.4
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
```

```
DataType=long
Offset=53
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch25]
Name=Tlin.5
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=61
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch26]
Name=WLin16.5
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=65
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch27]
Name=Tlin.6
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=73
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch28]
```

```
Name=WLin16.6
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=77
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch29]
Name=Tlin.7
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=85
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch30]
Name=WLin16.7
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=89
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch31]
Name=Tlin.8
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=97
CalA=0.0001
CalB=0.0
CalibrationEnable=no
```

```
DisplayEnable=no
NumberFormat=%8.3f

[Ch32]
Name=WLin16.8
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=101
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch33]
Name=Tlin.9
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=109
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch34]
Name=WLin16.9
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=113
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch35]
Name=Tlin.10
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
```

Offset=121
CalA=0.0001
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.3f

[Ch36]
Name=WLin16.10
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=125
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch37]
Name=WLin64.1
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=21
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch38]
Name=WLin64.2
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=33
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch39]
Name=WLin64.3

```
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=45
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch40]
Name=WLin64.4
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=57
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch41]
Name=WLin64.5
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=69
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch42]
Name=WLin64.6
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=81
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
```

NumberFormat=%8.0f

[Ch43]
Name=WLin64.7
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=93
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch44]
Name=WLin64.8
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=105
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch45]
Name=WLin64.9
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=117
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch46]
Name=WLin64.10
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=129

CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch47]
Name=Tinj
Producer=Tool.IP.IPLIN
Unit=s
ChShift=0.19
DataType=Word
Offset=0
CalA=0.001
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%g

[Ch48]
Name=TRel
Producer=Tool.IP.IPLIN
Unit=s
ChShift=0.19
DataType=Word
Offset=2
CalA=0.001
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%g

[Ch49]
Name=Vinj64
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=8
CalA=1.0
CalB=0.0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%8.0f

[Ch50]
Name=SPR
DisplayedName=SPR

Producer=MChProc
Unit=Ohm
ChShift=0.253
CalA=1
CalB=0
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=0
Grid=20
Left=0
Right=30
ReverseScale=no
GridEnable=yes
PenWidth=2
NbDecade=1
Formula=1000*{ch9}/{ch10}
Low=0
Reference1=1
Reference2=0
CalDate=08/03/17 10:39

[Ch51]
Name=N16
DisplayedName=N16
Producer=MChProc
Unit=Ohm.m
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=20
Left=40
Right=100
ReverseScale=no
GridEnable=yes
PenWidth=2
NbDecade=1
Formula=5107*{ch11}/{ch10}

```
Low=0
Reference1=100
Reference2=10000
CalDate=06/05/21 16:50

[Ch52]
Name=N64
DisplayedName=N64
Producer=MChProc
Unit=Ohm.m
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff
Grid=0
Left=40
Right=100
ReverseScale=no
GridEnable=no
PenWidth=2
NbDecade=1
Formula=20428*{ch12}/{ch10}
Low=0
Reference1=100
Reference2=10000
CalDate=06/05/21 16:50

[Ch53]
Name=N8
DisplayedName=N8
Producer=MChProc
Unit=Ohm.m
ChShift=0.354
CalA=1
CalB=0
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=800080
```

Grid=0
Left=40
Right=100
ReverseScale=no
GridEnable=no
PenWidth=2
NbDecade=1
Formula=2553*{ch13}/{ch10}
Low=0
Reference1=100
Reference2=10000
CalDate=06/05/21 16:50

[Ch54]
Name=N32
DisplayedName=N32
Producer=MChProc
Unit=Ohm.m
ChShift=0.659
CalA=1.09608
CalB=-4.80423
CalibrationEnable=yes
DisplayEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=80ff
Grid=0
Left=40
Right=100
ReverseScale=no
GridEnable=no
PenWidth=2
NbDecade=1
Formula=10214*{ch14}/{ch10}
Low=0
Reference1=100
Reference2=10000
CalDate=06/05/21 16:50

[Ch55]
Name=IPlin16.1
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff
Grid=0
Left=40
ReverseScale=no
GridEnable=yes
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch18}/{ch15}
Low=0

[Ch56]
Name=IPlin16.2
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch20}/{ch15}
Low=0

[Ch57]
Name=IPlin16.3
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
```

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch22}/{ch15}
Low=0

[Ch58]
Name=IPlin16.4
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch24}/{ch15}
Low=0

[Ch59]
Name=IPlin16.5
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
```

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch26}/{ch15}
Low=0

[Ch60]
Name=IPlin16.6
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch28}/{ch15}
Low=0

[Ch61]
Name=IPlin16.7
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
```

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch30}/{ch15}
Low=0

[Ch62]
Name=IPlin16.8
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch32}/{ch15}
Low=0

[Ch63]
Name=IPlin16.9
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
```

CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch34}/{ch15}
Low=0

[Ch64]
Name=IPlin16.10
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff00
Grid=0
Left=40
ReverseScale=no
GridEnable=no
PenWidth=2
Right=70
NbDecade=5
Formula=1000*{ch36}/{ch15}
Low=0

[Ch65]
Name=IPlin64.1
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff
Grid=0
Left=70
ReverseScale=no
GridEnable=yes
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch37}/{ch49}
Low=0

[Ch66]
Name=IPlin64.2
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch38}/{ch49}
Low=0

[Ch67]
Name=IPlin64.3
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
```

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch39}/{ch49}
Low=0

[Ch68]
Name=IPlin64.4
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch40}/{ch49}
Low=0

[Ch69]
Name=IPlin64.5
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
```

CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch41}/{ch49}
Low=0

[Ch70]
Name=IPlin64.6
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch42}/{ch49}
Low=0

[Ch71]
Name=IPlin64.7
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch43}/{ch49}
Low=0

[Ch72]
Name=IPlin64.8
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch44}/{ch49}
Low=0

[Ch73]
Name=IPlin64.9
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
```

```
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch45}/{ch49}
Low=0

[Ch74]
Name=IPlin64.10
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff00
Grid=0
Left=70
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
NbDecade=5
Formula=1000*{ch46}/{ch49}
Low=0

[Ch75]
Name=Ma
DisplayedName=Ma
Producer=MChProc
Unit=ms
ChShift=0.456
CalA=1
```

```
CalB=0
CalibrationEnable=no
DisplayEnable=no
NumberFormat=%0.1f
Formula=0.001*{ch17}*({ch55}+{ch56}+{ch57}+{ch58}+{ch59}+{ch60}+{ch61}+{ch62}+{ch6
3}+{ch64})

[Ch76]
Name=IPFW16
Producer=Tool.IP.IPFW16
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1.19869e-006
CalB=-0.0678421
DisplayEnable=no

[Ch77]
Name=IPFW64
Producer=Tool.IP.IPFW64
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1.29334e-006
CalB=-0.0753723
DisplayEnable=no

; PLUG channels ------------------------

; MSI1 channels calibrations ------------------------

; BRIDLE channels calibrations ------------------------

; GRA channels calibrations ------------------------

; IP channels calibrations ------------------------

; PLUG channels calibrations ------------------------

[Process]
Process1 = Processor,Start,mch\MChProc.exe
Process2 = Browser,Start,mch\MChCurve.exe
Process3 = Browser,Start,mch\MChNum.exe
Process4 = Browser,Start,Ip\IpWave.exe
```

```
[MChProc]
Minimized=no
XOffset=958
YOffset=423
XSize=339
YSize=175

[MChCurve]
DepthScale=100
GridSpacing=0.5
XOffset=650
ForceTimeMode=no
YSize=977
DepthColLeft=0.3
XSize=848
DepthSpacing=5
DepthColRight=0.4
Minimized=no
YOffset=3
Grid=yes

[MChNum]
NumDisplay1=Ch5
NbNumDisplay=8
NumDisplay2=Ch8
NumDisplay3=Ch50
NumDisplay4=Ch53
NumDisplay5=Ch51
NumDisplay6=Ch54
NumDisplay7=Ch52
NumDisplay8=Ch75
XOffset=315
YOffset=518
XSize=341
YSize=450
Minimized=no

[IpWave]

[WellCAD]

; END OF MERGED SUBS SECTIONS ////////////////////////////////////////

Template1=
[Ch78]
Name=Speed
Producer=Logger
```

```
Unit=m/min
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
[Ch79]
Name=Tension
Producer=Logger
Unit=daN
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
[Ch80]
Name=ToolPowerVoltage
Producer=Logger
Unit=V
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
[Ch81]
Name=ToolPowerCurrent
Producer=Logger
Unit=mA
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no

[Dashboard Panels]
Depth=no
Tension=no
Winch=no
Tool=yes
Telemetry=yes
Acquisition=yes
Browsers & processors=no
Status=yes
LedDisplayBkgColor=0
LedDisplayFontColor=7fff
AcqStandbyMsgBlinkingEnable=no
AutoHide=no
```

```
[Printer]
HeaderForm=Default.wch
HeaderContent=Default.wchc
PrinterType=System
ReplayDelay=1000

[FAC40Img]
RefreshRate=1000
AmplitudePalette=0,255,255,255,63,0,0,0
TravelTimePalette=0,255,255,255,63,0,0,0

[MChCurve]
RefreshRate=1000
HGridMajorWidth=2
HGridMajorColor=808080
HGridMinorWidth=1
HGridMinorColor=808080

[MChNum]
WarnOnStoreCalibration=yes
AutoClear=yes
AutoClearTimeOut=5000



[Tol Files]
RootDir=C:\Logger\Tools
BitmapDir=C:\Logger\Tools\bitmap
TemplateDir=C:\Logger\Tools\Templates
ToolstackDir=C:\Logger\Tools\My Stacks
HeaderDir=C:\Logger\Tools\Headers
CalibrationDir=C:\Logger\Tools\Calibrations
QLStandaloneToolDir=C:\Logger\Tools\QL-Standalone
AdapterDir=C:\Logger\Tools\adapter\altlog
StandaloneToolDir=C:\Logger\Tools\Standalone\altlog
LoggerDatabase=C:\Logger\Tools\Database\logger.system.db
[Browsers]
RootDir=C:\Logger
```

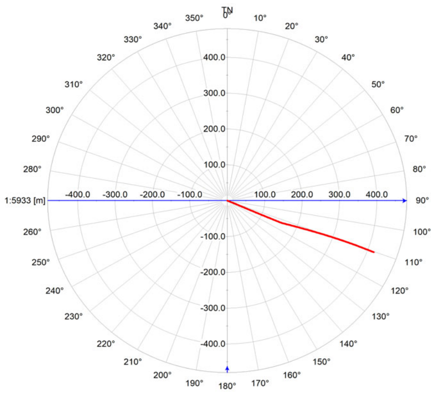
APPENDIX E

Geophysical Logs

Geophysical Record of Borehole: IG_BH04

Log Title: Deviation Log
Project Number: 20253946-4050
Client: Nuclear Waste Management Organization
Date: December 2021

Bull's Eye



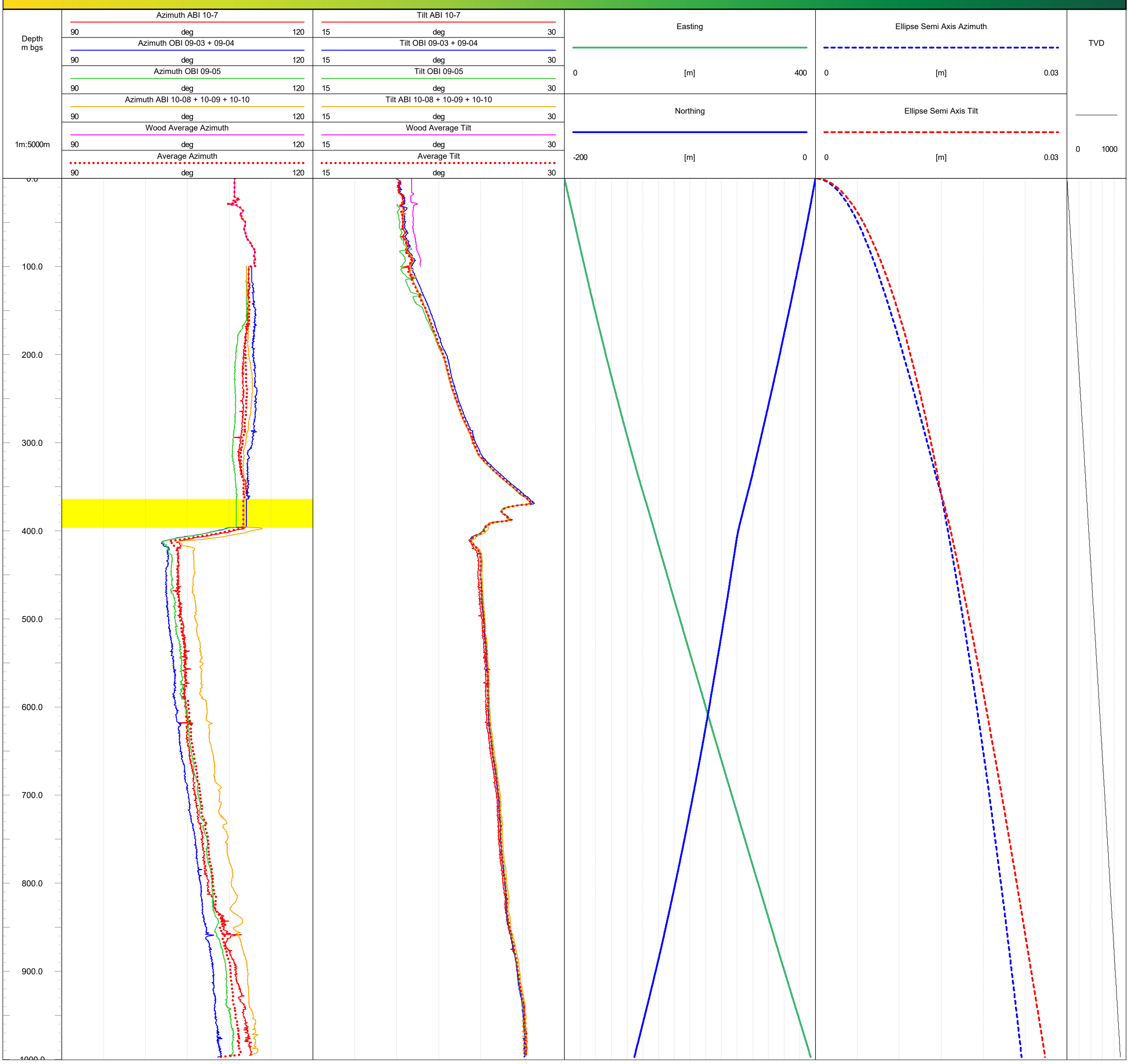
Datum: NAD83, UTM Zone 15N
Easting: 556,957.25 m
Northing: 5,486,488.05 m
Elevation: 443.46 m asl

Mean Inclination: 69.8 deg
Mean Azimuth (TN): 110 deg MN

Location: Ignace, Ontario
Log Date: April-May, 2021
Logged By: PL, CDL, OF

Depth Reference: "0" at Ground
Drilled Depth: 1000.36 m bgs
Borehole Diameter: 96 mm
Casing Diameter: 102 mm
Casing Depth: 100.77 m bgs
Static Water Level: Variable

Notes: Magnetic Declination calculated to be 1.361 degrees West for the site during the period of measurement.
Magnetic North indicated by green arrow on Bull's Eye plot.
Geomagnetic activity was monitored daily and no anomalies were reported.
Acoustic and Optical Televiewer deviation package accuracy is +/- 1.2 degrees for Azimuth and +/- 0.5 degrees for Tilt.
Highlighted area (364 to 396 m) is where metal wedges affected azimuth data. Azimuth data interpolated over this interval.



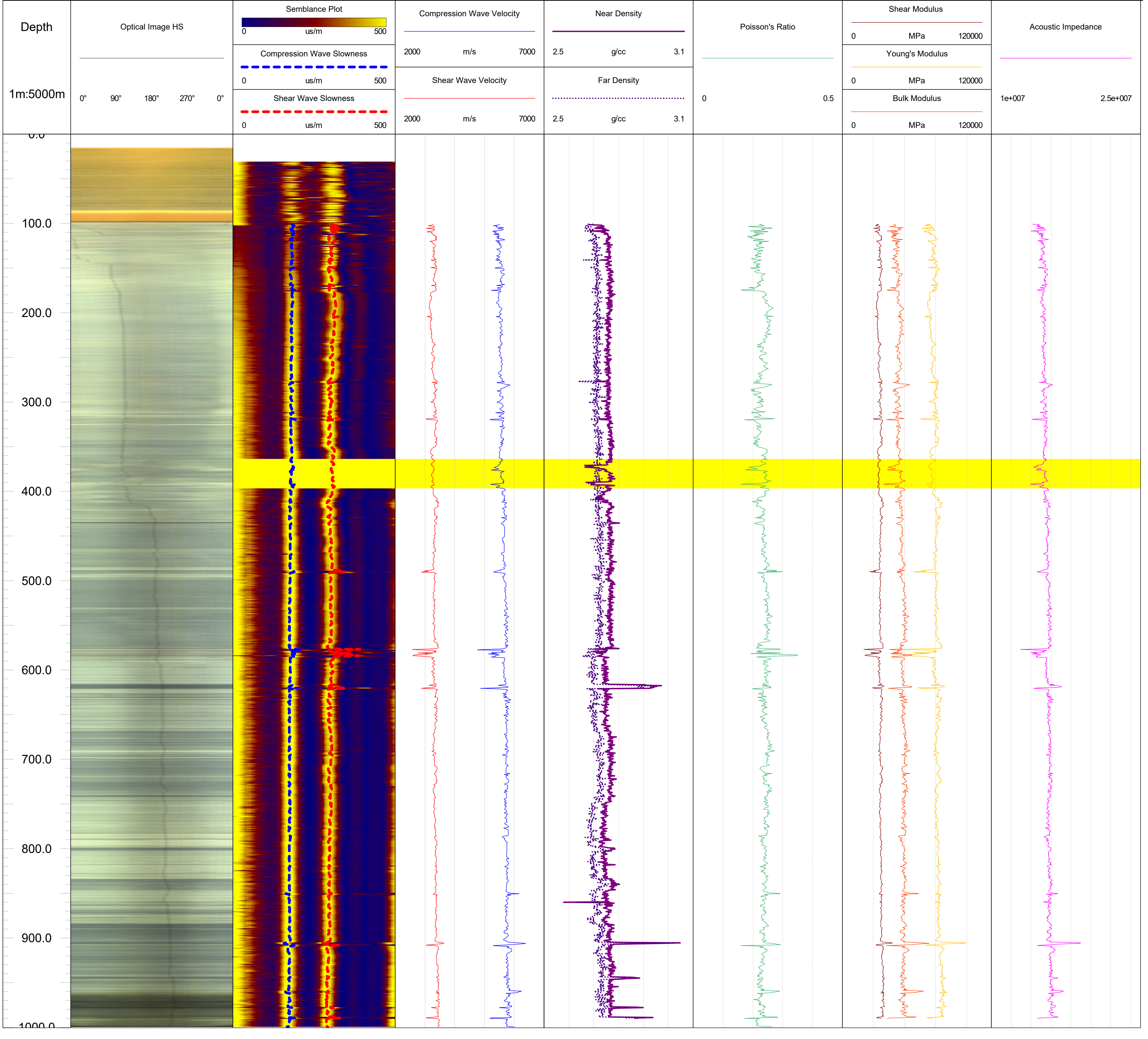
GOLDER
MEMBER OF WSP

Geophysical Record of Borehole: IG_BH04

Log Title:	Engineering Log
Project Number:	20253946-4050
Client:	Nuclear Waste Management Organization
Date:	December 2021

Datum:	NAD83, UTM Zone 15N	**Depth Reference:**	"0" at Ground	**Casing Depth:**	100.77 m bgs	**Location:**	Ignace
Easting:	556,957.25 m	**Drilled Depth:**	1000.36 m bgs	**Water Level:**	Variable	**Log Date:**	April 2021
Northing:	5,486,488.05 m	**Borehole Diameter:**	96 mm	**Borehole Inclination:**	69.8 deg		
Elevation:	443.46 m asl	**Casing Diameter:**	102 mm	**Casing Stickup:**	0.56 m	**Logged By:**	PL, CDL,OF

Notes: Highlighted area (364 to 396 m) is where metal wedges affected azimuth data. Azimuth data interpolated over this interval

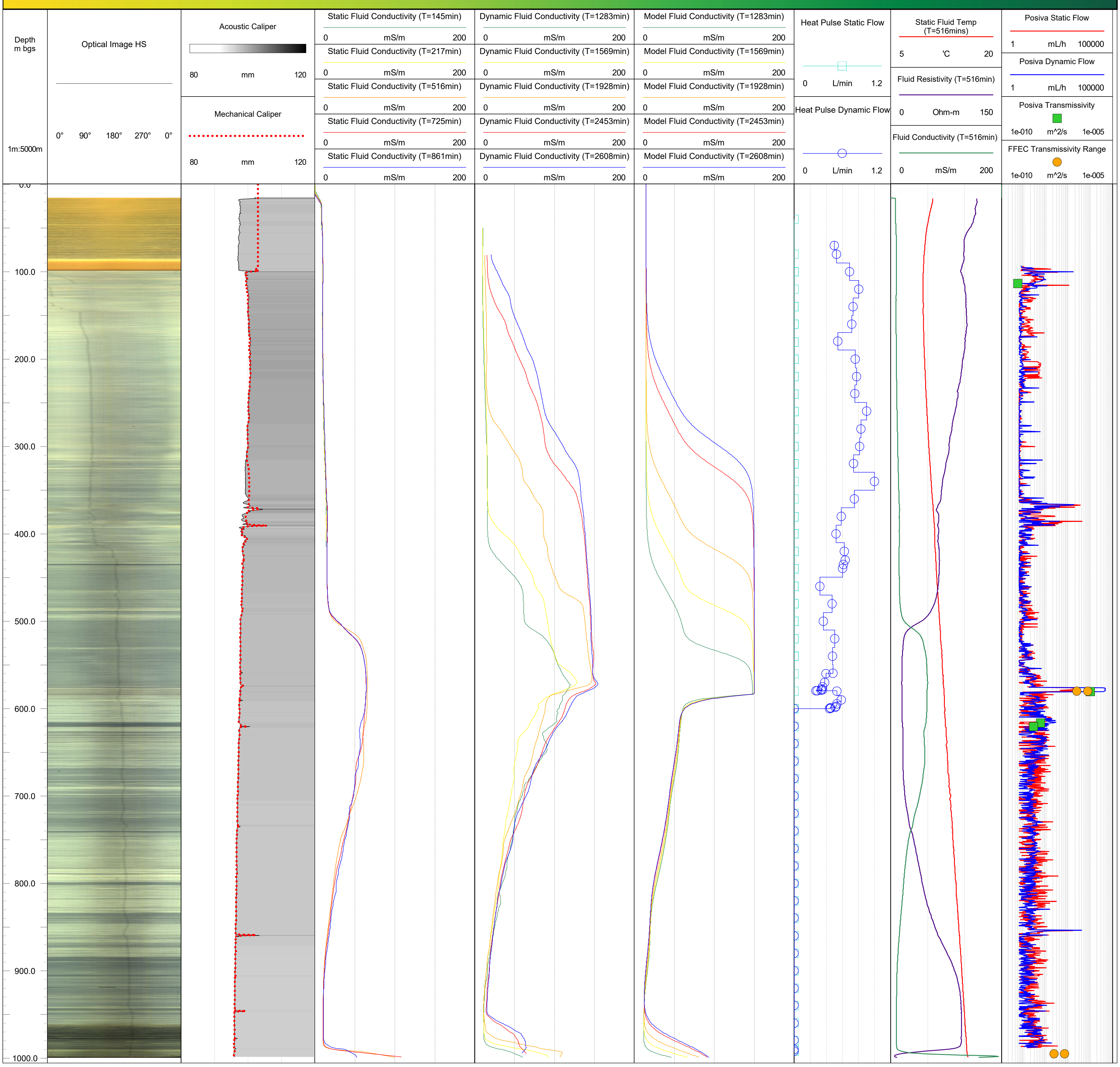


Geophysical Record of Borehole: IG_BH04

Log Title:	Hydrogeology Log
Project Number:	20253946-4050
Client:	Nuclear Waste Management Organization
Date:	December 2021

Datum:	NAD83, UTM Zone 15N	**Depth Reference:**	"0" at Ground	**Casing Depth:**	100.77 m bgs	**Location:**	Ignace, Ontario
Easting:	556,957.25 m	**Drilled Depth:**	1000.36 m bgs	**Water Level:**	Variable	**Log Date:**	April-May, 2021
Northing:	5,486,488.05 m	**Borehole Diameter:**	96 mm	**Borehole Inclination:**	69.8 deg		
Elevation:	443.46 m asl	**Casing Diameter:**	102 mm	**Borehole Azimuth:**	110 deg MN	**Logged By:**	PL, CDL, OF

Notes: Fluid conductivity measurements lose accuracy below 10 mS/m.
Final drilling rods were removed at T=0min
Pumping began at T=1165min

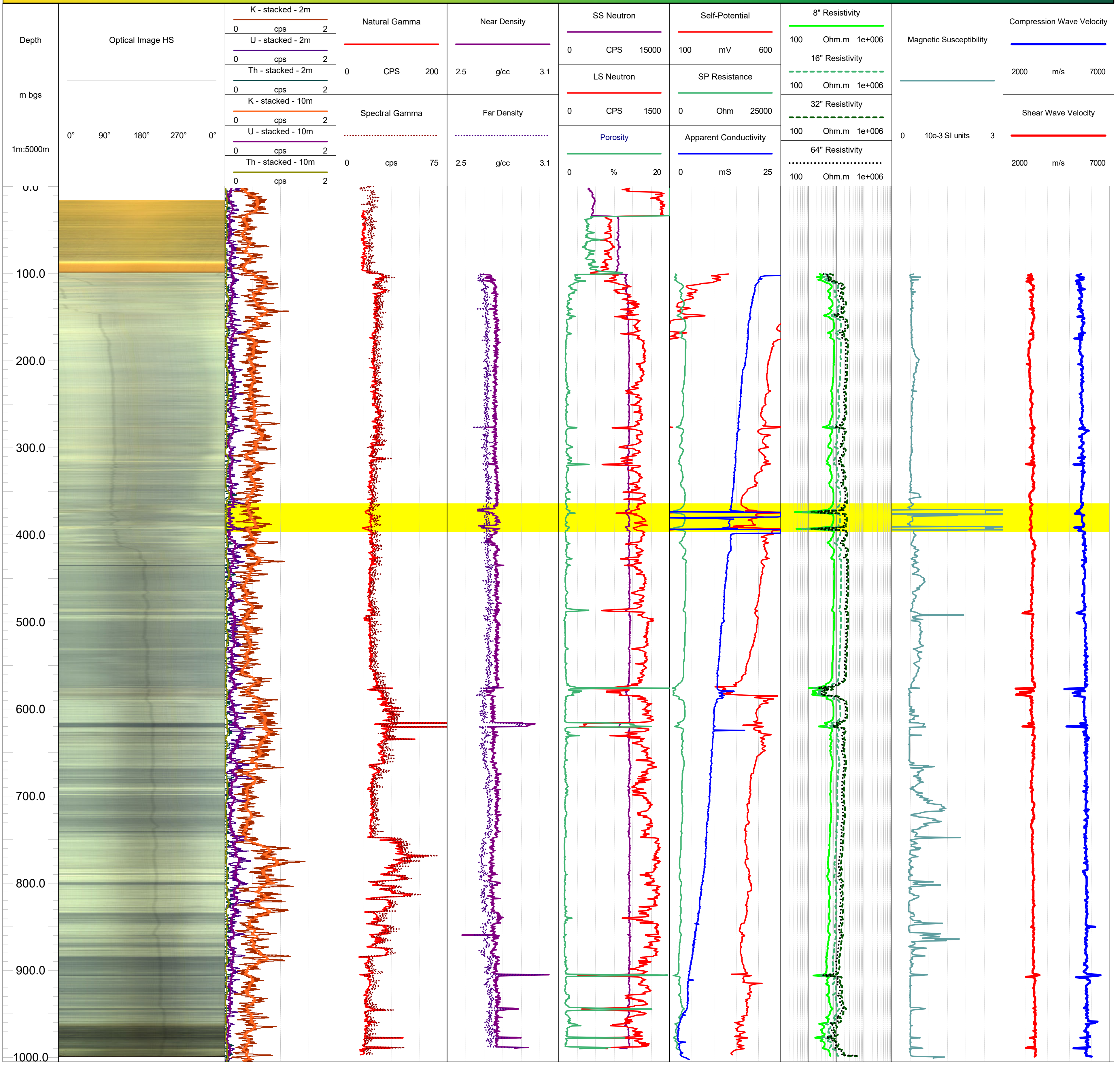


Geophysical Record of Borehole: IG_BH04

Log Title:	Lithology Log
Project Number:	20253946-4050
Client:	Nuclear Waste Management Organization
Date:	December 2021

Datum:	NAD83, UTM Zone 15N	**Depth Reference:**	"0" at Ground	**Casing Depth:**	100.77 m bgs	**Location:**	Ignace, Ontario
Easting:	556,957.25 m	**Drilled Depth:**	1000.36 m bgs	**Water Level:**	Variable	**Log Date:**	April-May, 2021
Northing:	5,486,488.05 m	**Borehole Diameter:**	96 mm	**Borehole Inclination:**	69.8 deg		
Elevation:	443.46 m asl	**Casing Diameter:**	102 mm	**Borehole Azimuth:**	110 deg MN	**Logged By:**	PL, CDL, OF

Notes: Highlighted area (364 to 396 m) is where metal wedges affected azimuth data. Azimuth data interpolated over this interval.

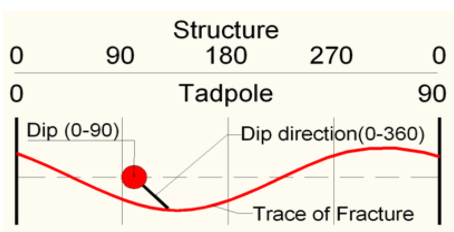


GOLDER
MEMBER OF WSP

Geophysical Record of Borehole: IG_BH04

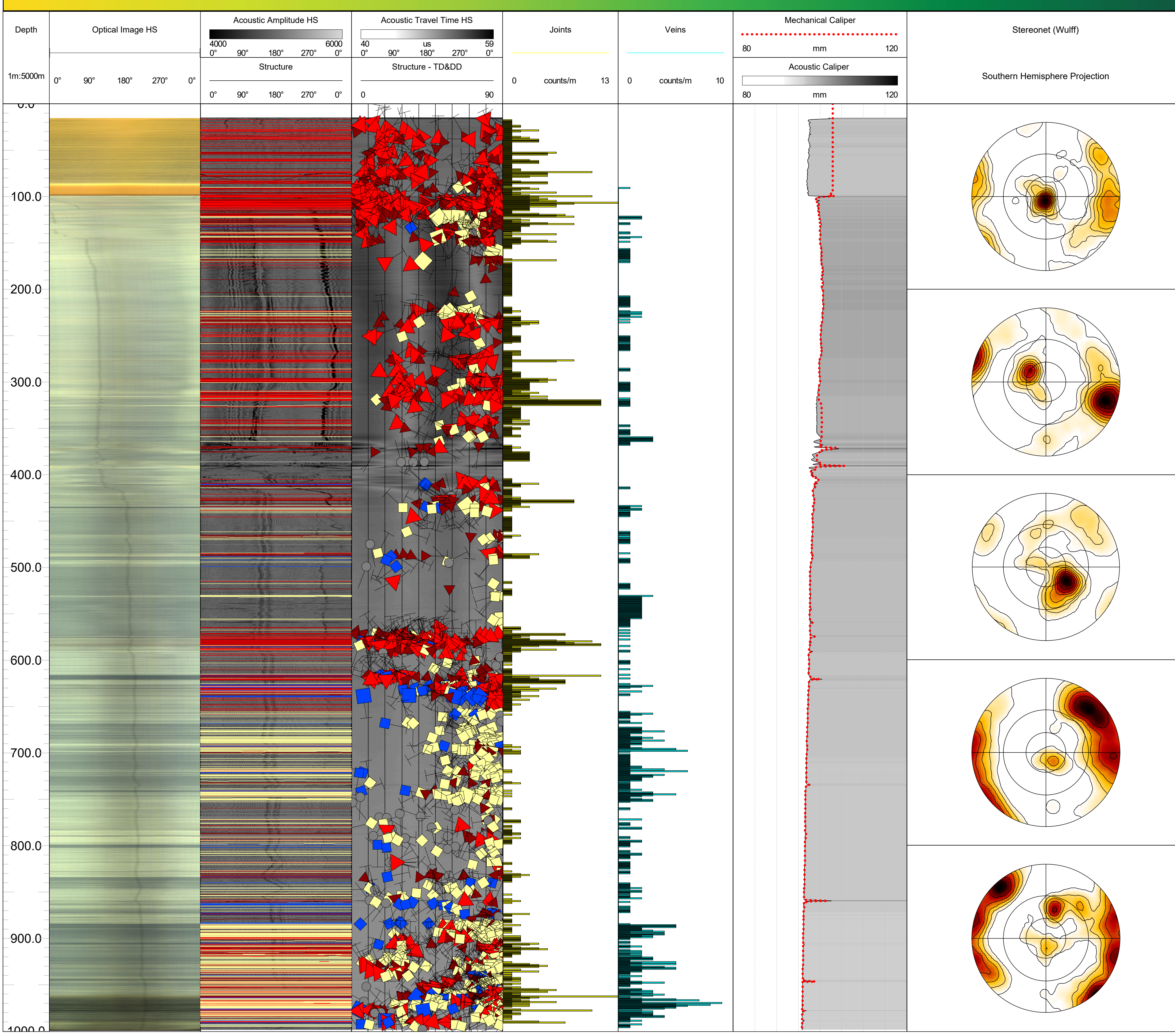
Log Title: Structural Log
Project Number: 20253946-4050
Client: Nuclear Waste Management Organization
Date: December 2021

Datum:	NAD83, UTM Zone 15N	**Depth Reference:**	"0" at Ground	**Casing Depth:**	100.77 m bgs	**Location:**	Ignace, Ontario
Easting:	556,957.25 m	**Drilled Depth:**	1000.36 m bgs	**Water Level:**	Variable	**Log Date:**	April-May, 2021
Northing:	5,486,488.05 m	**Borehole Diameter:**	96 mm	**Borehole Inclination:**	69.8 deg		
Elevation:	443.46 m asl	**Casing Diameter:**	102 mm	**Borehole Azimuth:**	110 deg MN	**Logged By:**	PL, CDL, OF



Igneous Primary Structure (Low) | Vein Intact (High) | Vein Intact (Low) | Joint Broken (High)
Joint Broken (Medium) | Joint Broken (Low) | Joint Intact (High) | Joint Intact (Medium)
Joint Intact (Low) | Contact Broken (Low) | Contact Intact (High) | Contact Intact (Low)

Notes:



APPENDIX F

FFEC Modelling Report

Fluid Electrical Conductivity modeling and interpretation for BH04

Borehole dilution analysis under stressed borehole conditions (Tsang et al, 1990) is an accepted method for characterizing inflow zones in boreholes in fractured bedrock formations. The static and dynamic FEC column logs for BH04 in this dilution experiment were somewhat different from the expected conditions prescribed for dilution experiments in that the initial column did not consist of a uniformly low conductivity associated with flushing with tap water, and there were shifts and plateaus on the dynamic profiles that appear to drift along with the flow rather than indicate specific pulses of inflow tied to specific inflow depths and expanding upward over time. It is assumed that a uniformly low-conductivity profile had been initially established, but that inadvertent changes produced in setting up the experiment allowed more conductive water to enter the column under otherwise static conditions (figure 1). The two nominally static FEC profiles obtained show the same broad “bulge” centered on what would show up as the dominant inflow zone and so likely produced by inflow and mixing of conductive water from that level. The consistent shape of the two profiles also demonstrate that no significant flow was occurring over the period when they were obtained.

The code used for this analysis (Paillet, 2012) is designed to deal with a nearly uniform initial condition, but allows for piecewise continuous sections of borehole column conductivity to be entered to give a stepped profile. This profile was then subjected to an extended artificial time to allow for diffusion in a static column to round out the steps to closely approximate the static FEC profiles shown in figure 1. Some 3000 minutes of such diffusion were sufficient to generate an initial FEC profile very close to that obtained during the initial stage of the experiment. That meant starting the model runs an extra 2000 minutes ahead of the nominal start of stressing at 1000 minutes.

Inspection of the dynamic FEC profiles starting at 1283 minutes shows only two obvious inflow zones at 995 and 580 m in depth. Model fits to the data in figure 2 are based on matching the “shoulder“ at the upper end of the two “slugs” of inflow as they propagated uphole under the drawdown produced in the dynamic phase of the experiment. The fit of the model to data was complicated by two separate factors:

First, the water level maintained during the stressed part of the experiment was changing with time so that the rates of inflow from the two zones were also probably changing during that period. The dilution model used to fit the FEC profile data uses a single steady inflow rate for each zone. For this reason, the fit of the model to the final FEC profile at 2608 minutes was used to guide the fit in figure 2 to give the best approximation to the overall average flow rate.

Second, the profiles above 580 m also show a bit of undulation rather than the smooth exponential decline expected from simple longitudinal diffusion under steady rates of inflow. The shape of these shallow fluctuations remains about the same as they propagate upwards with a bit of diffusive flattening. It is assumed that these profile fluctuations were introduced after the end of the static part of the experiment at 1000 minutes but before the first dynamic FEC profile was obtained. They are thereafter simply propagating with the flow and not indicative of inflowing water.

The possibility that these fluctuations could be explained by other flow zones is dismissed in figure 3. Here a small inflow of about 0.2 l/min was assumed to come in at 367 m in an early model run at a depth where a prominent caliper excursion indicates a fracture intersecting the borehole. Such a small inflow would introduce a definite spike in the profile at early times and then evolve into a distinct step at later times as shown in the figure. No such initially sharp and later expanding feature is evident in any of the dynamic FEC profiles except at 995 and 580 m.

For these reasons, the model fit with two inflow zones (995 and 580 m) shown in figure 2 was selected as corresponding to the best overall match between model and data sets that captures the general sense of movement of the inflowing solutes uphole under the influence of changing inflow rates and diffusion of the initial perturbations in the initial profile. Also note that the interval in the profiles below 580 m shows elevated FEC associated with the passage of the probe pushing solute downwards, a situated documented in initial verification of the model used here (Paillet, 2012).

The FEC profiles clearly show the depth of the inflow in a 2-meter interval just above a depth of 580 m. The inflow at a nominal depth of 995 m is not nearly as well defined because it occurs right at the bottom of the FEC profiles. Details of column mixing as the probe approached the end of the run and fluid motion induced by the approach of the probe to the bottom of the borehole impose a great deal of variability to the shape of the profile. For example, the signature of inflow is expected to show an initial rise to a value indicating the FEC of the inflowing water, and then establishment of a plateau at that value. Such a plateau is seen above 580 m indicating inflowing water has an FEC of about 159 mS/m and the inflow moves uphole at about 1.36 l/min representing the combined upward flow from both zones. Such a signature is not evident at the bottom of the profiles. Instead, there is fluctuation in the peak value that decreases towards the later times, and varies over a range of 60 to more than 150 mS/m. The inflow there is so low that a plateau does not have time to form before the end of the experiment. The mixing that produced this variation does not allow for a simple broadening of the FEC peak over time. There must have been some inflow there to produce a measureable excursion in FEC, and the overall spread of the peak with its variability indicates an inflow of less than 0.20 l/min. The model fit in figure 2 uses an inflow value of 0.12 l/min and an inflowing FEC value of 150 mS/m for the 995 m zone as summarized in table 1.

Estimates of the sensitivity of the model fit in figure 2 were made by running alternate models with somewhat different values of inflow and zone FEC to estimate how large a variation in these values would be needed to rule out a model fit within the range of FEC data variation. An example is shown in figure 4. This is a plot comparing the final FEC data profile (t = 2608 minutes) with the corresponding model fit in figure 2 and another model run with the same inflow FEC values but greater flow (0.19 l/min) at the 995 m zone and lower flow (1.15 l/min) at the 580 m zone. The data profile shows a spike at the inflow depth indicative of the FEC of inflow. Above that, there is a plateau representing the mixing of that inflow with upwards flow from below (with the low background conductivity of the static column). Changing the flow from below in the shifted model increases the mixing in the column at 580 m, reducing the level of the FEC plateau in comparison to the data, while the net decrease in combined flow above 580 m slows the upward shift in the “shoulder” (figure 4a). The increase in inflow at 995 m in the shifted model clearly shows that the small increase in flow does not match the model while demonstrating that small differences in inflow produce large differences in the peak FEC in the profile (figure 4b).

Recognition of differences between model fits is complicated by the change in inflow rate associated with the variation in drawdown, and the perturbations in the initial column conditions assumed to have occurred before the start of the experiment. Alternate model runs such as those in figure 4 using slightly different inflows and zone FEC demonstrate that differences of inflow and FEC at 580 m would need to exceed +/- 0.10 l/m and 15 mS/m respectively to be identified as significantly different from the results shown in figure 2. Greater uncertainty is associated with the inflow and FEC at 995 m because of the great variability in that part of the profile. Inflow has to be less than 0.20 l/min for all model profiles to lie within the range of FEC data, and peak FEC data values range from 60 to more than 150 mS/m. The estimates of inflow and FEC values for this zone are given as +/- 0.08 l/min and +/- 30 mS/m in table 1. The slightly lower uncertainty in inflow results from the low upper limit of possible flow inferred from the data. The larger uncertainty in the FEC and the nominal 150 mS/m listed for the 995 m zone in table 1 suggests that there is little difference between the FEC of inflow from the two zones. The estimated TDS values for the two zones are based on the relationship between water conductivity and solute content for average North American waters given by Fishman and Friedman (1989).

Estimates of transmissivity associated with the 995 and 580 m zones were constrained within the limits of estimated drawdown using the method described by Paillet (1998, 2000). Water level was drawn down to a depth of 50 m during the experiment, and had been measured at a little above 20 m before the experiment began. Since it is unclear whether this was representative of the static water level in the formation, it is assumed that the drawdown driving the observed flow as more than 10 m and possible as much as 30 m. These values were used to determine upper and lower limits for the transmissivity of the 995 and 580 m zones in table 1.

Figure 1 – Comparison of initial stepped FEC column input and static initial condition created by allowing steps to smooth out by diffusion to match the measured static FEC column condition.

Figure 2 – Model fit for the series of measured FEC column profiles during the pumping; model parameters include inflows of 0.11 and 1.25 liters per minute for zones at 995 and 580 m in depth with estimated formation water conductivities of 150 and 159 mS/m.

Figure 3 – Model run made to allow a small inflow of 0.20 l/m with water conductivity of 1500 mS/m at the 367 m zone where a significant kick is shown on both the mechanical and acoustic caliper logs; model compared to data at early and late times to illustrate evolution of inflow signature.

Figure 4 – Comparison of model fit with a model for slightly different inflows (0.19 and 1.1 l/min for the 995 and 580 m zones) to demonstrate the sensitivity of the inflow values used in the model fit to FEC data.

Table 1 – Model fit parameters for BH04

Depth (m)	Inflow (l/min)	Water conductivity mS/m	Est TDS (mg/l)	Transmissivity (m^2/day)
580	1.25 +/- 0.10	159 +/- 15	1065	0.021<T<0.064
995	0.11 +/- 0.08	150 +/- 30	1000	0.002<T<0.006

References cited

Fishman, M.J. and L.C. Friedman, 1989, Method for determining inorganic substances in water and fluvial sediments, *U S Geological Survey Techniques of Water Resources Investigations*, Book 5, Chapter A1.

Paillet, F.L., 1998, Flow modeling and permeability estimation using borehole flow logs in heterogeneous fractured formations, *Water Resources Research, 34*, 997-1010.

Paillet, F.L., 2000, A field technique for estimating aquifer parameters using flow log data: *Ground Water*, v. 38, no. 4, p. 510-521.

Paillet, F. L., 2012, A mass-balance code for the quantitative interpretation of fluid column profiles in ground-water studies, *Computers and Geosciences*, v 45, p 221-228.

Tsang, C.F., P. Huschmied and F.V. Hale, 1990, Determination of fracture inflow parameters from a borehole fluid conductivity method, *Water Resources Research*, 26, 561-578.

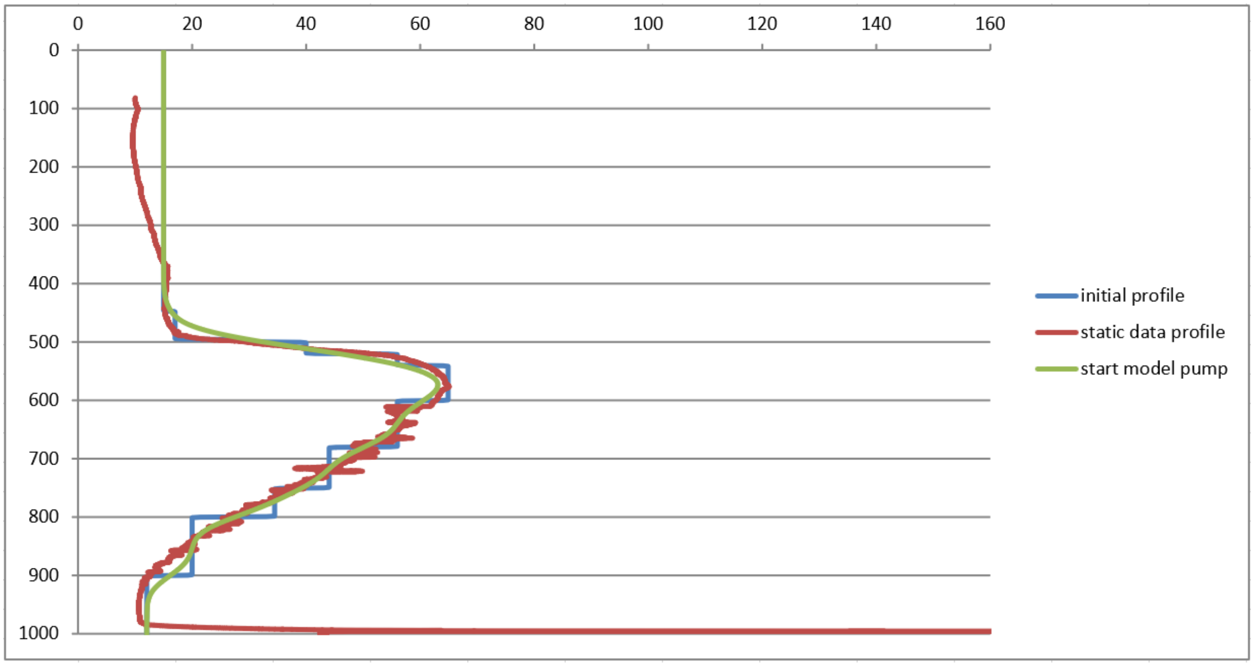


Figure 1 – Comparison of initial stepped FEC column input and static initial condition created by allowing steps to smooth out by diffusion to match the measured static FEC column condition.

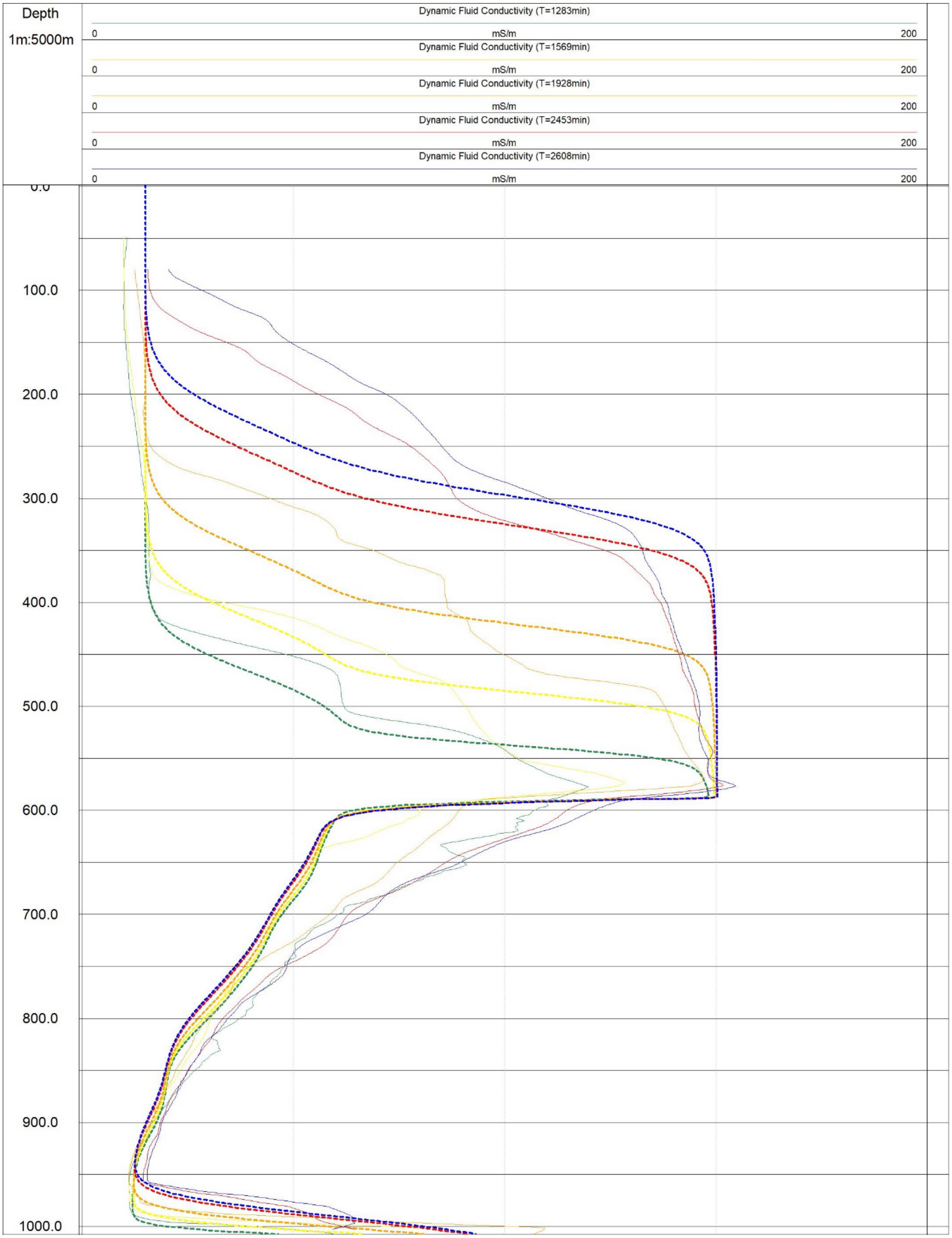


Figure 2 – Model fit for the series of measured FEC column profiles during the pumping; model parameters include inflows of 0.11 and 1.25 liters per minute for zones at 995 and 580 m in depth with

estimated formation water conductivities of 150 and 159 mS/m. Solid lines are field collected data, dashed lines modelled data.

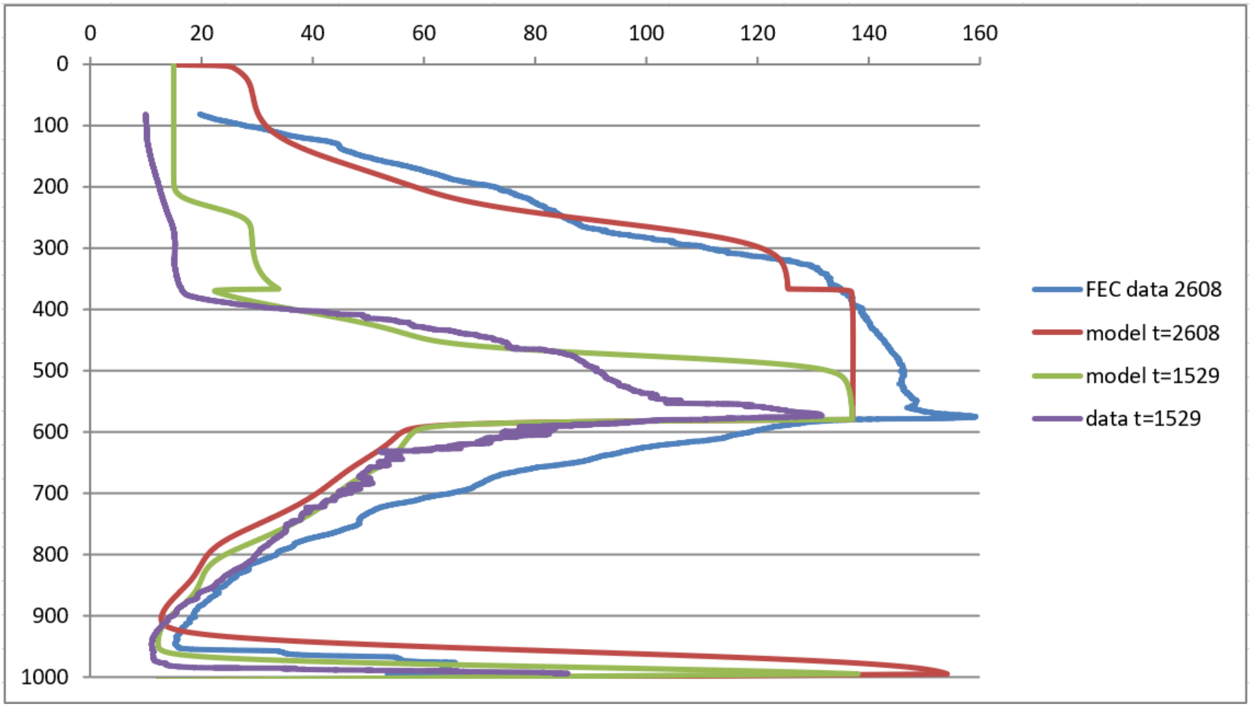


Figure 3 – Model run made to allow a small inflow of 0.20 l/m with water conductivity of 1500 mS/m at the 367 m zone where a significant kick is shown on both the mechanical and acoustic caliper logs; model compared to data at early and late times to illustrate evolution of inflow signature.

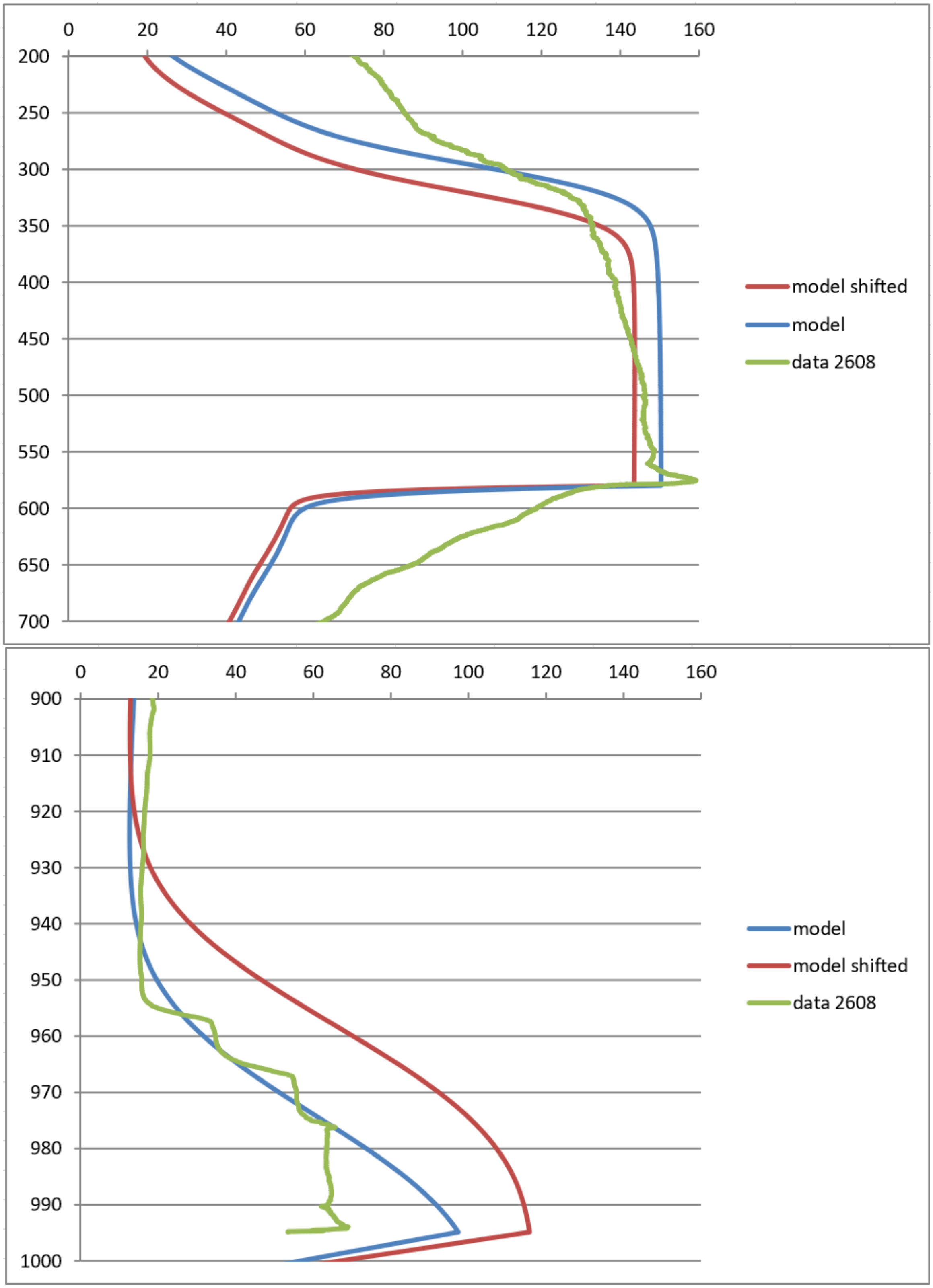


Figure 4 – Comparison of model fit with a model for slightly different inflows: 0.19 and 1.1 l/min for the 580 m (top) and 995 m (bottom) zones to demonstrate the sensitivity of the inflow values used in the model fit to FEC data.

APPENDIX G

Posiva Testing Report

Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06, Ignace Area

Posiva Flow Log measurements at the Ignace site in Ontario, Canada, Borehole IG_BH04

9.6.2022
PS-000895

Posiva Solutions

POSIVA FLOW LOG MEASUREMENTS AT THE IGNACE SITE IN ONTARIO, CANADA, BOREHOLE IG_BH04

ABSTRACT

The Posiva Flow Log, Difference flow method (PFL DIFF) uses a flowmeter that incorporates a flow guide and can be used for relatively quick determinations of hydraulic conductivity and equivalent freshwater hydraulic head of fractures/fractured zones in boreholes. This report presents the principles of the method and the results of measurements carried out in borehole IG_BH04 at the Ignace site in July 2021.

The applied section lengths of the flow guide were 5 m and 0.5 m. Flow into the borehole or from the borehole to the bedrock was measured within the section length. The measurements were carried out in pumped and in natural (i.e. un-pumped) conditions. The transmissivity (*T*) and equivalent freshwater hydraulic head (*h*) of zones were calculated from the obtained flow and pressure results.

In addition of flow and pressure measurements single point resistance (SPR) and electrical conductivity (EC) of water was measured. EC was measured from flow measurement channel mainly to monitor water conditions during flow measurement. The probe might carry water within it's measurement section and therefore EC results might not represent the actual borehole water EC at certain length in borehole.

The measurement covered 888.3 meters (100.7 m - 989 m) of borehole and four water flowing fractures were found. Fractures were found at lengths of 113.7 m, 580.9 m, 616.5 m and 620.6 m The largest flow was 1900 ml/h in unpumped conditions and 44700 ml/h while pumped drawdown was c. 13 meters. The highest transmissivity was $9.97*10^{-7}$ m^2/s.

Keywords: Groundwater, flow, measurement, bedrock, borehole, electrical conductivity, Posiva Flow Log.

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Appendices IG_BH04.1.1 – IG_BH04.1.45	Borehole IG_BH04, Flow rate, pressure and single point resistance
Appendix IG_BH04.2	Borehole IG_BH04, Transmissivity and head of detected fractures
Appendix IG_BH04.3	Borehole IG_BH04, Table of transmissivity and head of detected fractures
Appendix IG_BH04.4	Borehole IG_BH04, Hydraulic conductivity (K) of 5 m sections
Appendix IG_BH04.5	Borehole IG_BH04, Table of hydraulic conductivity of 5 m sections
Appendix IG_BH04.6	Borehole IG_BH04, Fresh water head in the borehole
Appendix IG_BH04.7	Borehole IG_BH04, Air pressure, water level in the borehole and pumping rate during flow logging
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PREFACE

This report has been produced by Posiva Solutions Oy for Golder (Golder Associates Ltd) as a part of their site investigation project for Nuclear Waste Management Organization (NWMO).

Petri Heikkinen conducted the field work at the Ignace site in Ontario, Canada. Peter Leith from Golder Associates Ltd supported field work by monitoring measurement at nightshift. Monitoring of measurement was supported via remote connection from Posiva's office in Finland. Data processing and preparing daily documentation was supported from Posiva's office. Jere Komulainen has been responsible for quality control during the field work and reporting.

GLOSSARY

This glossary includes the key terms used in this report, as well as acronyms or special terms.

masl	Metres above sea level
PFL DIFF	Posiva Flow Log Difference Flow Method, uses a flow meter that incorporates a flow guide and can be used for relatively quick determinations of hydraulic conductivity and fresh water head
SPR	Single Point Resistance
EC	Electrical conductivity
T_{PFL}-value or T	Transmissivity of fracture (m^2/s), measured with PFL
T_{min}	Minimum transmissivity based on measurement accuracy
T_{max}	Maximum transmissivity based on measurement accuracy
$HeadOfF_{min}$	Minimum head of fracture based on measurement accuracy
$HeadOfF_{max}$	Minimum head of fracture based on measurement accuracy

1 INTRODUCTION

The Nuclear Waste Management Organization (NWMO) has started the site investigations on two sites, the other of which being Ignace in Ontario, to identify a site where Canada's used nuclear fuel can be safely contained and isolated in a deep geological repository.

One of the studies conducted at site is Posiva Flow Logging (PFL) which is a method that has been developed by Posiva in Finland. Posiva Flow Log, Difference Flow Method (PFL DIFF) can be used to locate water flowing fractures intersecting boreholes and determining the flow rate between a fracture and a borehole. Using a special flow guide, rather than measuring the flow along the borehole, the flow into or out of a borehole at a chosen length interval can be measured directly using the method. This makes it possible to determine the transmissivity of the fractures and the equivalent freshwater hydraulic head in fractures. One advantage of the method is that it is faster than the conventional double-packer injection test.

The equipment employed in the PFL DIFF method (a trailer-mounted winch and cable, a downhole probe and a computer) can be used in boreholes of lengths up to 1500 m which are 56 mm or more in diameter.

A high-resolution absolute pressure sensor is used to measure the total pressure along a borehole, with measurements being carried out in parallel with flow measurements. The results obtained are used in calculating the equivalent freshwater hydraulic head along the borehole.

Measurements using the PFL DIFF method were performed in borehole IG_BH04 at the Ignace site between July 11th and July 18th 2021. Technical information of the core drilled holes is given in Table 1-1. The location of borehole IG_BH04 as Ignace site is presented in ***Figure 1-1***.

Table 1-1. *Technical information of the borehole.*

Borehole	Diameter (mm)	Ground level coordinates			Azimuth (degrees)	Inclination (degrees)	Max. length (m)	Casing	
		X (m) north	Y (m) east	Z (masl)				Casing length (m)	Casing above ground level (m)
IG_BH04	96	5486488.05	556957.25	443.46	110.01	−69.80	1000.2	100.77	0.27

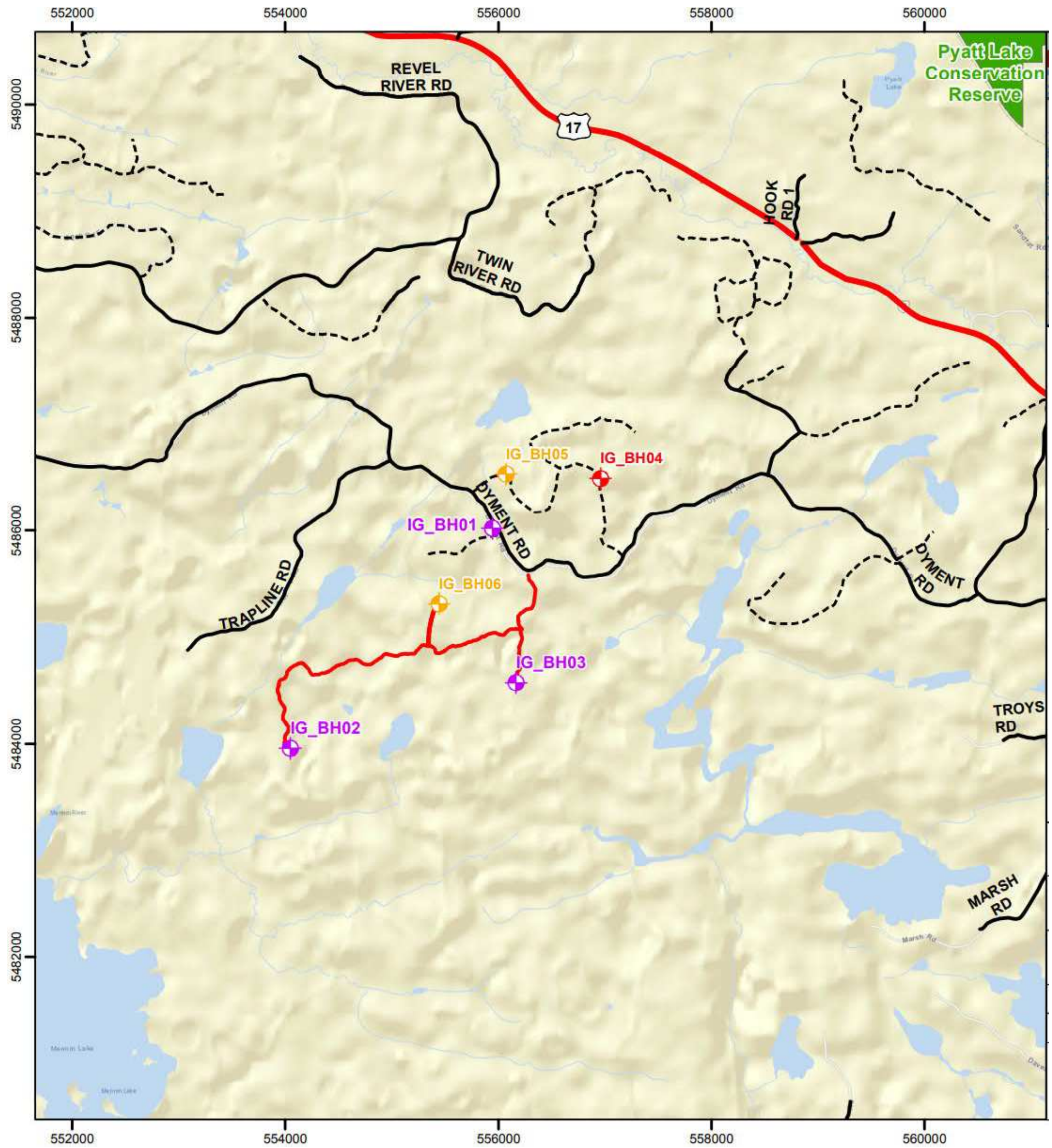


***Figure 1-1**. Location of borehole IG_BH04 at Ignace site.*

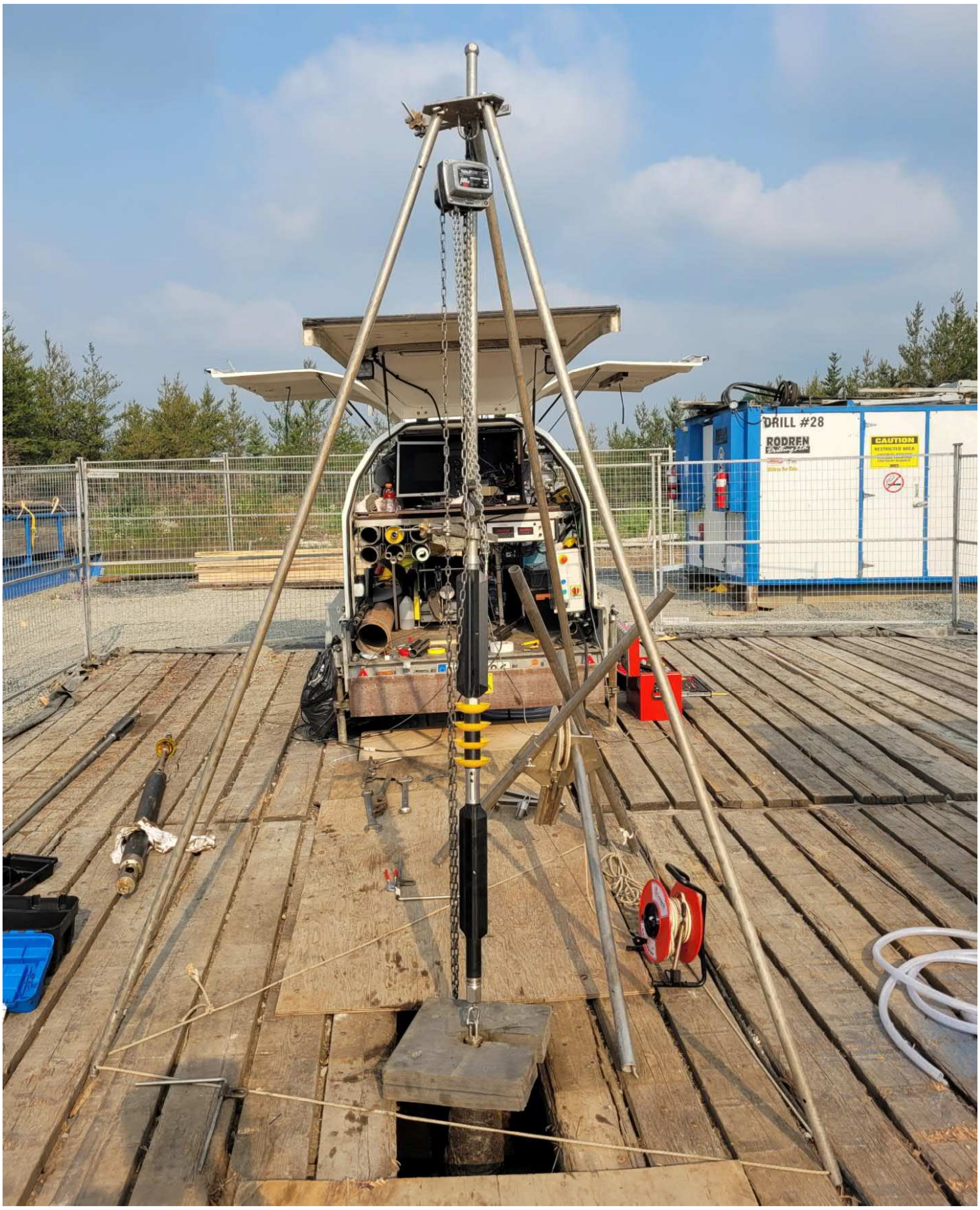


Figure 1-2. Borehole IG_BH04 and PFL measurement equipment installations.

This report documents the execution of field work, represent the obtained measurement results and derived results and describe data processing.

2 PRINCIPLES OF OPERATION

2.1 Difference flow method PFL DIFF

Unlike conventional borehole flowmeters which measure the total cumulative flow rate along a borehole, the PFL DIFF probe measures the flow rate into or out of defined borehole sections. The advantage that follows from measuring the flow rate in isolated sections is improved detection over the incremental changes of flow along the borehole. As these are generally very small, they can easily be missed when using conventional flowmeters. Technical illustration of the PFL DIFF probe is presented in Figure 2-1.

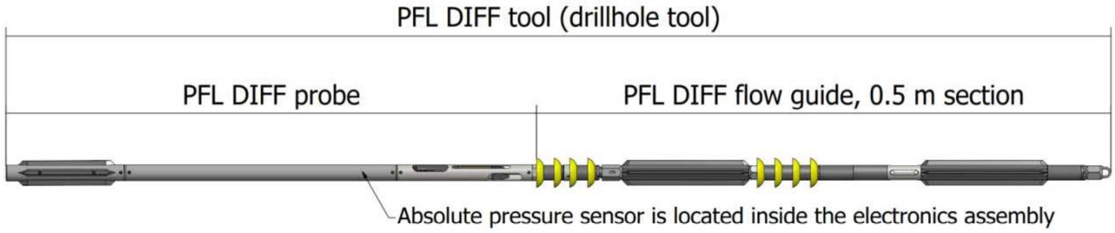


Figure 2-1. *Technical illustrations of the PFL DIFF tool.*

Rubber sealing disks are used to isolate the flow of water in the test section from the flow in rest of the borehole, see Figure 2-2. Flow into or out from the test section is directed through the flow sensor. Flow along the borehole is directed around the test section by means of a bypass pipe and is discharged at either the upper or lower end of the probe, depending on the flow direction in the borehole. A schematic illustration representing a cross-section of the PFL DIFF probe's structure is presented in Figure 2-3. It should be noted that, depending on pressure difference between a fracture and a borehole, the direction of the measured flow can be from the bedrock into the borehole as the magenta coloured arrows represent in Figure 2-2 and Figure 2-3, or from the borehole into the bedrock in which case the arrowheads in Figure 2-2 and Figure 2-3 would be inverted.

During the measurement campaign flows within measurement section are measured in unpumped conditions and while water level in borehole is lowered by pumping water out of the borehole. Two separate measurements with two different section lengths (e.g. 5 m and 0.5 m) are used in pumped conditions. The 5 m setup is used first to obtain a general picture of the flow anomalies. It is also good for measuring larger (less than 5 m in length) fractured zones. The 0.5 m section setup can separate anomalies which are close to each other. Different section lengths are also used to confirm that a flow anomaly is real and not caused for example by a leak at the rubber disks.

In addition to incremental changes in flow, the PFL DIFF probe can also be used to measure:

- The electrical conductivity (EC) of water. The electrode used in the EC measurements is located on top of the flow sensor, see Figure 2-2.
- The single point resistance (SPR) of the borehole wall (grounding resistance). The electrode used for SPR measurements is located between the uppermost rubber sealing

disks, see Figure 2-2, and is used for the high-resolution length matching between different measurement runs.

- The prevailing water pressure profile in the borehole. The pressure transducer is located inside the watertight electronics assembly and is connected to the borehole water through a tube, see Figure 2-1.
- The temperature of the water in the borehole. The temperature sensor is part of the flow sensor, see Figure 2-2.

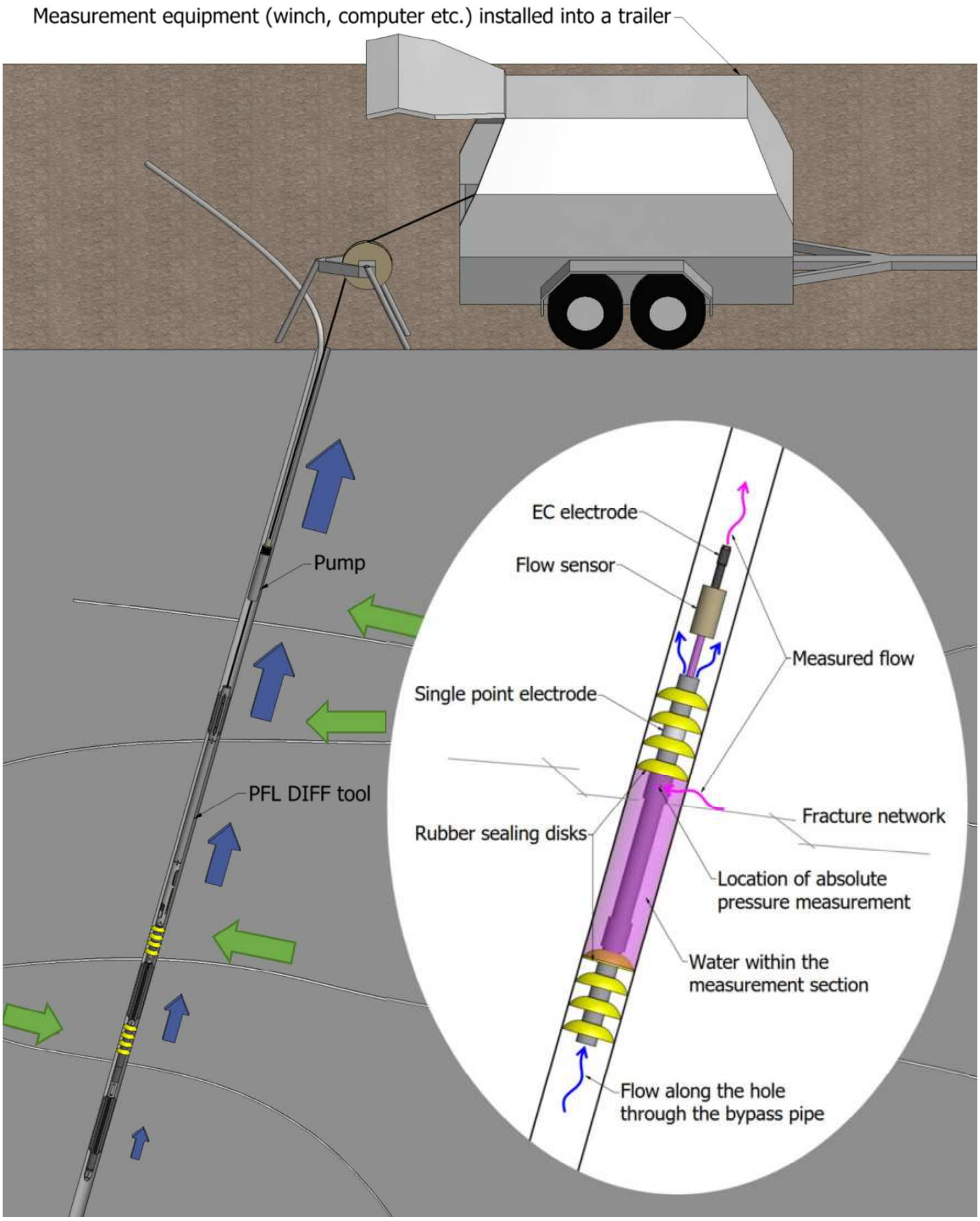


Figure 2-2. *Schematic illustration of the probe used in the PFL DIFF. Flow directions (green arrows) are indicated in case the pressure in the borehole is lower than in the*

fracture, i.e. when there is inflow into the borehole. Water from the fracture flows into the flow channel through the opening in the base and continues back to the borehole via the flow and EC sensors (magenta arrows). The flow along the borehole (blue arrows) is directed through the flow guide by the by-pass pipe.

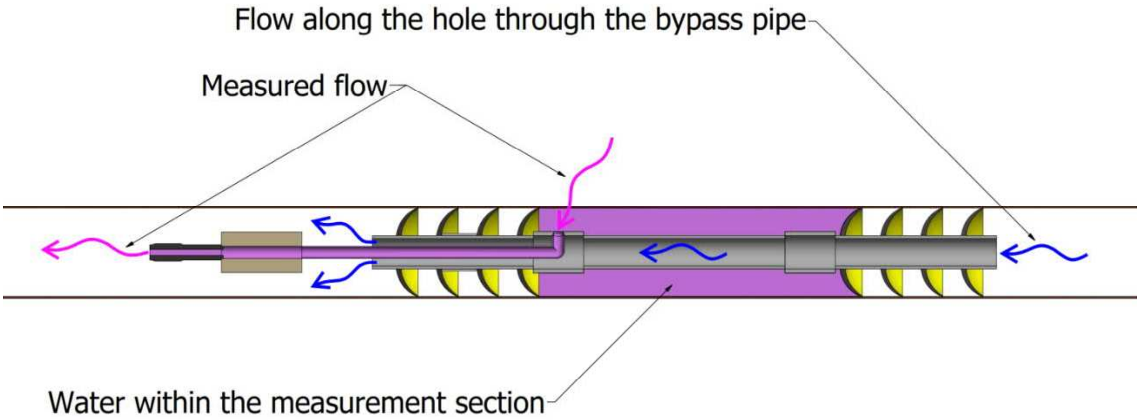


Figure 2-3. *Schematic illustration representing a cross-section of the PFL DIFF probe.*

The measurement range for flow rate is 30 mL/h – 300 000 mL/h in general. The PFL DIFF probe has been calibrated for flow range of 6 mL/h – 300 000 mL/h in laboratory but usually conditions at field raise the lower limit to ca. 30 mL/h. Therefore in some cases flow rates less than 30 mL/h can be measured. On the other hand, the lower limit of 30 mL/h cannot be reached in all borehole conditions. Examples of possible sources for disturbance are rough borehole wall, drilling debris entrained in the borehole water, bubbles of gas in the water, changes in water salinity and very high flow rates (some 30 L/min, i.e. 1 800 000 mL/h or more) along the borehole. The measurement range of 30 mL/h – 300 000 mL/h has been determined based on practical experience and is valid in most cases but exceptions, as stated above, exist.

The length reference point is the ground level (length 0 m). The measurement length point is situated in the PFL DIFF probe at the upper end of the test section (see Figure 2-2). The length parameter in the results is the distance along the borehole between these two points.

When assessing the locations of anomalies in boreholes, it must be taken into consideration that there is always length error in the results. Length error can be caused by following reasons:

1. The cable stretches under tension. Based on information from the cable manufacturer, the cable's stretching is 1.15 m/km/kN. The tension values here are estimates only and can vary greatly depending on the device setup and borehole properties. Length errors have been determined in the boreholes where there are known length marks on the wall of the borehole. The error has been approximately 1 m (before the length correction based on the length marks) at the length of ca. 1000 m. This is approximately same amount as calculated based on cable stretching.

2. If the point interval of flow measurement is x, a worst case length error of $\pm x$ can potentially occur for a fracture location.

3. The length of the test section is not exact. The specified section length denotes the distance between the nearest upper and lower rubber sealing disks. Effectively, the section length can be longer. At both ends of the test section there are four rubber sealing disks. The distance between each disk is 5 cm. This will cause rounded flow anomalies: a flow may be detected already when a fracture is situated between the four rubber sealing disks. This phenomenon can cause an error of ±0.05 m. A similar error can occur when the flow along the borehole is measured.

The total worst case length error can be estimated. In the worst case all the errors are summed up in the worst possible way. The maximum length error would be:

$$E = \pm 0.001d + x + 0.05 \text{ m}$$

Where
E is the total estimated worst case error (m)
d is the length of the probe (m) and
x is the length increment of flow measurement (m)
0.05 m comes from reporting fracture locations with 0.1 m resolution

During measurements in IG_BH04 the highest tension was c. 190 kg when measurement run was started at bottom of the borehole. Therefore the estimation above are valid for the results presented in this report.

The length error can be essentially decreased if there are known length marks on the borehole wall that can be synchronized with the PFL DIFF log. The length marks are features on the borehole wall that can be detected by the PFL DIFF, usually by the single point resistance electrode. The length marks can be artificially made features. They can also be geological features in drill cores that can be connected to SPR anomaly. SPR is measured at 0.01 m point intervals. Lower end of casing pipe is usually used as such length reference.

Fractures nearly parallel with the borehole may also be problematic. Fracture location may be difficult to define accurately in such cases.

3 EQUIPMENT SPECIFICATIONS AND CALIBRATION

The PFL DIFF equipment has been designed for hydrogeological measurements conducted in core drilled boreholes. Several quantities are measured to provide data of hydrogeological properties and to verify the representativeness of measurement results.

The entire PFL DIFF measurement equipment consists of the PFL DIFF tool that measures the properties in the borehole and a trailer that contains a measurement computer, winch and other devices that support the actual taking of the flow measurements. The measurement computer is used to control the measurement and to display measurement data from the ongoing taking of measurements. Data communication between the measurement computer and the downhole probe is digital, therefore it is not affected by the 1500 m long cable.

Once it commences, measurement is fully automatized and can be monitored remotely. This utility provides a cost efficient way of conducting the measurements, as manual labour is needed only when the measurement setup is changed and a new measurement run started. Usually this can be done during the daytime. Depending on the length of the measured borehole, the actual measurement can be conducted during the following night.

The range and accuracy of measurements conducted with PFL equipment are presented in ***Table 3-1***. The ranges and accuracies are either from the sensor manufacturer or determined based on calibration at laboratory. The specifications have been checked to be valid based on calibration but, for example, flow and temperature measurements can be affected by conditions in the borehole. For example, flow measurement can be affected by salinity changes in borehole water. Usually, this can be seen as an elevated lower limit of measurement range, but this has not been seen to affect measurement accuracy.

Table 3-1. *Range and accuracy of sensors in the PFL DIFF equipment.*

Sensor	Range	Accuracy
Flow	30 – 300 000 mL/h	±10% curr. value
Temperature (central thermistor)	0 – 50 °C	0.1 °C
Temperature difference (between outer thermistors)	−2 – (+2) °C	0.0001 °C
Electrical conductivity of water (EC)	0.02 – 11 S/m	±5% curr. value
Single point resistance	5 – 500 000 Ω	±10% curr. value
Groundwater level sensor	0 – 0.1 MPa	±1% full-scale
Air pressure sensor	800 – 1060 hPa	±5 hPa
Absolute pressure sensor	0 – 20 MPa	±0.01% full-scale

The quality of PFL DIFF measurement results are assured by calibrating equipment annually. Moreover, quality checks are done during measurements. The quality checks during the measurements include estimating the rationality of measured values (large errors), comparing measured parameters when possible (changes in values from water level sensor and pressure sensor should be equal if the probe is not moved and three thermistors should give the same temperature value) and comparing flow rate calculated using different calibration functions.

PFL DIFF probes (***Figure 2-1***) undergo the calibration process annually. The basic annual calibration includes the calibration of flow, electrical conductivity (EC), single point resistance (SPR), absolute pressure and temperature sensors. In addition to PFL DIFF probes, PFL trailers contain sensors that are used in measurements. These are the pressure sensor for borehole water level monitoring and the air pressure sensor. These are also calibrated annually. The PFL trailer has cable with length markings and due to the stretching of the cable, the locations of length markings are checked at the calibration course. The procedures for individual calibrations are listed below.

- Temperature: The flow sensor includes three thermistors and the temperature calibration has to be carried out before flow calibration. The thermistors' resistivity changes in relation to temperature. Therefore, based on the calibration function, temperature is determined based on resistivity. In the calibration process, temperature between 5–50 degrees Celsius is measured using a high precision thermometer and thermistors' resistivity is recorded. The calibration function is fitted based on the dependency between resistivity and temperature.

- Flow rate: The flow sensor is calibrated by pumping water through a flow sensor and comparing the measured flow value with the PFL DIFF probe and reference value. The reference value is obtained by measuring the amount of water that flows through the flow sensor in one minute with a precision scale. The annual calibration confirms the previous calibration results at room temperature. In case calibration functions that have been proved to be valid no changes are needed. Full flow sensor calibration is needed if calibration functions need to be changed based on basic calibration. This means calibrations in two different temperatures.

- Electrical conductivity: The EC sensor is calibrated using at least two different conductivity standard liquids. Full calibration with at least 6 liquids is conducted annually or when the calibration function needs to be changed based on basic calibration.

- The actual quantity that an EC electrode measures is electrical resistivity (Ω), which is converted to conductivity (S/m). In the calibration process, temperature of the liquid is measured and the EC value in the measured temperature is plotted as a function of resistance measured with the PFL DIFF probe.

- Single point resistivity: The SPR sensor is calibrated by connecting the SPR electrode to the body of a PFL DIFF probe with a known reference resistor and checking if the measured value is the same. A total of 18 reference resistors between 1 Ω and 200 kΩ are used for calibration.

- Absolute pressure: The pressure sensor inside the PFL DIFF probe is calibrated comparing it to the reference pressure sensor. If the pressure value has a constant error throughout the measurement range, this is compensated by adding offset calibration. If linearity (error depends on pressure value) of the sensor changes the sensor is sent to the manufacturer for calibration.

- Air pressure: Air pressure measured with a barometer in the PFL Trailer is compared to air pressure data from other onsite barometric measurements. Pressure offset can be compensated, but in case of linearity errors sensors needs to be sent to the manufacturer for calibration.

- Water level sensor: The pressure sensor for water level measurement is calibrated using a calibration pump that includes a reference pressure sensor. Small changes are compensated by calibration function. In case of large errors, the sensor is replaced with a new one.

- Cable length: Cables in PFL Trailers are known to stretch under tension and the stretching is partially permanent, meaning that the cable becomes slightly longer over the years of use. To compensate for stretching, cable marks are attached to new cables before taking them into use. In the cable calibration process the cable is laid on the calibration course and positions of marks are compared to length calibration points on the course. During the comparison, the tension of the cable is about 120 kg (average tension in measurements). The cable length marks are not removed but the error is recorded in the cable calibration file so that the error can be compensated for when the measurements are interpreted. The cable calibration is valid for a period of two years after calibration. As the cable tension during measurement depends on such factors as borehole inclination, logging direction and probe setup, the tension can be something other than 120 kg (tension during calibration). Based on information from the cable manufacturer, the cable's stretching is 1.15 m/km/kN. In PFL DIFF loggings, the cable tension is usually between 75 kg and 200 kg, therefore the error in length determination is estimated to be less than one metre at a length of 1000 m.

In addition to the above calibration activities, equipment checks are also made at the site. Prior to the PFL DIFF runs, the water level is measured with a manual dipmeter and the result is compared to results obtained with a water level sensor and the PFL DIFF probe. The pumping rate recorded by the flow meter is checked by measuring flow rate with a graduated bucket and stopwatch.

4 INTERPRETATION

4.1 Equivalent freshwater hydraulic head

The absolute pressure sensor of the PFL DIFF probe measures the sum of atmospheric pressure and the hydrostatic pressure in the borehole. Atmospheric pressure is registered also separately. The equivalent freshwater hydraulic head along the borehole under natural and pumped conditions can be determined from the measured data. The atmospheric pressure recorded at the site is first subtracted from the absolute pressure measured by the pressure sensor and the equivalent freshwater hydraulic head can then be calculated.

The equivalent freshwater hydraulic head (h) at a certain elevation z is calculated using the following expression:

$$h = \frac{p_{\mathrm{abs}} - p_{\mathrm{b}}}{\rho \cdot g} + z \qquad \text{4-1}$$

Where
h is the equivalent freshwater hydraulic head (masl)
p_{abs} is the absolute pressure (Pa)
p_{b} is the barometric (atmospheric) pressure (Pa)
ρ is the density of water 1000 kg/m^3
g is the standard gravity 9.80665 m/s^2
z is the elevation at the measurement location (masl)

Exact z-coordinates are important in calculating equivalent freshwater hydraulic head as an error in the z-coordinate leads to an equal error in the calculated head.

4.2 Transmissivity and equivalent freshwater hydraulic head of fracture

Measured flow rates are interpreted to transmissivities by using Thiem's formula, which describes a steady-state and two-dimensional radial flow into the borehole (Marsily 1986):

$$h_f - h = \frac{Q}{T \cdot a} \qquad \text{4-2}$$

Where
h is the equivalent freshwater hydraulic head in the borehole (at borehole radius r_0)
h_{f} is the equivalent freshwater hydraulic head at the radius of influence (R)
Q is the flow rate into the borehole
T is the transmissivity of the test section
a is a constant that depends on the assumed flow geometry

For radial flow, the parameter a is:

$$a = \frac{2\pi}{\ln(R/r_0)} \qquad \text{4-3}$$

Where

r_0 is the radius of the borehole

R is the radius of influence, i.e., distance to a constant head boundary

If measurements of flow rate are carried out using two levels of hydraulic head in the borehole, i.e., in natural and in pumped conditions, then the undisturbed (natural) equivalent freshwater hydraulic head and the transmissivity of the tested borehole sections can be calculated. Equation 4-2 can be written for the undisturbed and pumped conditions as:

$$Q_0 = T_\mathrm{f} \cdot a \cdot (h_\mathrm{f} - h_0) \text{ and} \qquad \text{4-4}$$

$$Q_1 = T_\mathrm{f} \cdot a \cdot (h_\mathrm{f} - h_1) \qquad \text{4-5}$$

Where

h_0 and h_1 are the equivalent freshwater hydraulic heads in the borehole at the test level

Q_0 and Q_1 are the measured flow rates in the test section

T_f is the transmissivity of the test section

h_f is the undisturbed equivalent freshwater hydraulic head in the tested zone far from the borehole

In general, since very little is known about the flow geometry, radial flow without skin zones is assumed. Radial flow geometry is also justified because the borehole is at a constant head, and no strong pressure gradients along the borehole exist except at its ends.

The radial distance R to the undisturbed hydraulic head h_f is not known and must therefore be assumed. In this case, a value of 500 for the quotient R/r_0 is selected. This corresponds to a radius of influence in the order of 24 m when the diameter of the borehole is 96 mm. The assumption of constant radius of influence leads to definition of PFL transmissivity which is practically $\Delta Q/\Delta h$, i.e. the specific capacity ($T_\mathrm{PFL} \approx \Delta Q/\Delta h$).

Equivalent freshwater hydraulic head h_s and the PFL transmissivity $T_\mathrm{PFL,f}$ can be calculated using the results from two separate measurements applying the following equations,

$$h_\mathrm{f} = \frac{h_0 - bh_1}{1 - b} \text{ and} \qquad \text{4-6}$$

$$T_\mathrm{PFL,f} = \frac{1}{a} \cdot \frac{Q_0 - Q_1}{h_1 - h_0} \qquad \text{4-7}$$

Where $b = Q_0/Q_1$

4.3 Sensitivity of transmissivity and head to the errors in flow and pressure measurements

The flow measurements are conducted in two pressure conditions to provide data for calculation of fracture transmissivity and head. In theory the two pressure conditions can be any pressures as long as they are not the same. In reality the difference between the pressures has to be large enough to cause notable changes in flow but still keep the pumping rate at reasonable level so that fracture flows would be mostly within the measurement limits (i.e. under the upper limit of measurable flow rate, see Section 2.1 for details). Achieving notable changes in flow rate is important because if flow rates are near equal, even a small error in measured flow can cause a significant error when calculating transmissivity and head. The most commonly used drawdown in PFL DIFF measurements is 10 m.

The Figure 4-1 shows how the measurement accuracy of flow rate and pressure affects the precision of transmissivity and fracture/section head interpretation. Blue and red dots, measurement runs 1 and 2 respectively, represent the measured flow and head values. The slope of the black line that has been drawn along trough the measurement runs 1 and 2 points is inversely proportional to the transmissivity (Eq. 4-2). The head of fracture or section is the head value at which the flow is zero, which is plotted in Figure 4-1 with a black cross.

The error in flow rate measurement is within ±10% of the measured value, and the accuracy of absolute pressure sensor ±2 kPa which implies ±0.2 m error in head. The blue and red lines with arrow endings in Figure 4-1 represent the errors of measured flow and head values (±10% in flow, ±0.2 m in head). A rectangle shape formed from the lines represents the accuracy of the measurements, i.e. the measurement run value should be within the rectangles when errors are taken into account. Orange line in the figure indicates the maximum transmissivity (T_{max}) and the green line minimum transmissivity (T_{min}) that is calculated with the error limits. The highest fracture head value (h_{max}) is plotted with an orange cross and the lowest head value (h_{min}) with a green cross.

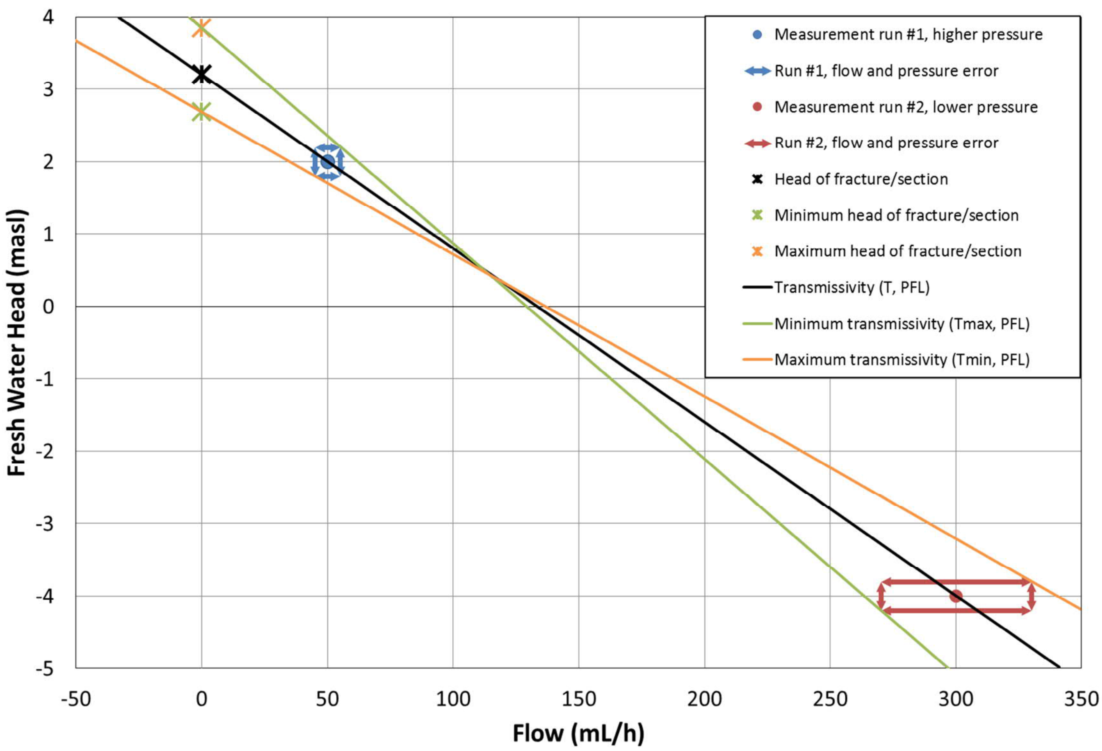


Figure 4-1. *Demonstrative plot how measurement accuracy of flow rate and pressure affects derivation of transmissivity and head.*

The Figure 4-1 represents a case in which flow rates in both pressure conditions have been positive. It is possible that flow direction changes between the measurements or flow rate cannot be determined in both pressure conditions. When flow directions are different, lowest fracture/section head is not necessarily determined by line representing the largest transmissivity as in Figure 4-1, but the same principles apply. If the flow rate cannot be determined for both measurements, a zero flow value is used in transmissivity and head calculations instead. In error calculation the rectangle determining all possible values is formed by estimating what is the highest flow rate that should be detectable based on the measurement. For example if lower limit of flow measurement is 30 mL/h, the fracture flow rate must be something between –33 mL/h and 33 mL/h when taking the possible error in flow measurement into account. This means that in these conditions fractures with transmissivity smaller than $1.44 \cdot 10^{-9}$ m^2/s can be missed.

5 EXECUTION OF MEASUREMENTS

Before flow measurements are conducted, a dummy logging is performed in boreholes in order to assess the borehole suitability for the PFL measurements. The dummy collects loose solid material from a borehole wall. The solid material collected by the dummy is used to evaluate whether it is safe to continue measurements with the PFL DIFF equipment. Dummy logging is considered successful if there are no stones exceeding the thickness limit of 3 mm (smallest dimension of a solid) inside the dummy when it is lifted up from a borehole. Dummy logging does not completely eliminate the risk of equipment getting stuck but it obviously reduces the risk, as well as provides crucial information on the openness of a borehole. Technical illustration of dummy probe is presented in Figure 5-1. Dummy probe was modified to be suitable for 96 mm borehole by adding plastic cover to enlarge the diameter of the dummy probe.

Figure 5-1. *Dummy probe for 76 mm boreholes.*

Full length of the borehole IG_BH04 was dummy logged two times. At first run there was large rock (c. 5 cm) and many smaller ones in the dummy probe. After the second run there was only small rocks and borehole was assessed to be safe for using the actual measurement probe. At length of 855 m (upper end of dummy probe) movement of dummy probe stopped due to tension limit. The dummy probe was moved back and forth couple of times and the dummy probe passed the above mentioned length eventually. Presumably there was bad section in the borehole but it did not cause more problems later on.

The measurements in IG_BH04 were carried out between July 13th and 17th 2021. The measurement programme is presented below.

1. Flow logging without pumping (length of section = 5.0 m, step = 0.5 m).
2. Flow logging with pumping (length of section = 5.0 m, step = 0.5 m).
3. Flow logging with pumping (length of section = 0.5 m, step = 0.1 m).

The performed measurements are listed in chronological order in Table 5-1. The results are discussed in more detail in Chapter 6 .

Table 5-1. *Table of performed PFL DIFF measurements in IG_BH04.*

Started	Finished	Lengths	Activity
13.7.2021 11:48	14.7.2021 15:44	93.86 - 988.9m	Flow logging without pumping, section length 5 m.
14.7.2021 18:24	16.7.2021 07:18	93.77 - 988.9 m	Flow logging with pumping, section length 5 m.
16.7.2021 9:58	17.7.2021 14:50	99.39 - 122.83 m 579.17 - 582.19 m 612.85 - 622.42 m 636.52 - 369.03 m 722.57 - 725.57 m 731.58 - 736.08 m 978.83 - 984.84 m	Flow logging with pumping, section length 0.5 m.

6 RESULTS

The measurement results are presented in plots and tables in the appendices. The list of the appendices can be found after the Table of Contents.

6.1 Flow logging and single point resistance (SPR)

The measurement programme for the boreholes contained several flow logging sequences. These were collected into the same diagram with pressure and SPR results; see the appendices IG_BH04.1.1 – IG_BH04.1.45 titled “Flow rate, pressure and single point resistance”. SPR has usually a lower value of resistance on a fracture where flow is detected. Many other resistance anomalies result from other fractures and geological features. As the SPR electrode is located between the upper rubber sealing disks of the PFL DIFF tool, the locations of resistance anomalies associated with leaky fractures coincide with the lower end of the flow anomalies.

Detected fractures are shown on the length scale together with their locations. As they are interpreted on the basis of flow curves, they represent transmissive fractures. Coloured triangles show the magnitude and direction of flows.

The very bottom section of a borehole remains always unmeasured since there are weights and a centralizer attached to the lower end of the PFL DIFF tool. The total length of weights and the centralizer was 5 meters. The rubber sealing disks fitted to the PFL DIFF probe must also be “flipped” (to achieve correct orientation of the rubber disks) before starting the measurement and this requirement reduces the total measurable borehole length by at least an additional ca. 20 cm. Fallen rock and debris at the lowest point of a borehole are also common, thus preventing measurement from being started from the very bottom. The lowest measurement point in the borehole was 988.9 m. In this location the measurement section covered length interval from 993.9 m to 988.9 m. Based on these dimensions lower end of weights was lowered to length of 999.1 m. Length of borehole is 1000.2 m.

Magnitude of fracture-specific flow rates on the basis of the measurement results were evaluated. The first step in this procedure is to identify the locations of individual transmissive fractures and then evaluate their flow rates. At first fracture locations are evaluated based on flow measurement results obtained from measurement conducted with 5 m long measurement section. More precise location of a fracture and flow rate is determined based on results obtained from measurement conducted with 0.5 m long measurement section. In cases where the distance between individual fractures is less than half a metre, it may be difficult to evaluate flow rates. In such cases, a stepwise increase or decrease in the flow data plot is equivalent to the flow rate of a specific fracture.

In unpumped conditions only 5 m long measurement section was used and that measurement run was used to determine fracture flow rate in unpumped conditions. If fracture has been found but flow rate cannot be determined either in unpumped conditions or in pumped conditions detection limit is reported instead. At length of 113.7 m fracture was detected but flow rate in unpumped conditions could not be determined as it was below the noise/base level of flow results. ±20 ml/h was marked to indicate that there can be flow but it is something between -20 ml/h and +20 ml/h.

In general detection limit throughout the borehole was below 30 ml/h meaning that all flows above 30 ml/h have most probably been detected. At lengths of 373 m and 392 m drilling of borehole has been steered with wedges and these caused increased detection limit. The rubber disks probably leaked and caused flow through the flow sensor. Based on SPR results wedges are shorter than 5 meters so they fit within measurement section and therefore possible fractures would have been detected.

6.2 Transmissivity and equivalent freshwater hydraulic head in fractures

Equivalent freshwater hydraulic head and transmissivity of fractures ($T_{PFL,f}$) were calculated from the flow data using the method described in Chapter 4 . The plotted results of these calculations are presented in Appendix IG_BH04.2 titled “Transmissivity and head of detected fractures”. Equivalent freshwatetr hydraulic head in measured fractures is stated in the plots if both of the flow values at the same length were non-zero. Transmissivity is stated for every detected fracture.

The measured flow rates, transmissivity and equivalent freshwater hydraulic head for each detected fracture in a tabulated form are presented in Appendix IG_BH04.3 titled “Table of transmissivity and head of detected fractures”. Minimum transmissivity (T_{min}), maximum transmissivity (T_{max}), minimum head of fracture ($HeadOfF_{min}$) and maximum head of fracture ($HeadOfF_{max}$) were calculated for each fracture as described in Section 4.3 . The results have been presented in same figures and tables.

The highest fracture transmissivity was $9.97*10^{-7}$ m^2/s and the lowest $5.37*10^{-10}$ m^2/s. The lowest value is quite uncertain as flow rate in pumped conditions was 24 ml/h and detection limit during flow logging in unpumped conditions was ±20. The reported transmissivity value has been calculated assuming flow in unpumped conditions was 0 ml/h but in reality it can be anything between -20 ml/h and +20ml/h. For this fracture maximum transmissivity limit ($1.12*10^{-9}$ m^2/s) could be calculated but no minimum limit.

Hydraulic conductivity of borehole sections have been calculated based on fracture transmissivities by summing up fracture transmissivities in borehole section and dividing the sum by length of borehole section. The results have been presented in Appendix IG_BH04.4 titled "Hydraulic conductivity (K) of 5 m sections" and Appendix IG_BH04.5 titled "Table of hydraulic conductivity of 5 m sections".

6.3 Equivalent freshwater hydraulic head, water level, air pressure and pumping rate

Equivalent freshwater hydraulic head in the borehole during the flow measurements, as described in Section 4.1 , is presented in Appendix IG_BH04.6. Water level in the borehole, air pressure and pumping rate during the performed flow measurements are presented in Appendix IG_BH04.7.

Water level stayed stable (variation 0.14 m) during measurement run 1. Measurement runs 2 and 3 were conducted while borehole was pumped and drawdown was c. 13 m. During measurement run 2 water level varied quite lot, drawdown being between 12.1 m and 13.7 m. In this case this was acceptable as main objective of measurement run 2 was to detect flowing fractures not to measure flow rates in steady pressure conditions. The reason for varying water level was difficulties to maintain steady low pumping rate. Pumping rate was clearly below 1 l/min but it is difficult to say the exact pumping rate as the pumping rate varied quite a lot and therefore it was difficult to measure with a graduated bucket. The pump applied has capacity of c. 50 l/min and it was used in a way that most of the pumped water was circulated back to borehole so that pump has enough water to pump. Nevertheless adjusting the circulation was quite difficult and this affected pumping rate and water level. During the run 3 measurement operator adjusted the water circulation more frequently and water level stayed more stable but still water level varied c. 0.65 m. When comparing to drawdown of 13 m this was not considered to be problem in regards with determining fracture transmissivities.

Water was not pumped out of the borehole during measurement run 1 therefore all water coming into borehole should also exit the borehole. Only two flowing fractures were detected in unpumped conditions. At length of 580.9 m flow rate into borehole was 1900 ml/h and at length of 616.5 m flow rate into fracture was 142 ml/h. There is quite large unbalance between in and out flows. Reason for unbalance is unclear but possibility that such a large outflow had been missed is very small. Possible reasons for unbalance are leakage at casing pipe or between casing pipe and bedrock, fracture at very bottom of the borehole that could not be measured and unstable pressure conditions during measurement run (especially when transmissivity is large even a small change in water level can have large effect to fracture flow rate)

Pumping rate was difficult to determine accurately but order of magnitude was 0.5 l/min. Sum of fracture flows in pumped conditions was 0.749 l/min so it is of the same order of magnitude.

6.4 Electrical conductivity and temperature

Electrical conductivity and temperature of water was measured during every flow logging run. It should be noted that these results represent the water conditions in measurement section. When the probe is moved along the borehole it carries water within the measurement section and therefore the results does not necessarily represent the borehole water conditions in the measured length. The main objective of these measurements is to monitor conditions in borehole as they might affect the measurement results especially lower limit of flow results.

Electrical conductivity and temperature results have been presented in Appendices IG_BH04.8 and IG_BH04.9. The highest measured electrical conductivity value was measured at the bottom of the borehole (0.36 S/m). In the upper parts of the borehole electrical conductivity is lower and effect of pumping can be seen when results from measurement runs conducted in unpumped conditions and in pumped conditions are compared. Especially between length of 440 m and 580 m it can be seen that water coming from fracture 580.9 m is being carried upwards in the borehole and electrical conductivity at this length interval is clearly higher in pumped conditions.

6.5 Summary of results

Three measurement runs were conducted in borehole IG_BH04. One in unpumped conditions and two while borehole was pumped to obtain 13 m drawdown in water level. Total of four water flowing fractures were found and total flow from fractures into borehole was 749 ml/min with 13 m drawdown.

Quality of results is good. Flow detection limit was below c. 30 ml/h throughout the borehole. The quality of SPR results enabled length matching between different measurement runs. Pressure measurements and water level measurement were successful. The variation in pressure measurements is due to problems with pumping. Pumping equipment used is meant for higher pumping rates and in this case pumping rate was clearly below 1 l/min.

Fracture with the largest transmissivity was found at length of 580.9 m ($9.97*10^{-7}$ m^2/s).

Electrical conductivity of water was measured in connection with flow logging. The highest electrical conductivity values (0.36 S/m) were found at bottom of the borehole.

7 NONCONFORMITIES

Dummy logging was repeated two times as there was large rock in the dummy probe after it was lifted out of the borehole after the first run (**Figure 7-1**). When the dummy probe was moved upwards in the borehole during the second run it got partially stuck at length of 855 m (upper end of dummy probe). Dummy probe was released downwards and after three attempts to pass the location the probe went through the length.

Figure 7-1. Rock inside dummy probe after the first dummy run.

Total flow out of the borehole was very small while 13 m drawdown was created to borehole by pumping water out of the borehole. Pumping rate flow meter has not been designed to measure such a low flow rate therefore pumping rate had to be measured with a graduated bucket and stop watch. Based on the measurements pumping rate decreased during the pumping period and it is difficult to say how stabile the pumping rate has been during the measurement runs and what is the average pumping rate. This imply transient flow conditions in borehole. Fracture flow at length of 580.9 m was clearly larger than flows from other fractures while borehole was pumped therefore it can be assumed that flow from this fracture changed. Flow changes in other detected fractures cannot be ruled out but they cannot be confirmed either. Based on pumping rate change transmissivity of fracture at length of 580.9 m can be smaller than reported but not larger. In ideal situation pumping would be continued so long that it stabilizes before measurement is started but due to time constraints this is not possible.

Maintaining a very low and at the same time steady and constant pumping rate turned out to be difficult. The best attempt was made to keep the pumping rate as constant as possible by circulating most of the water back to borehole. In addition, the water circulation was used to prevent driving the pump without load. Controlling the circulation was difficult and at the end water level was at pump inlet in which case air got into pump. This caused water level to change about 0.5 m quite fast. Half a meter is not very significant compared to 13 m drawdown therefore is was acceptable especially during measurement run 2 when objective was to detect flowing fractures not to measure steady flow rate. During measurement run 3 pumping was monitored by measurement operator which eliminated notable changes in water level. Only at the end of measurement run 3 water level rose because pump had to be lifted out of the borehole to get probe pass the lower end of casing pipe. Lower end of casing pipe had sharp edge and it cut the centralizer in a way that the probe got stuck (**Figure 7-2**). After several attempts probe passed the lower end of casing pipe. Flowing fractures had not been detected at this length so changed water level did not matter.

Figure 7-2. A cut at PFL probe centralizer caused by sharp edge at lower end of casing pipe.

8 SUMMARY

Difference flow and other related measurements were performed in borehole IG_BH04 in July 2021 at the Ignace investigation site. Three measurement runs were conducted. The first run was conducted with 5 m long measurement section in unpumped conditions. The second run also with 5 m long section but conducted in pumped conditions with c. 13 m drawdown in borehole water level. In the third run borehole sections where fractures were found were measured with 0.5 m long measurement section. Fracture locations were determined based on this measurement run.

The locations of water-conducting fractures were obtained with the resolution of 0.1 m. The transmissivity and equivalent freshwater hydraulic head of these fractures were calculated from the flow and pressure results. Equivalent freshwater hydraulic conductivity of borehole sections were also calculated based on fracture transmissivities. Altogether 4 flowing fractures were found at 888.3 m borehole length. The upper most fracture was found at length of 113.7 m and lowest at length of 620.6 m. The highest transmissivity was $9.97*10^{-7}$ m^2/s and lowest $5.37*10^{-10}$ m^2/s. Base level of flow measurement was below 30 ml/h which means that larger flows have not been missed.

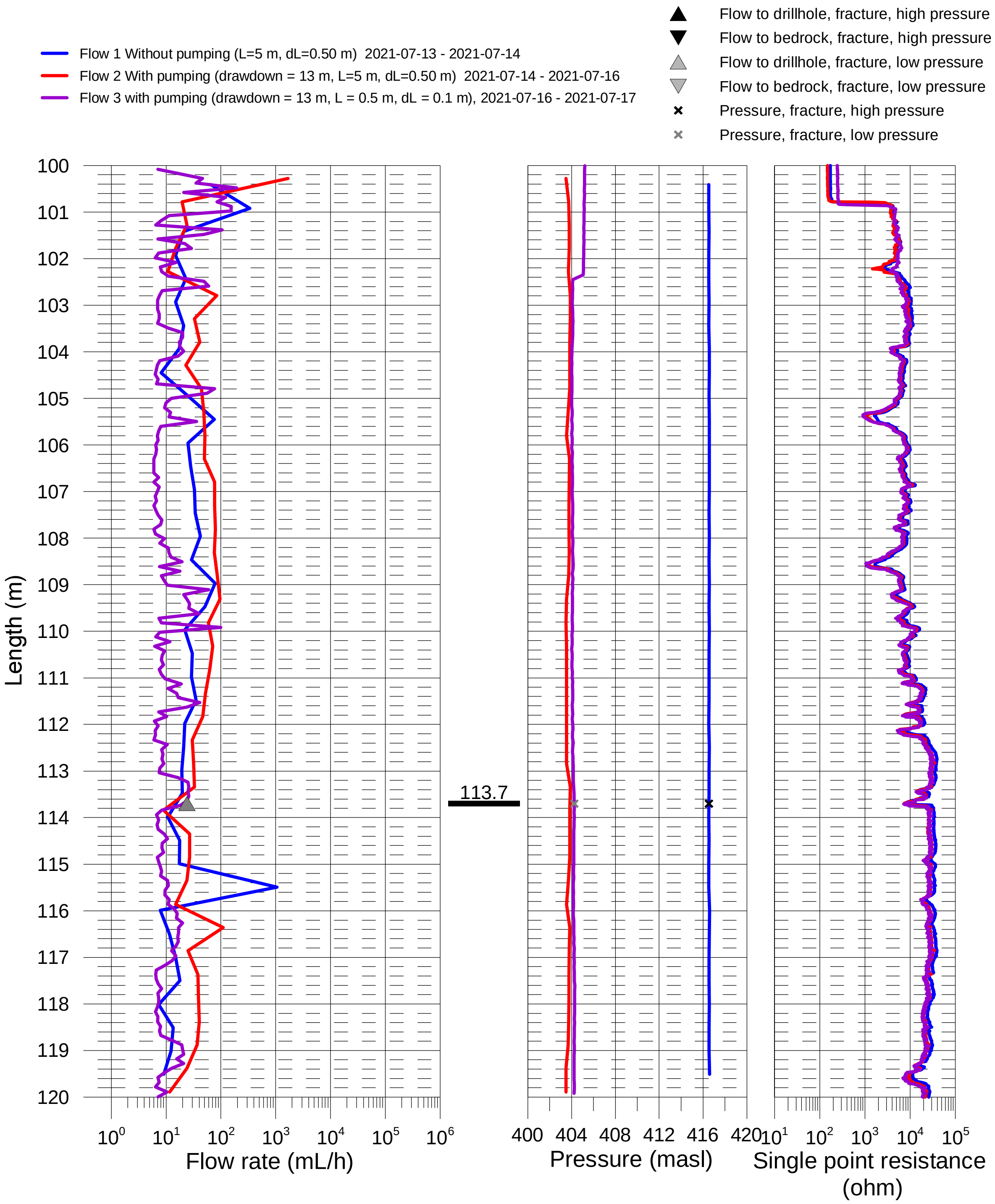
Electrical conductivity of water was measured alongside with flow logging. The highest electrical conductivity value (0.47 S/m) was found at bottom of the borehole.

Measured and derived results have been presented in appendices. Flow, pressure and single point resistance measurement results are presented in multiple plots each covering 20 m of borehole length. Derived transmissivity and equivalent freshwater hydraulic head values have been presented in plots and tables.

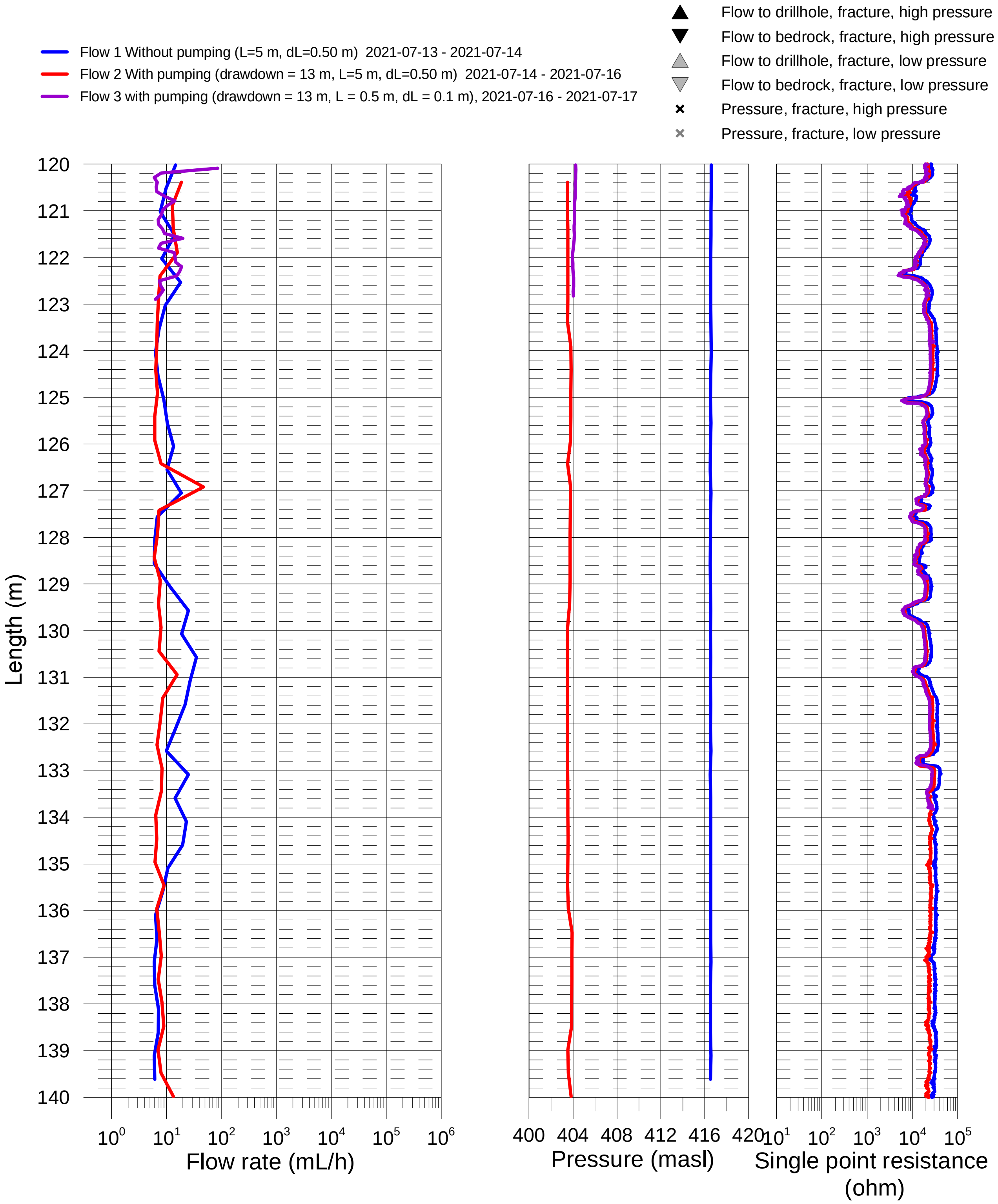
REFERENCES

Marsily, G., 1986. Quantitive Hydrology, Groundwater Hydrology for Engineers. Academic Press, Inc., London

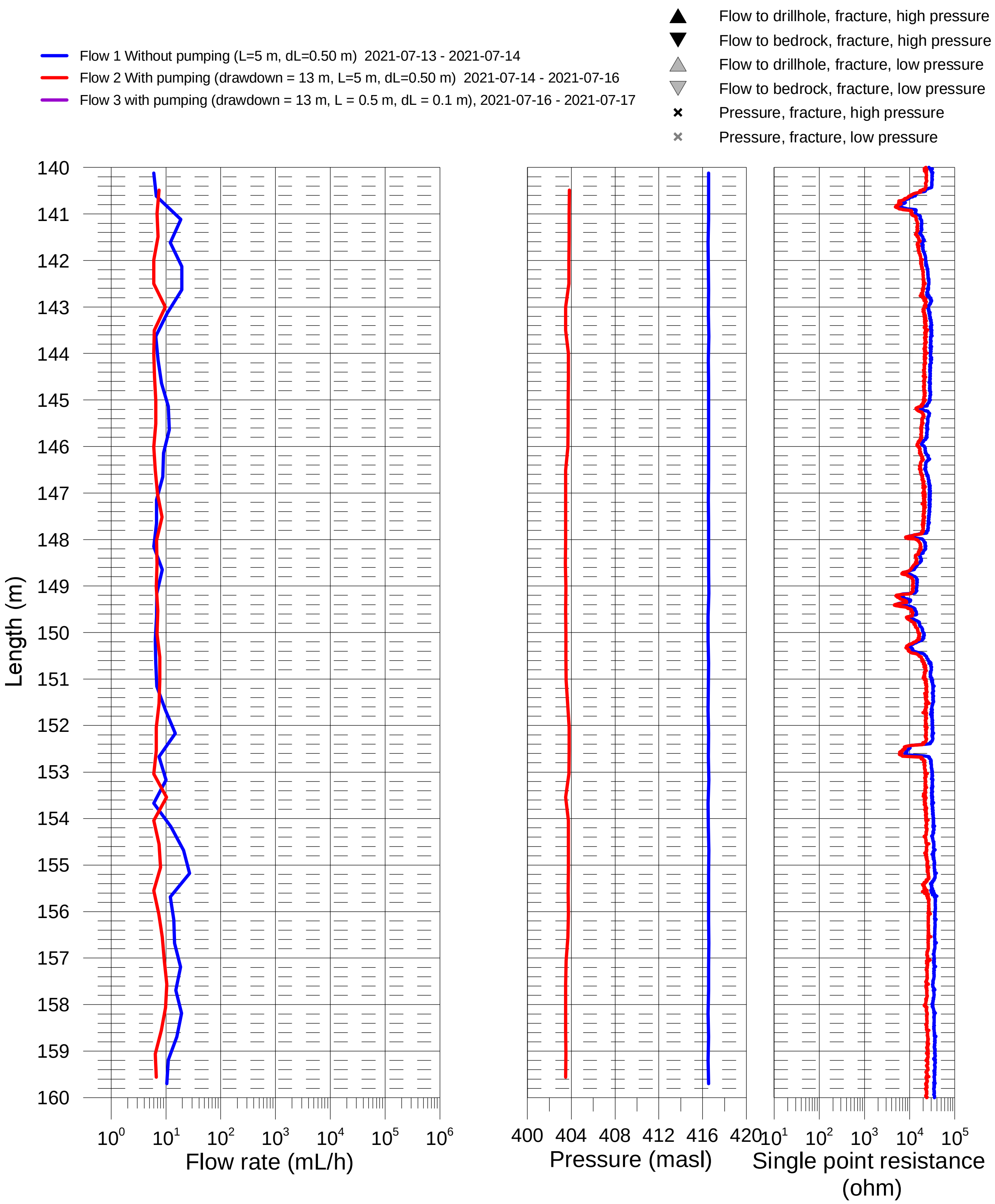
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



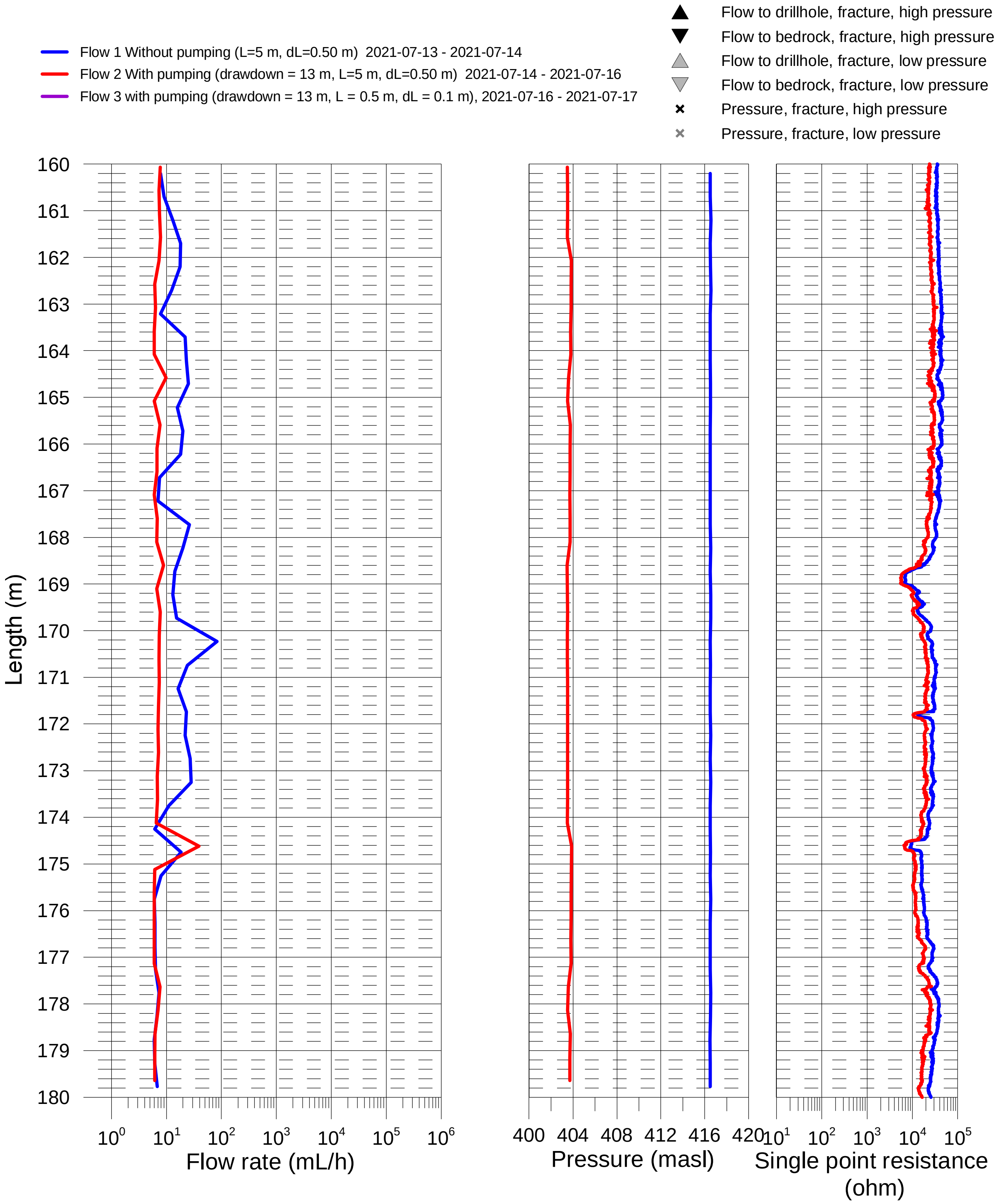
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



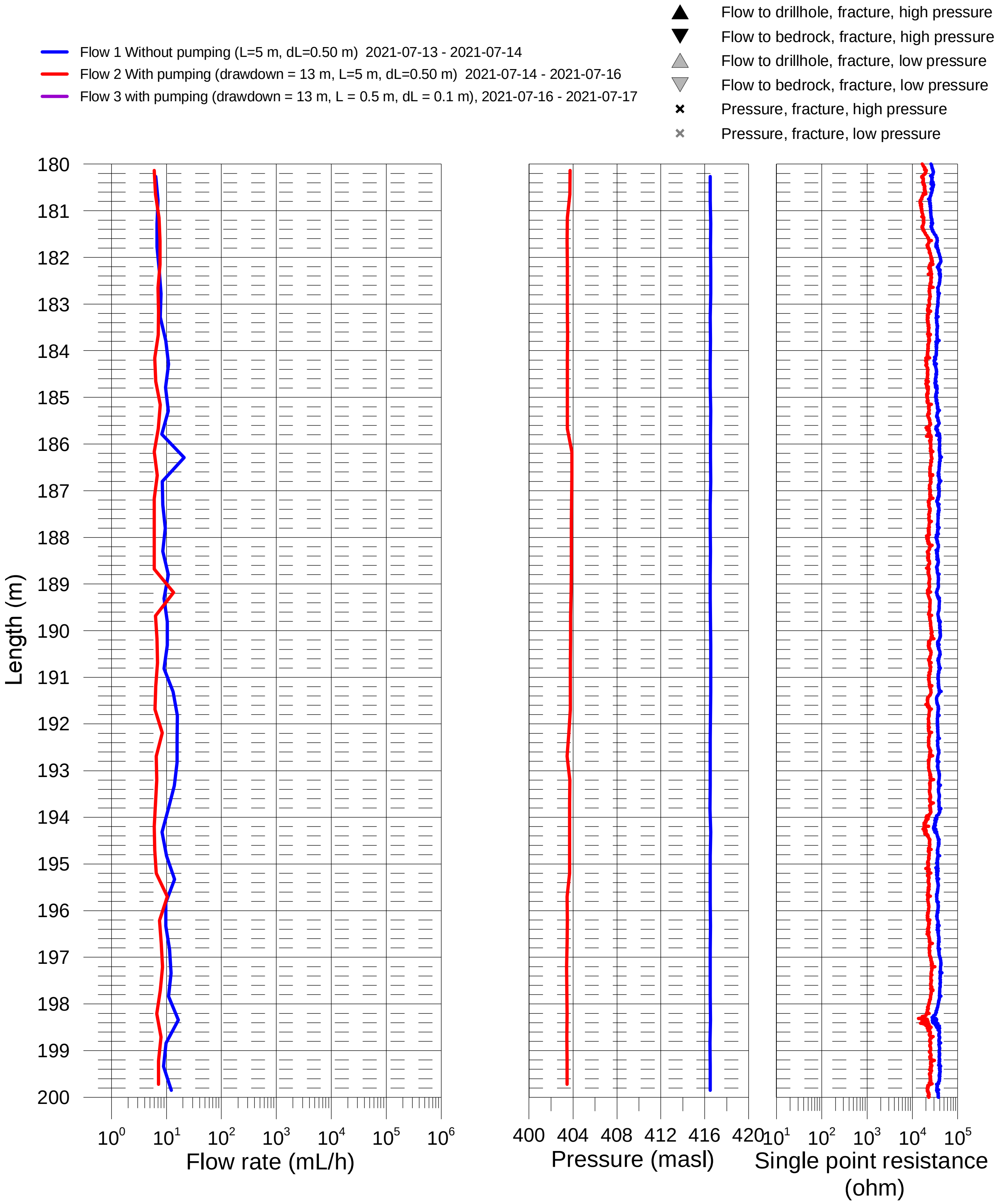
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



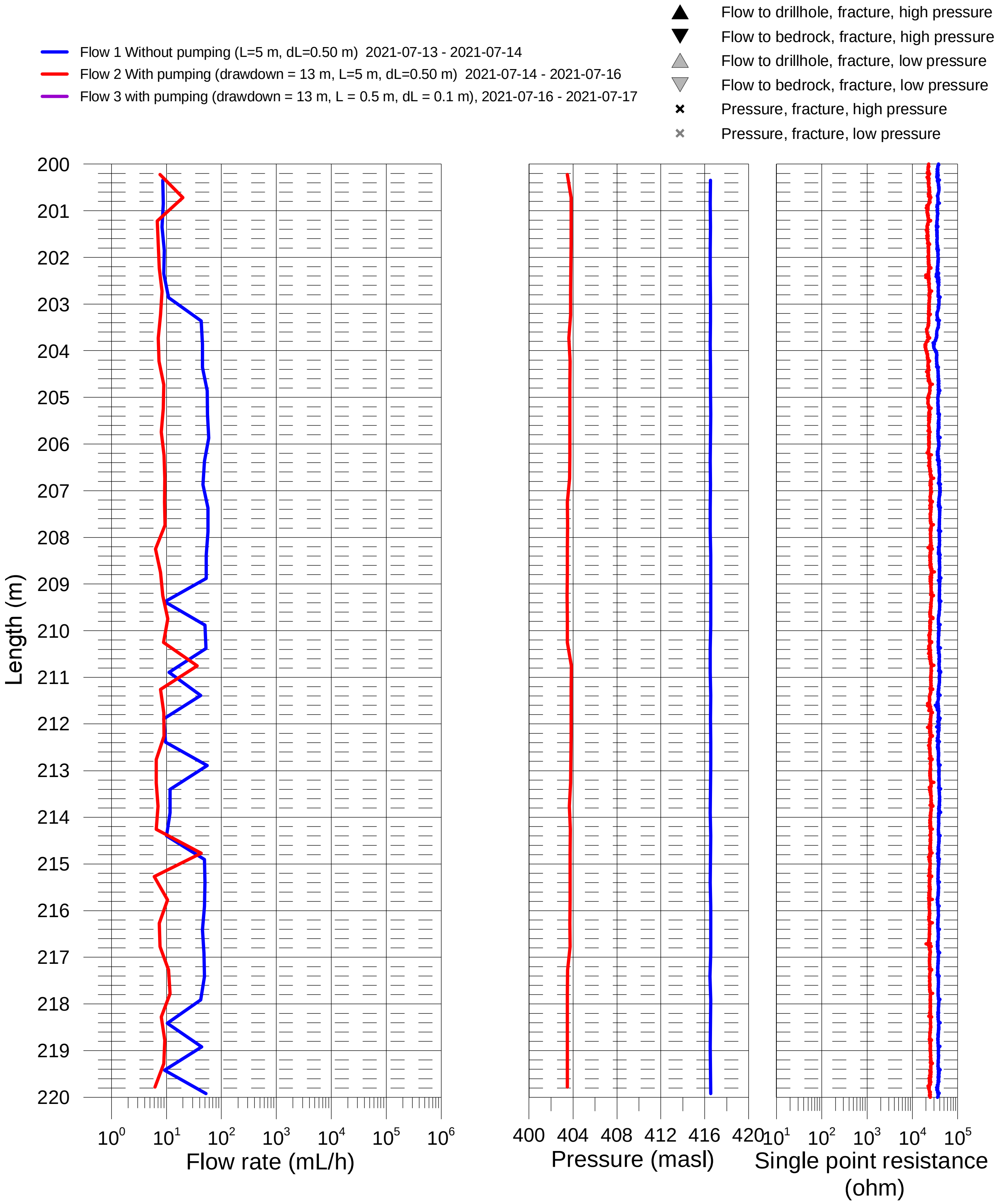
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



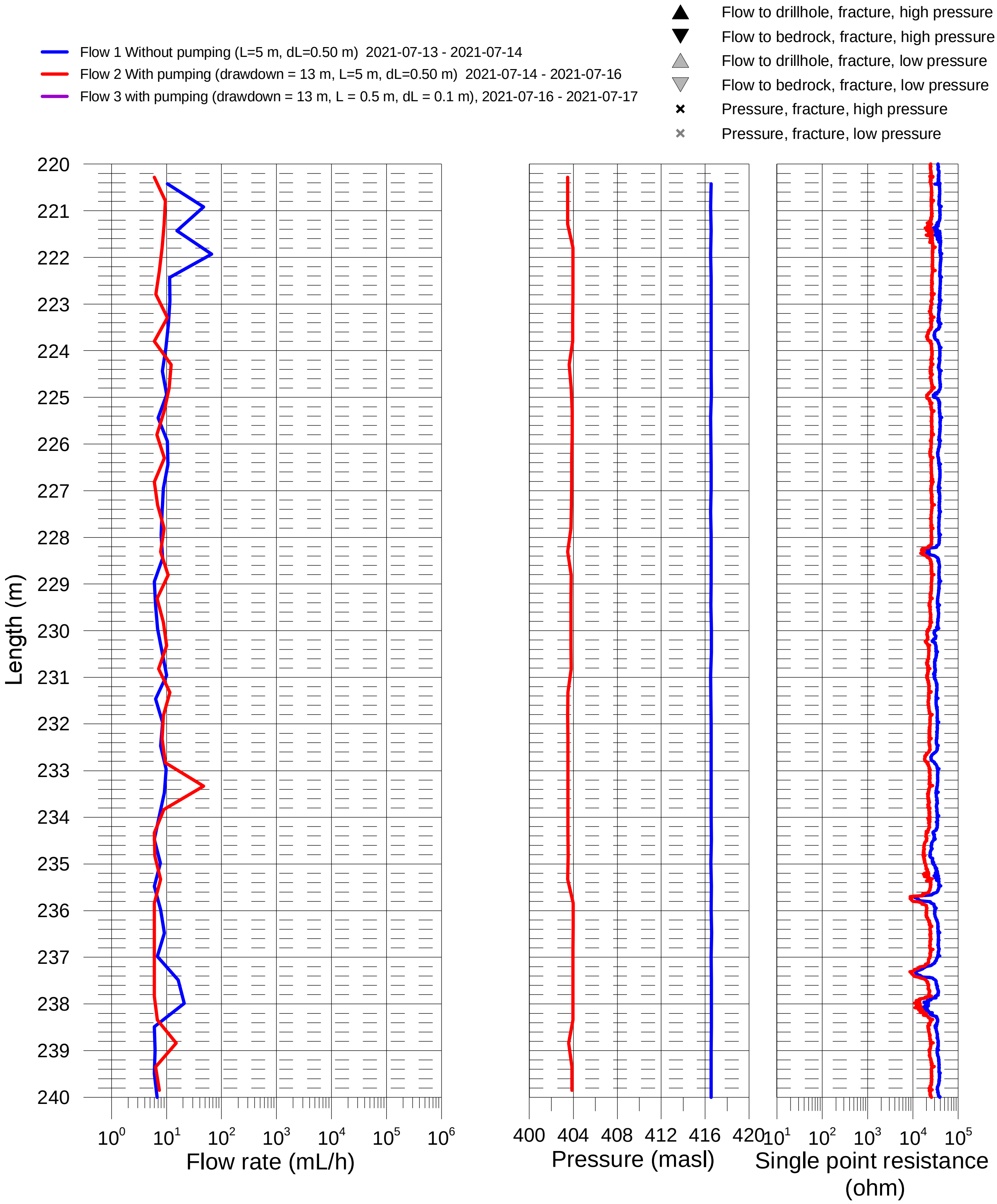
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



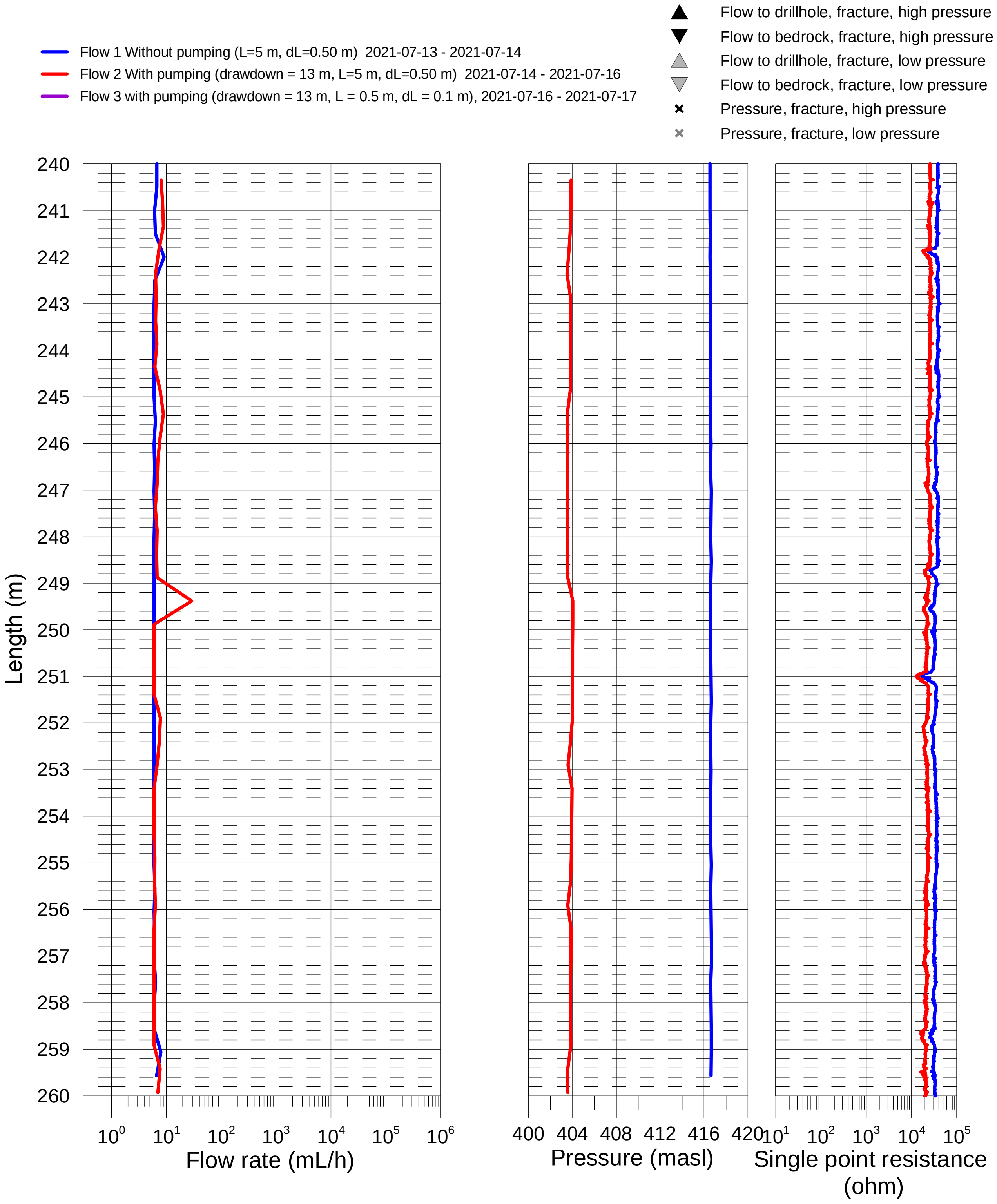
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



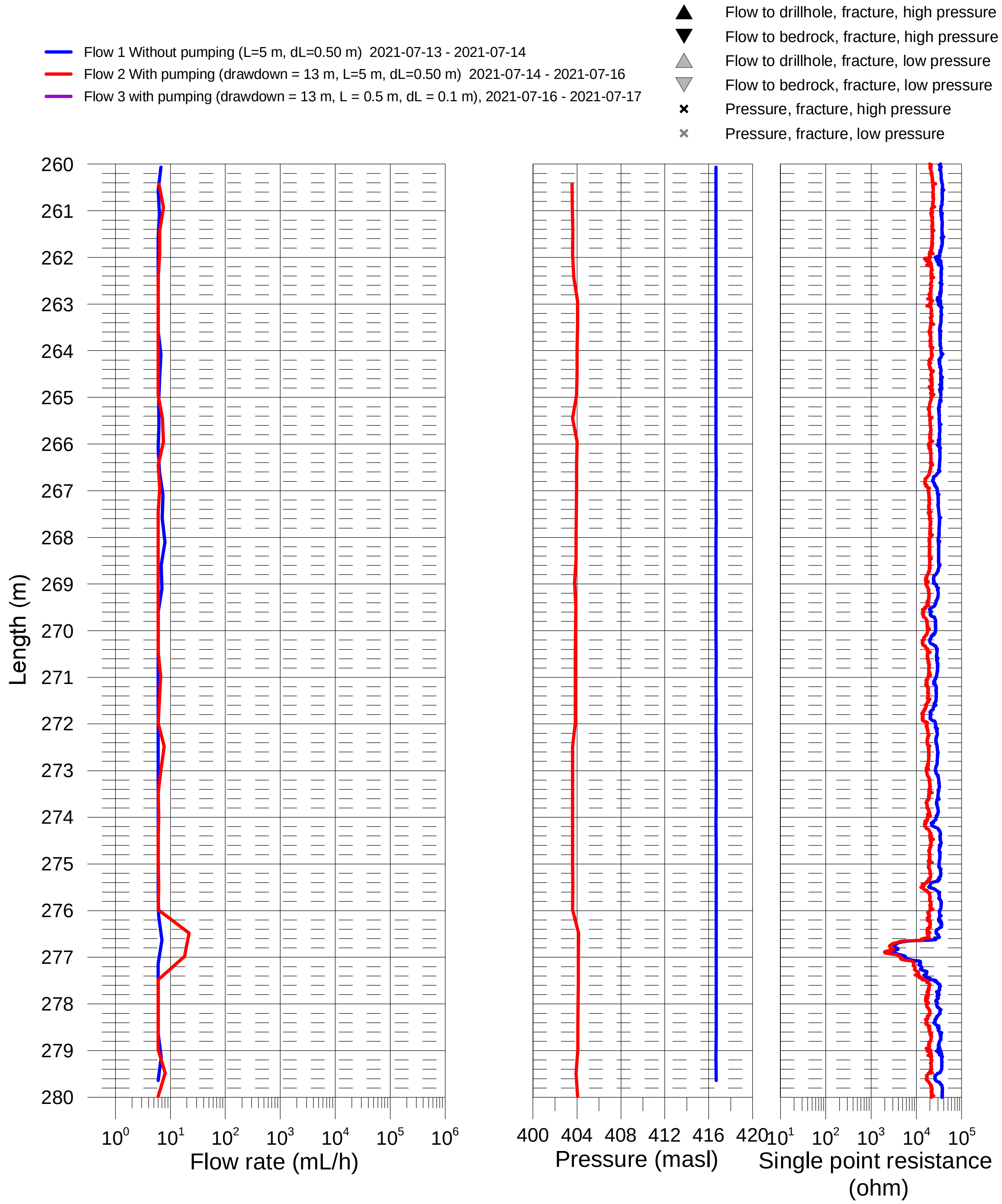
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



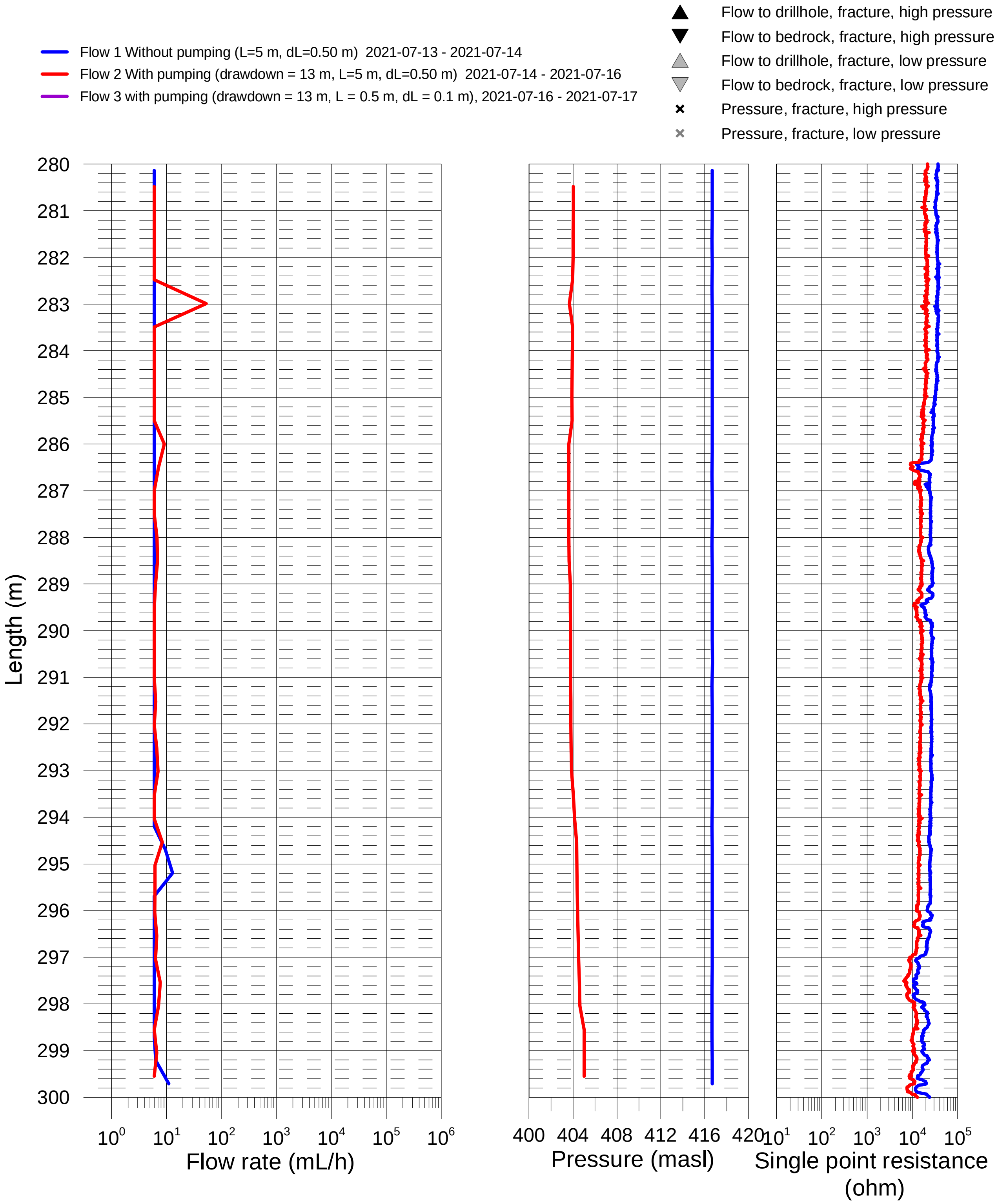
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



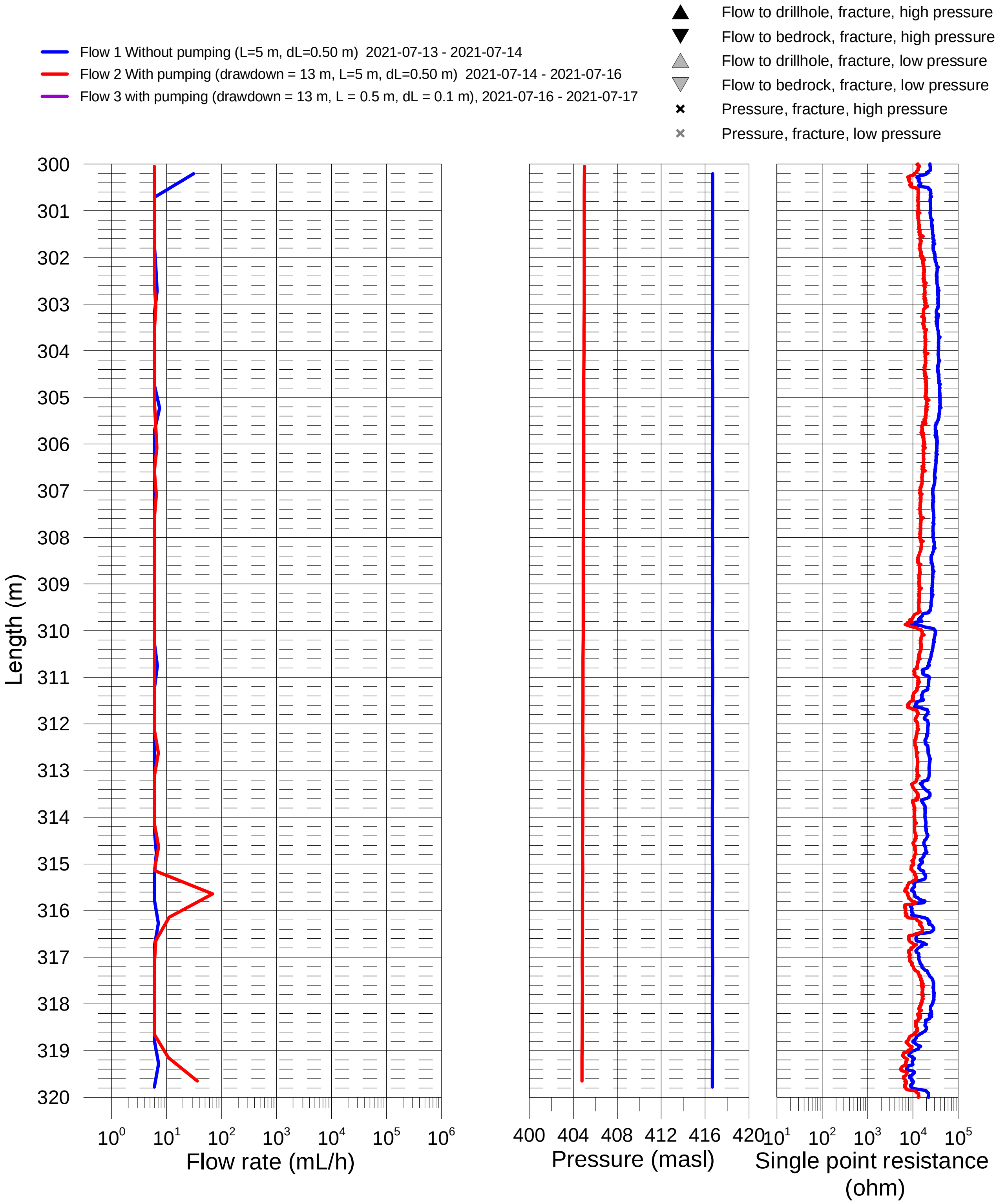
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



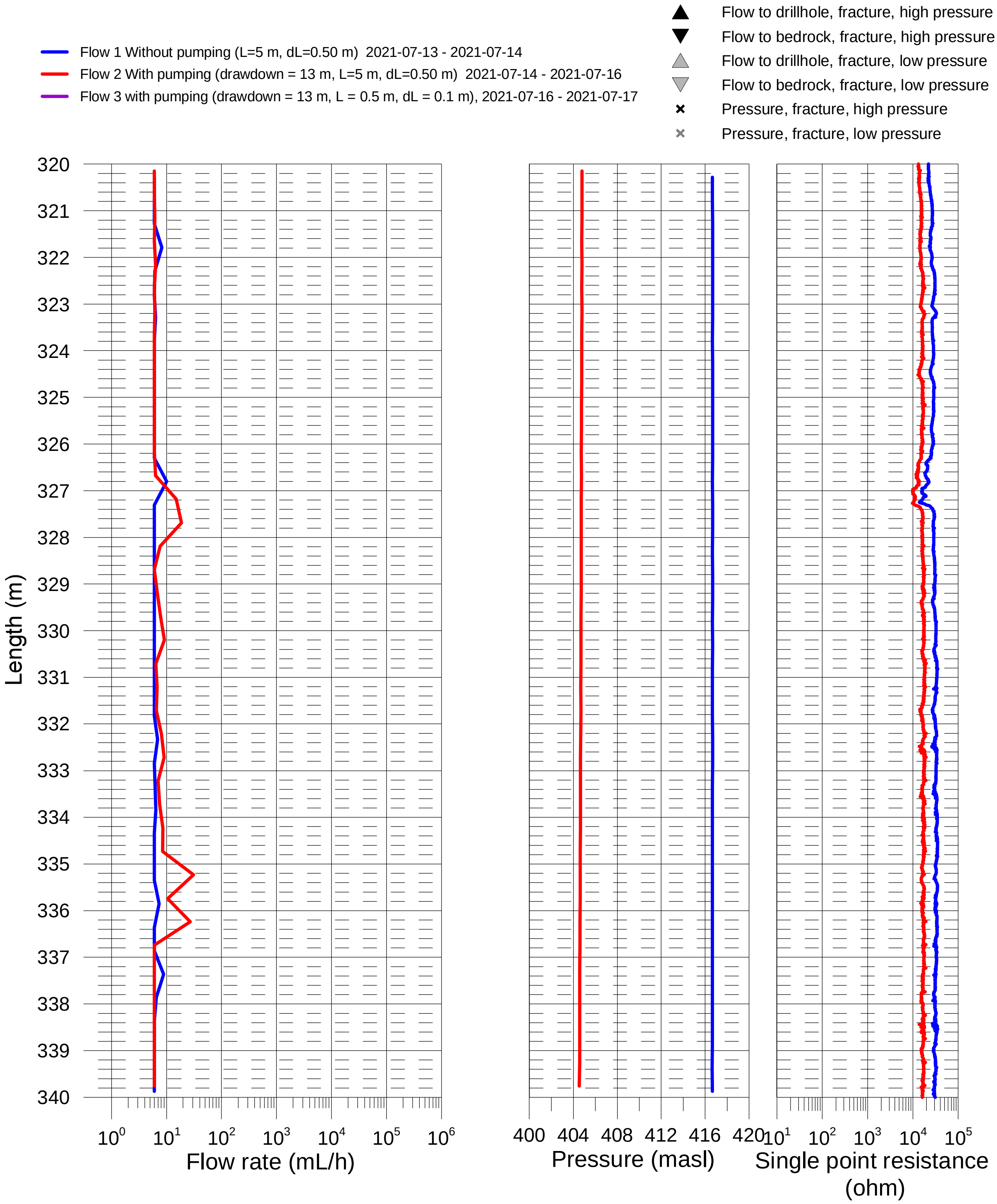
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



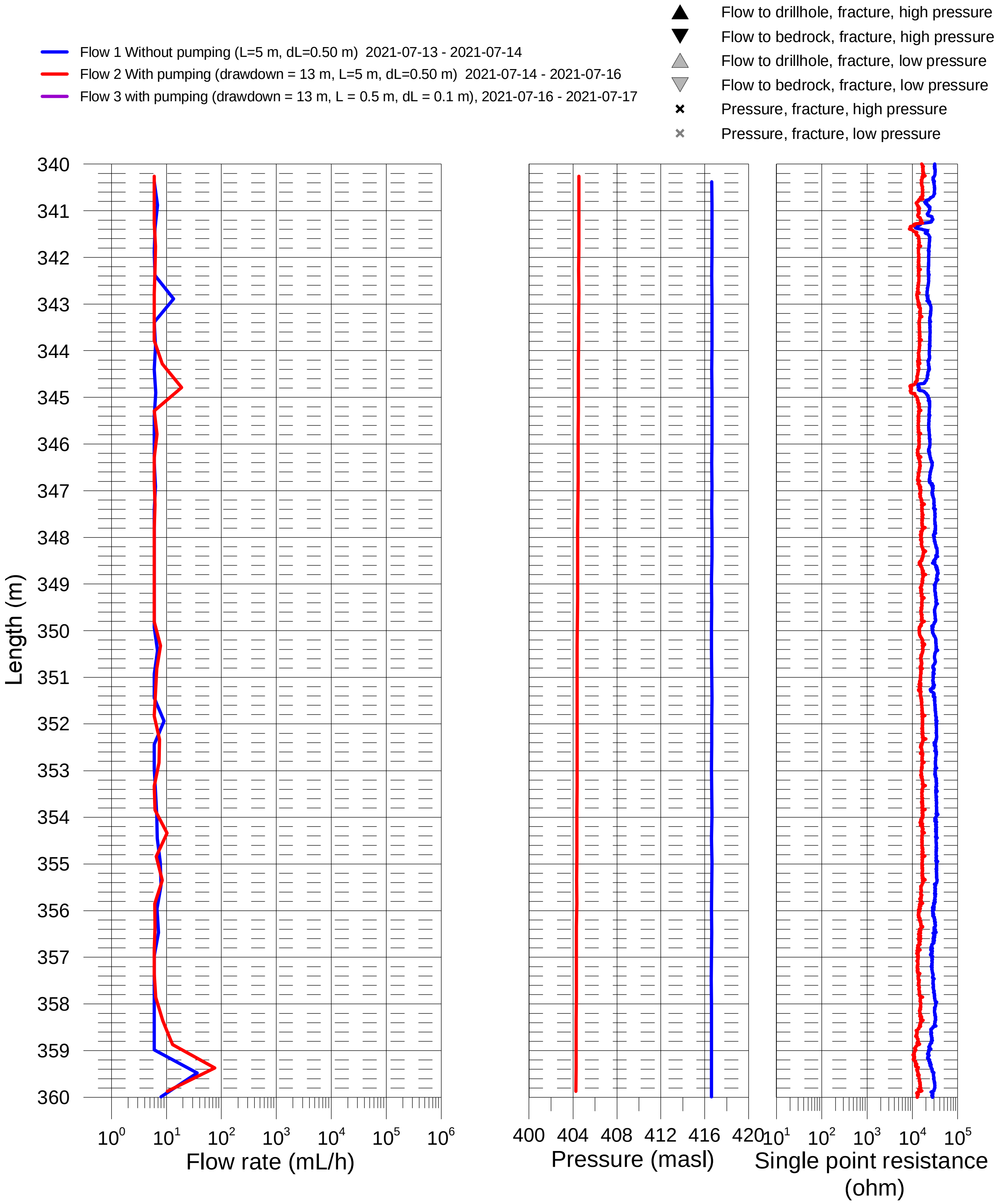
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



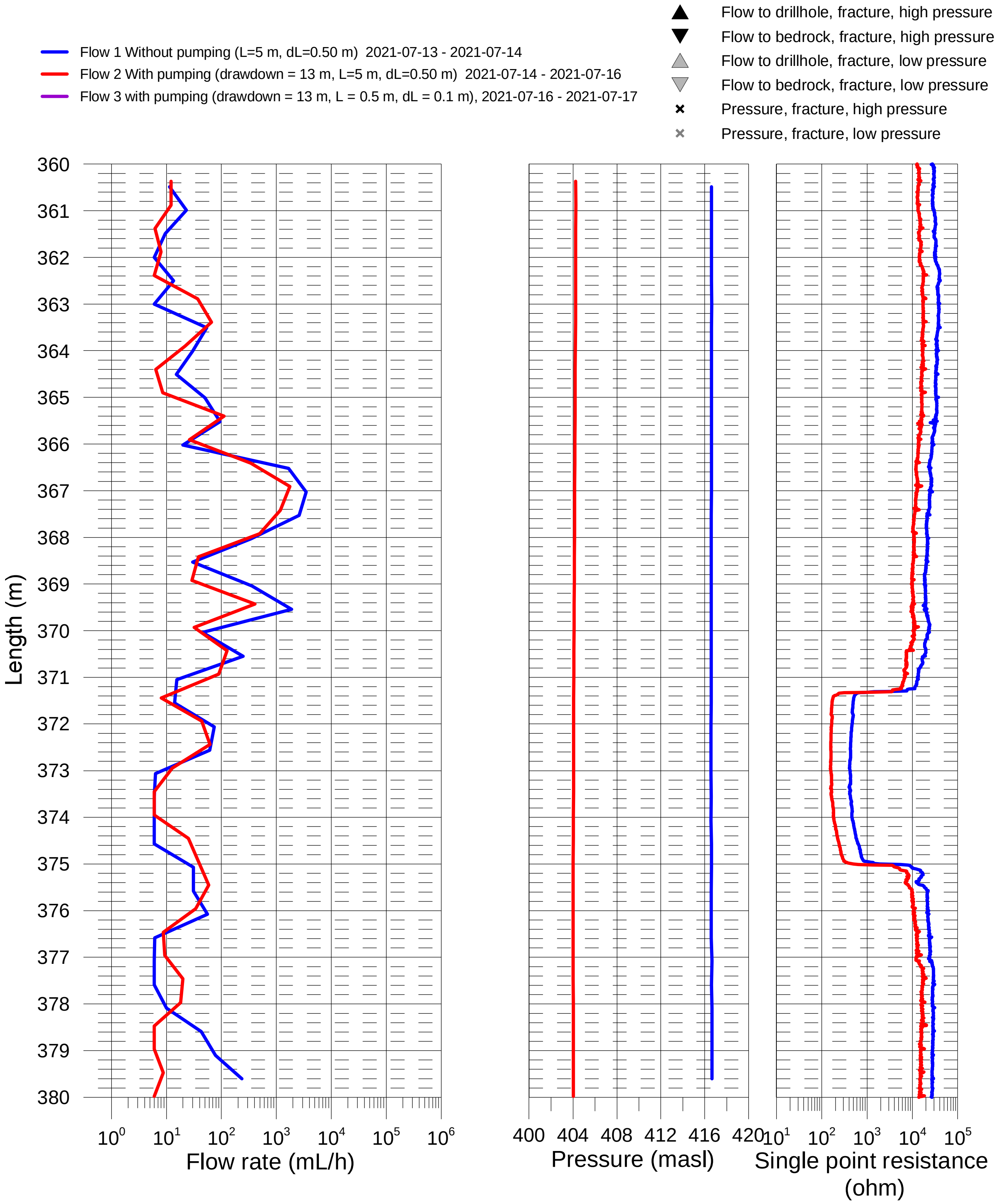
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



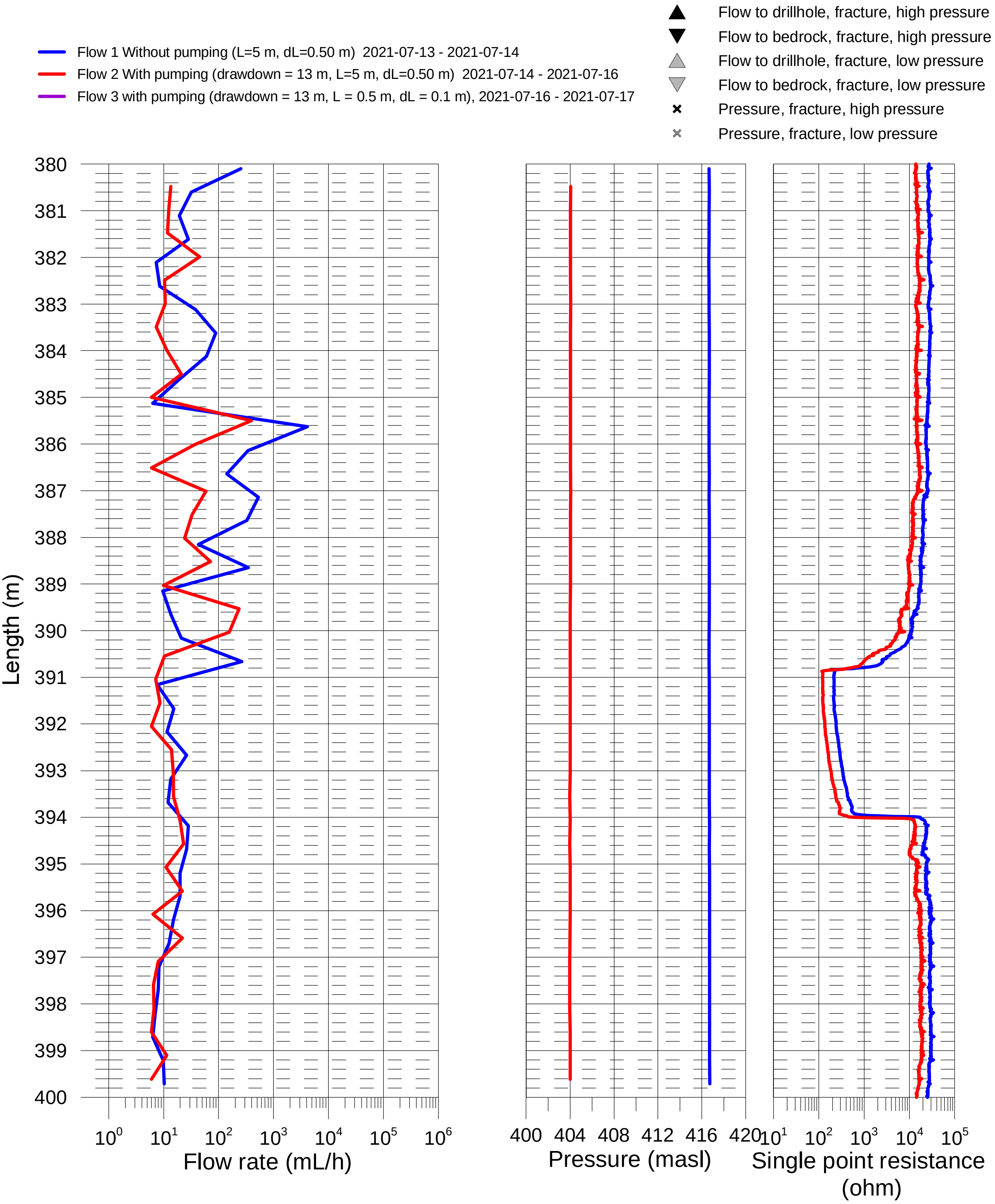
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



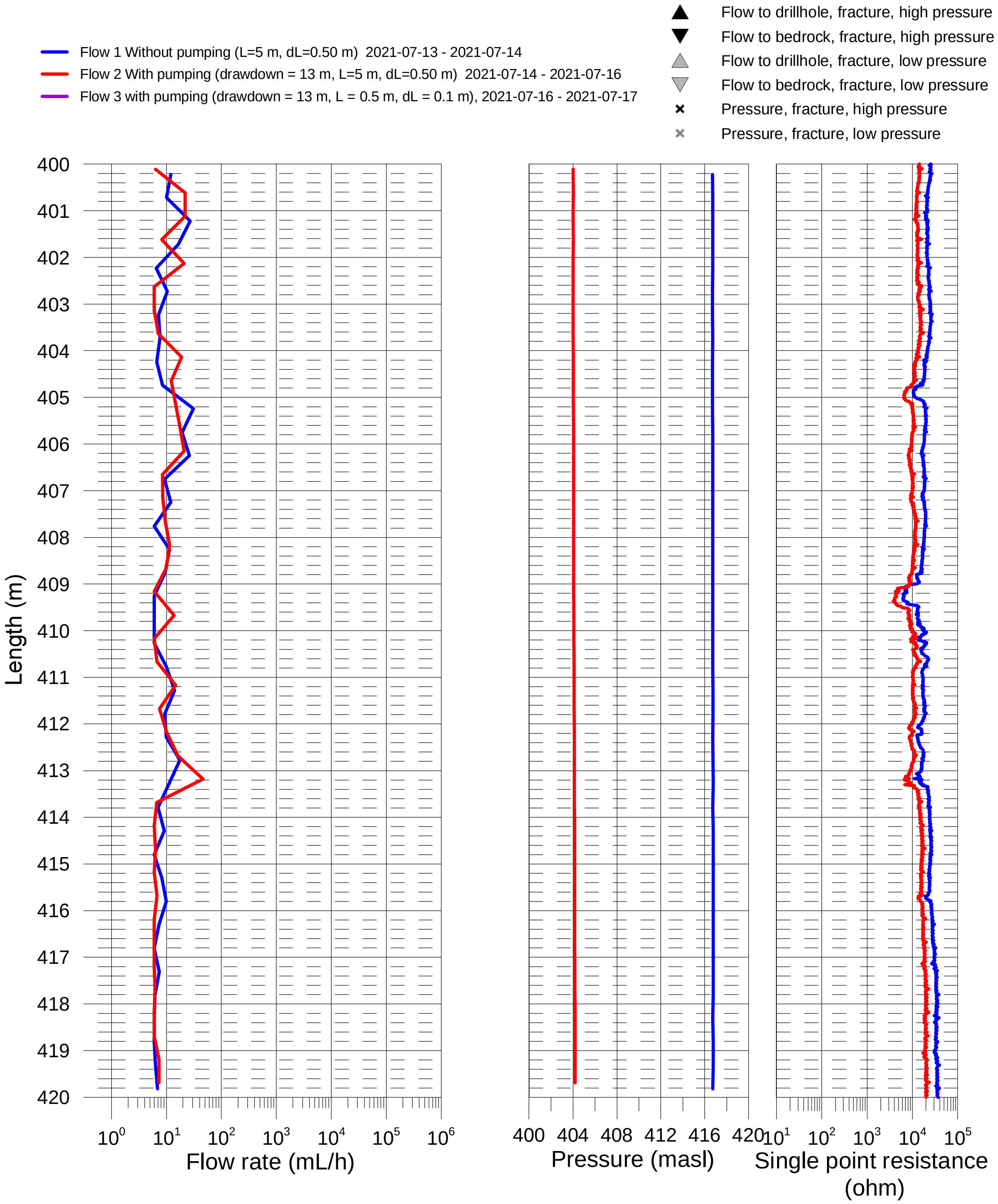
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



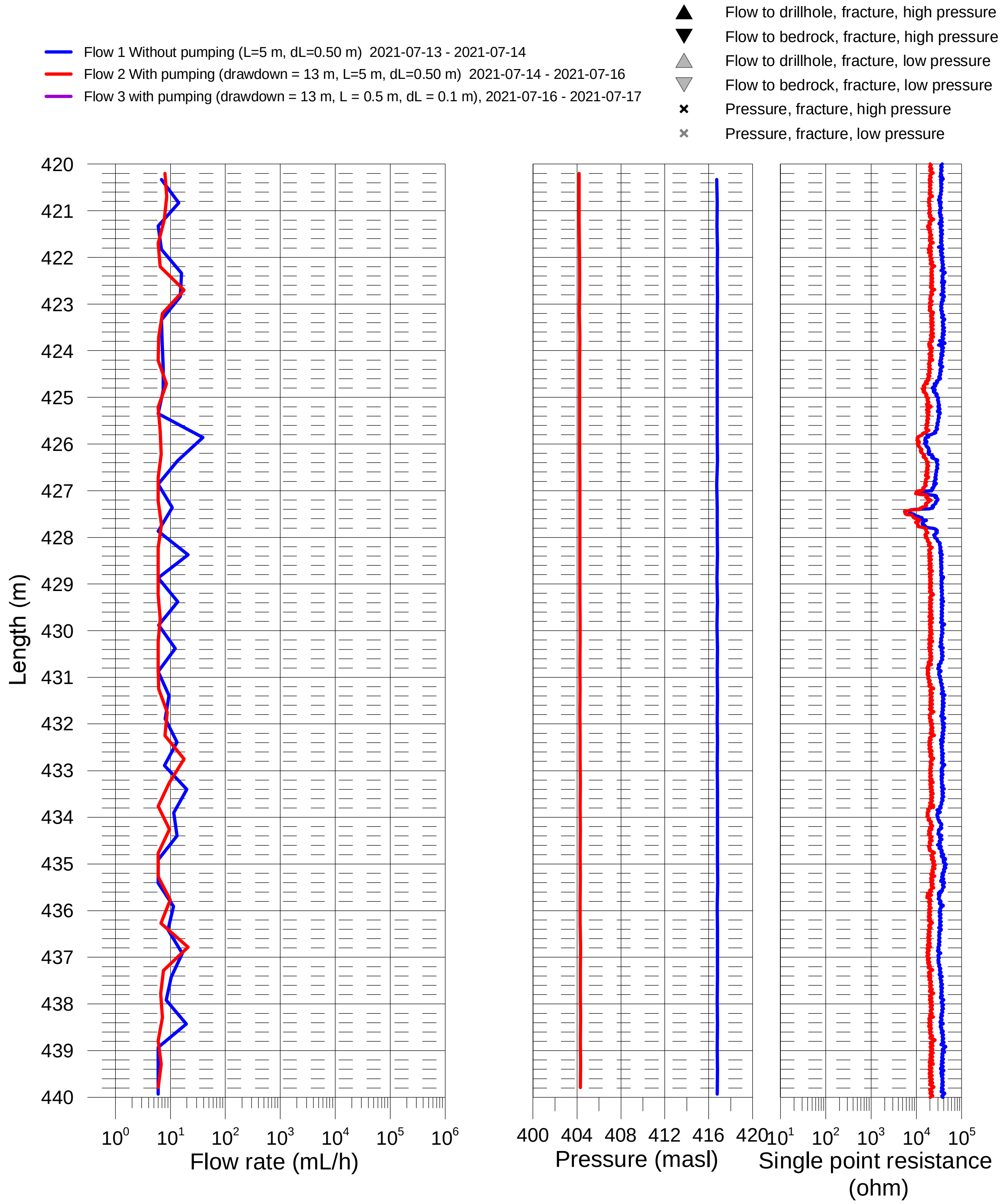
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



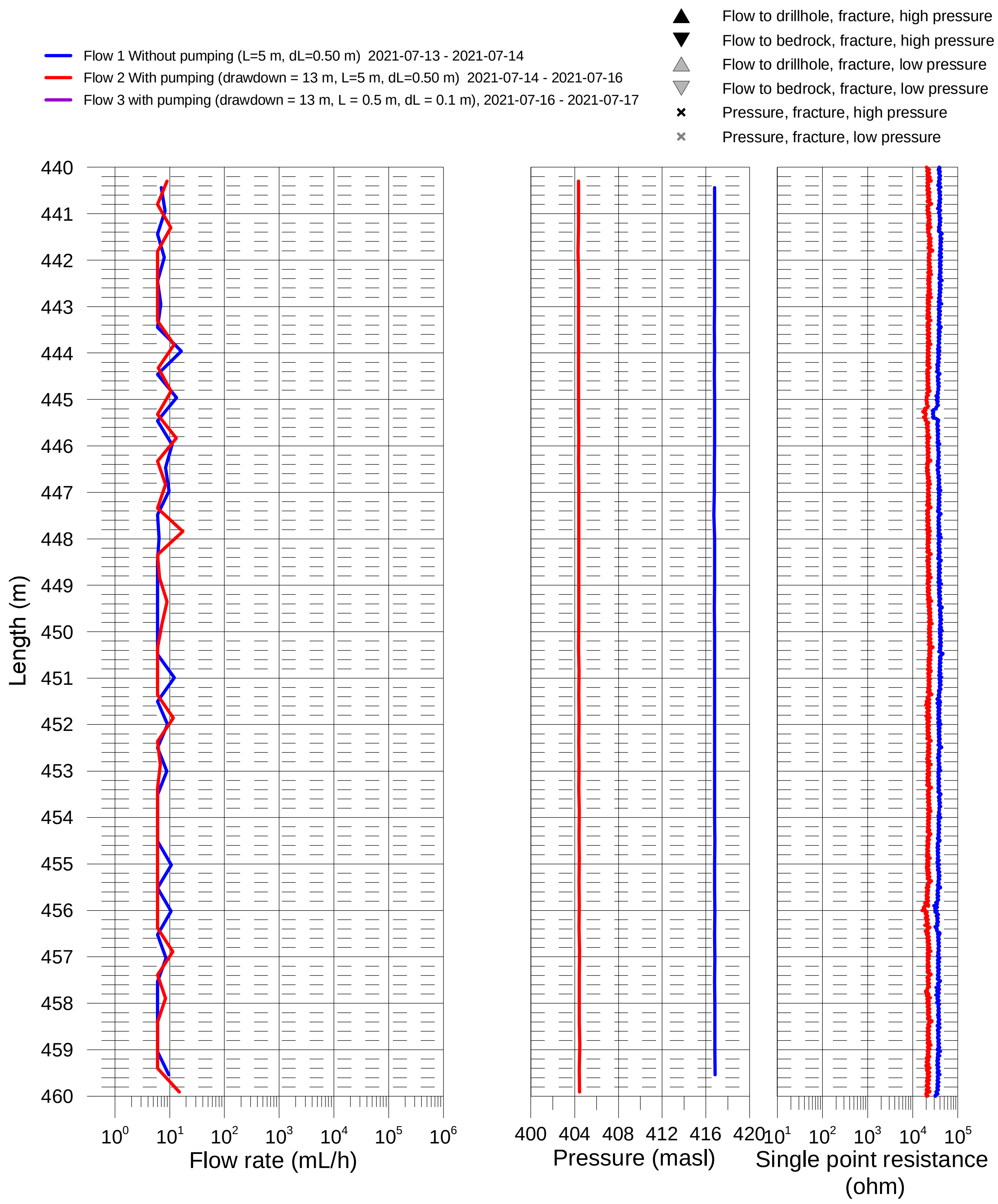
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



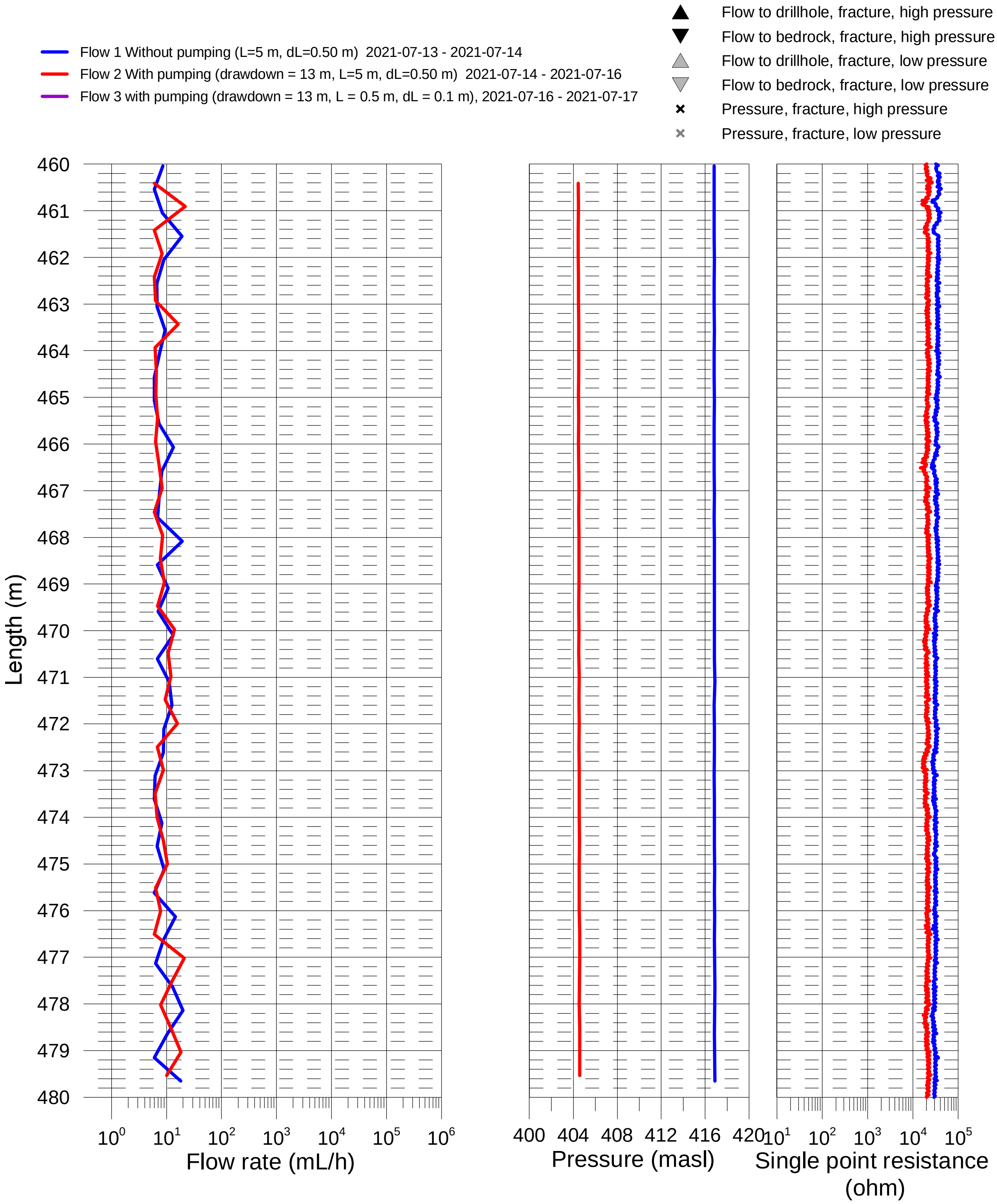
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



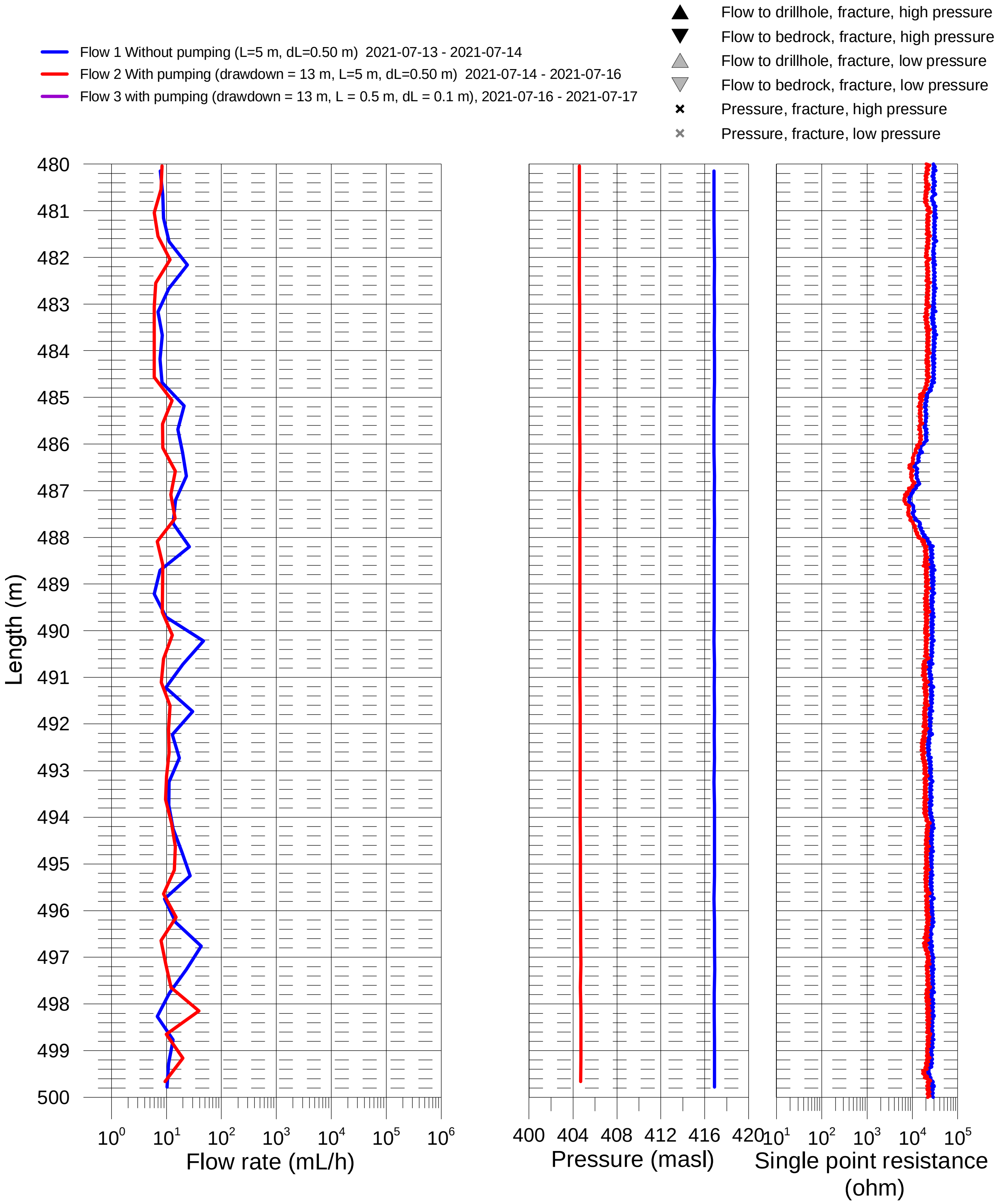
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



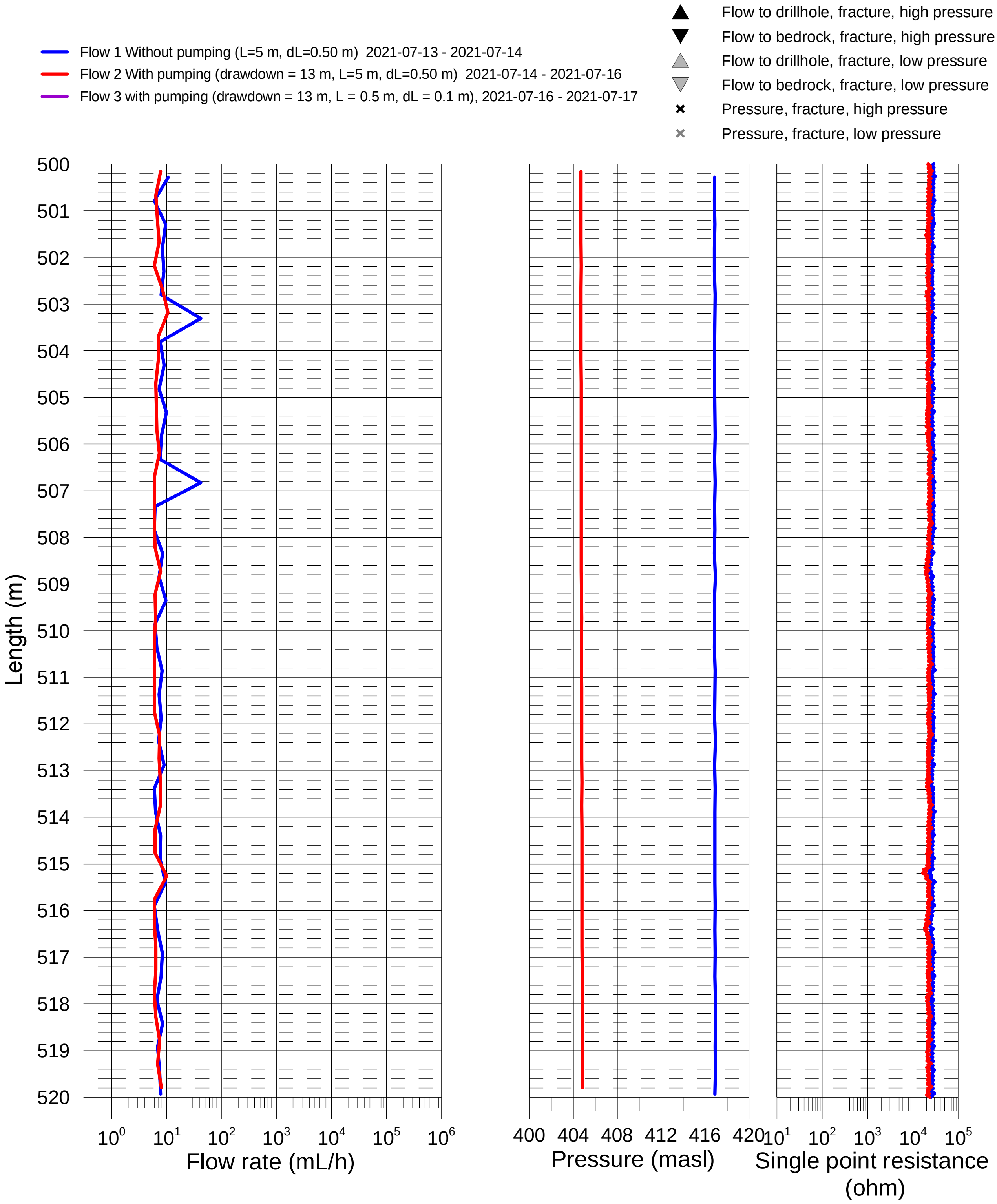
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



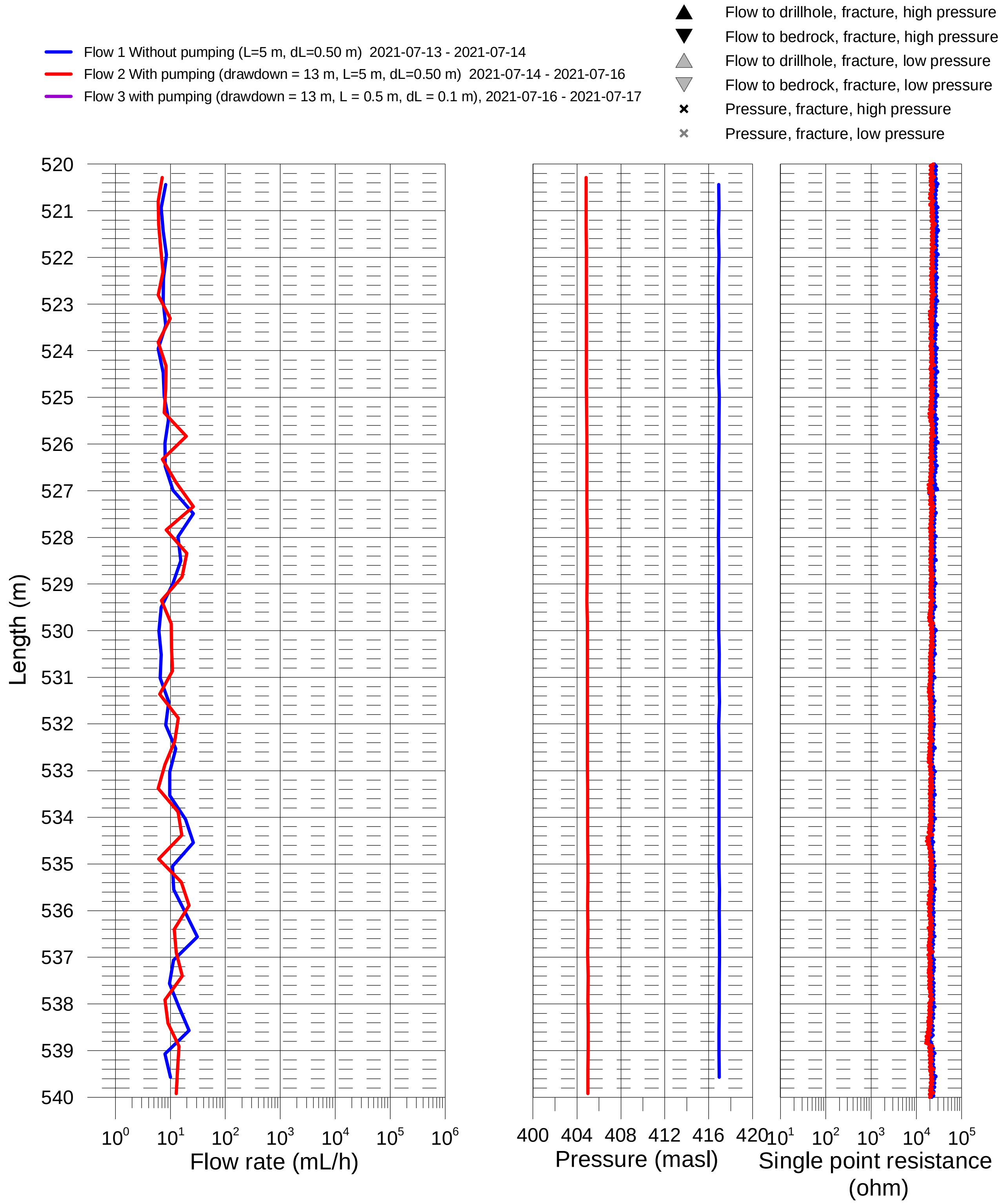
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance

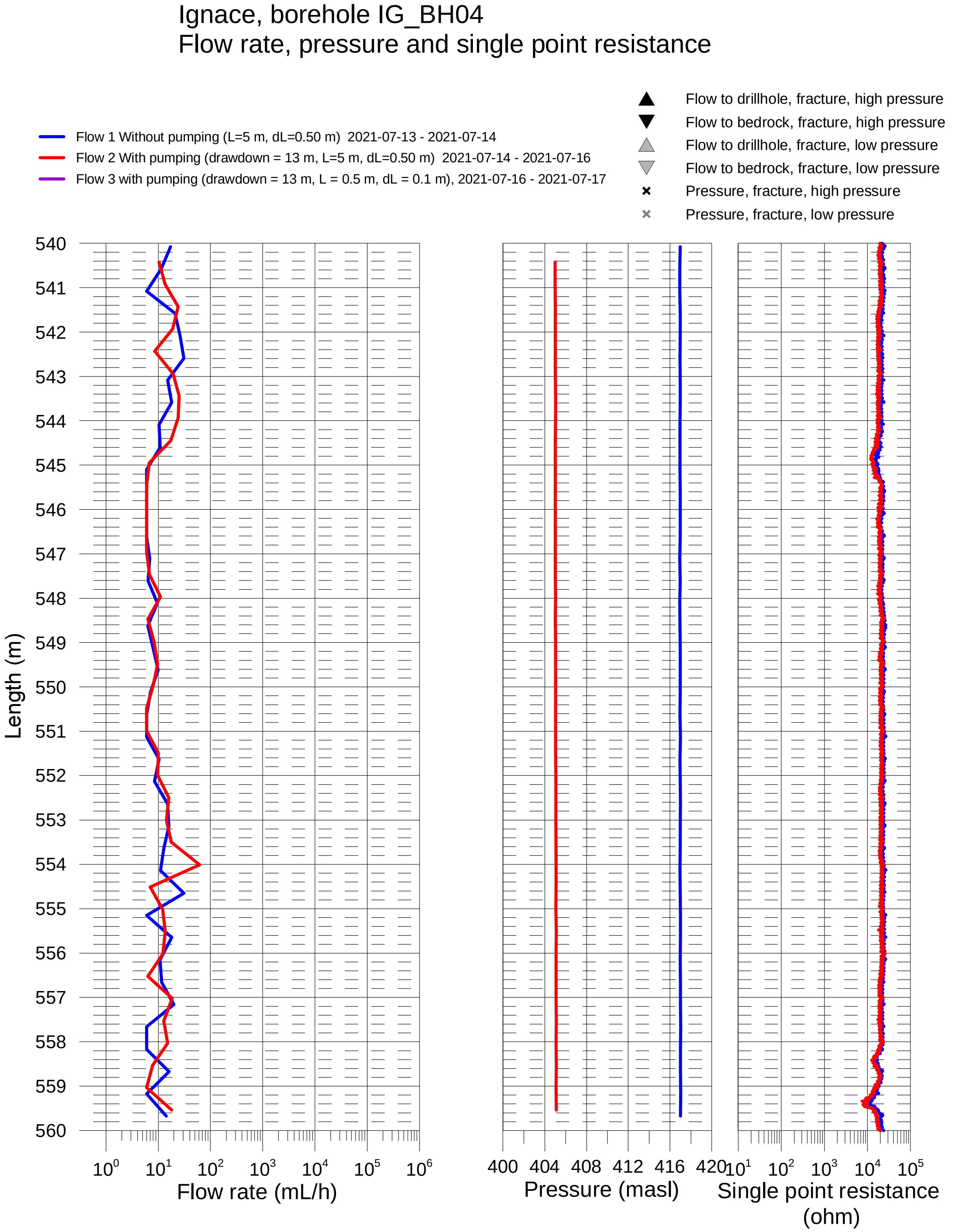


Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance

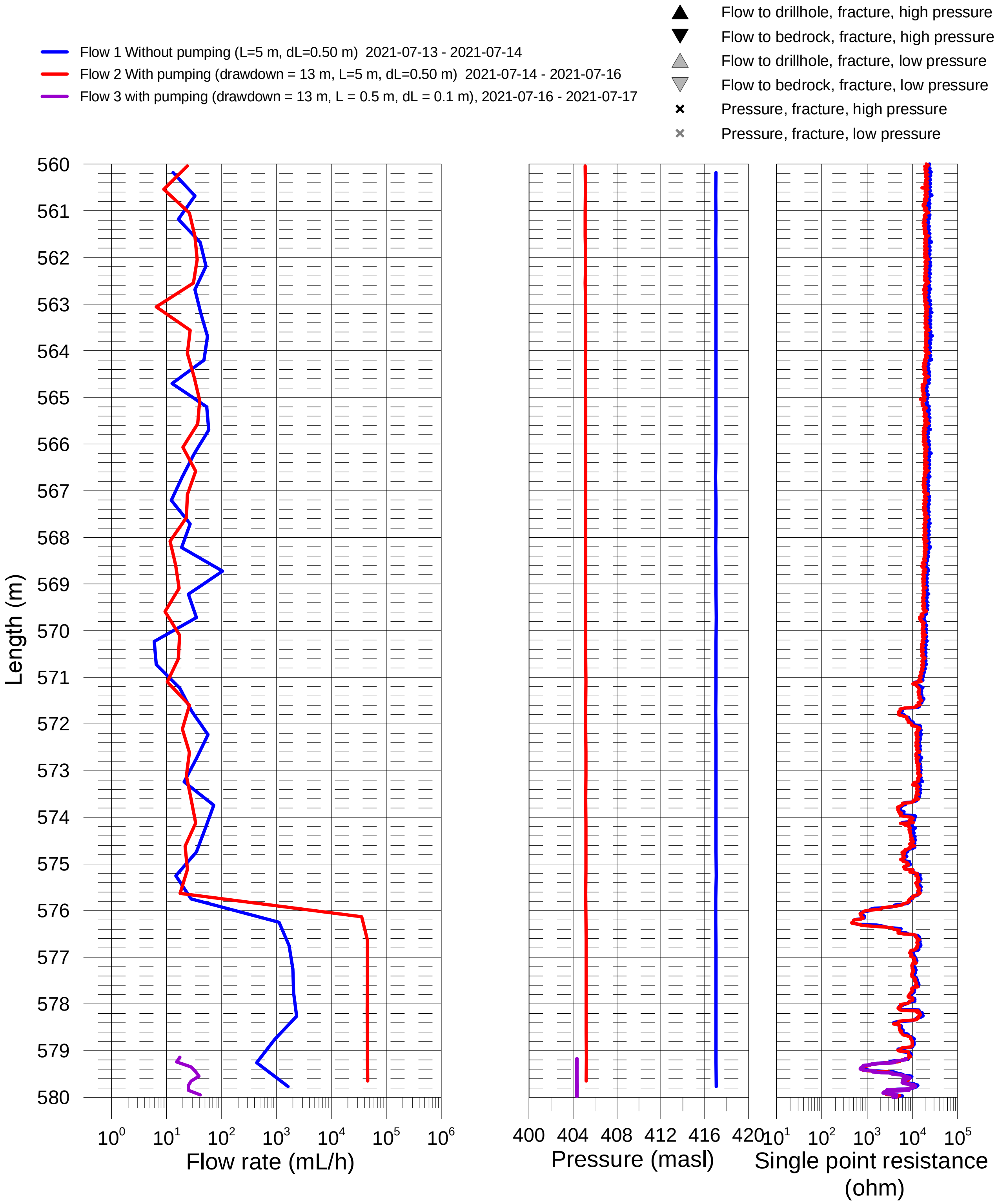


Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance

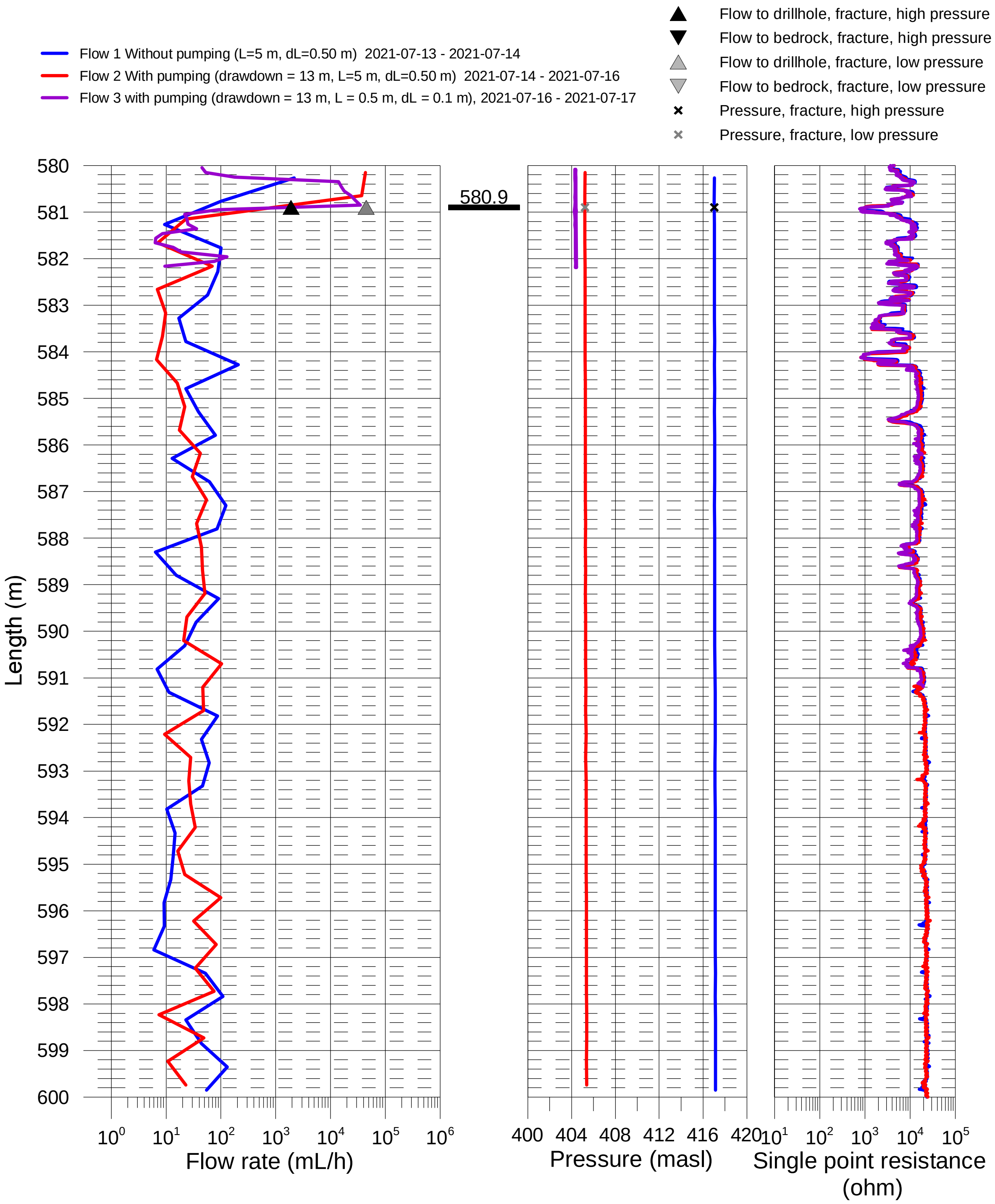



Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance
Flow 1 Without pumping (L=5 m, dL=0.50 m) 2021-07-13 - 2021-07-14
Flow 2 With pumping (drawdown = 13 m, L=5 m, dL=0.50 m) 2021-07-14 - 2021-07-16
Flow 3 with pumping (drawdown = 13 m, L = 0.5 m, dL = 0.1 m), 2021-07-16 - 2021-07-17
Flow to drillhole, fracture, high pressure
Flow to bedrock, fracture, high pressure
Flow to drillhole, fracture, low pressure
Flow to bedrock, fracture, low pressure
Pressure, fracture, high pressure
Pressure, fracture, low pressure
Length (m)
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
400 404 408 412 416 420
Pressure (masl)
10^1 10^2 10^3 10^4 10^5
Single point resistance (ohm)

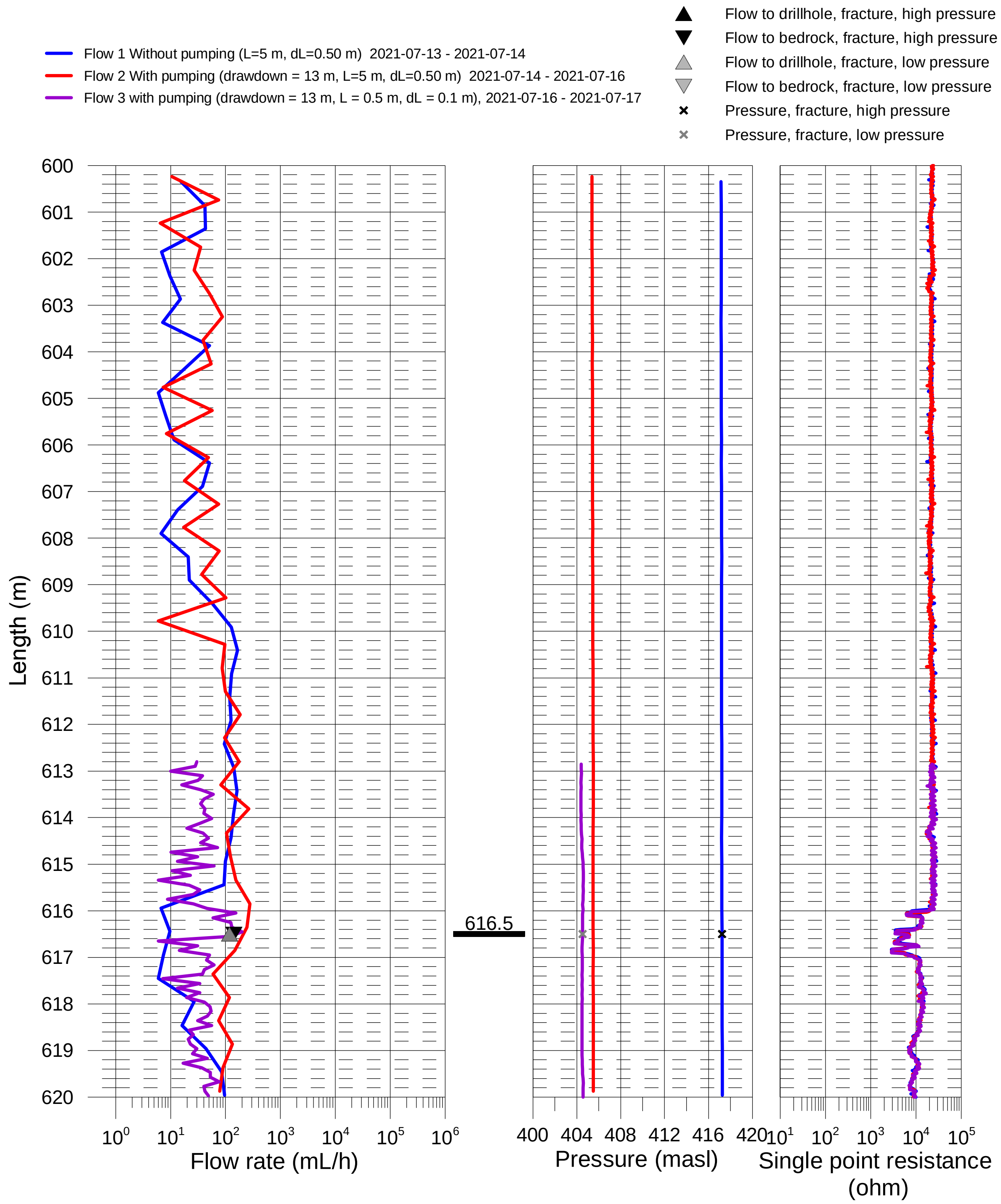
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



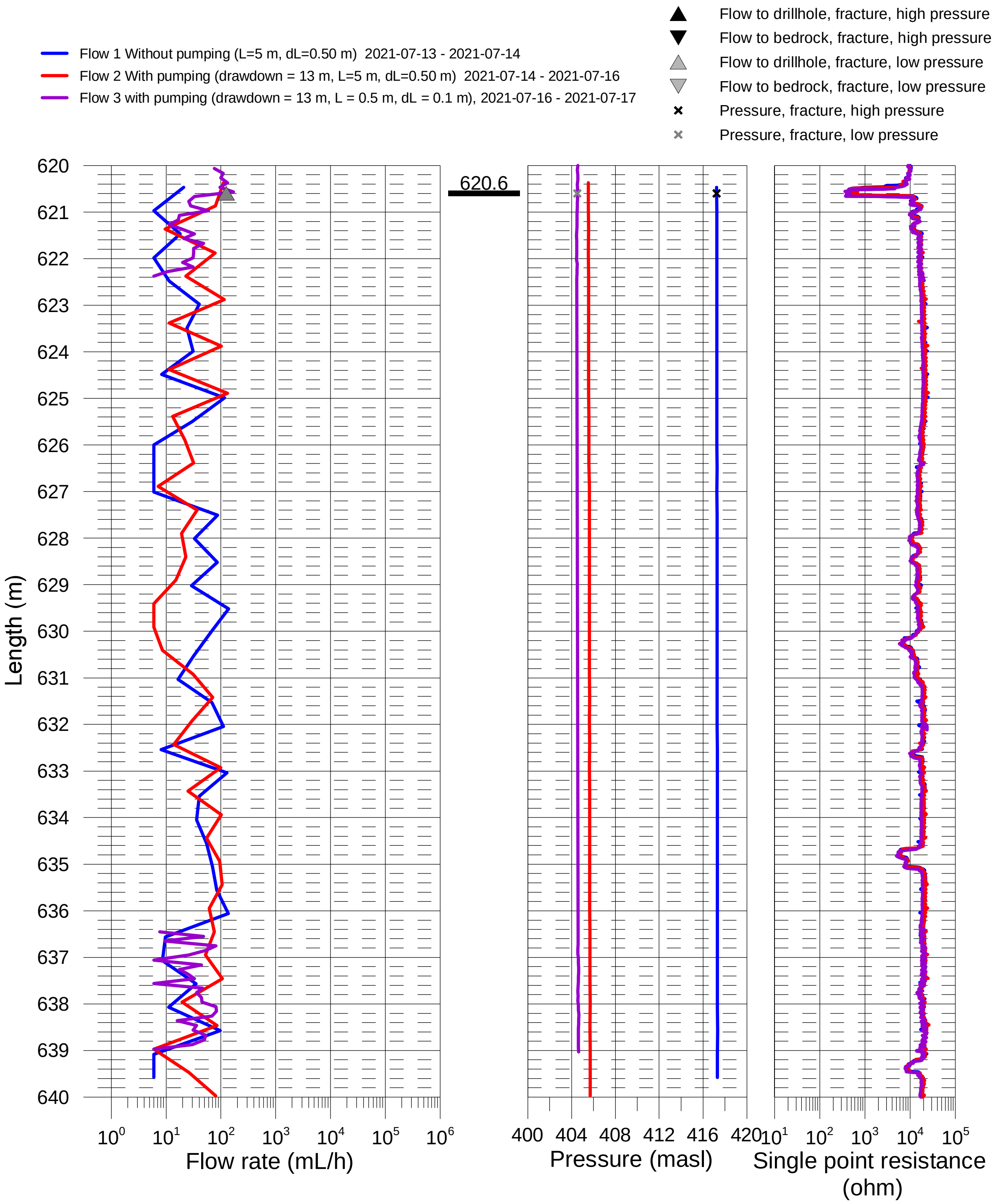
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



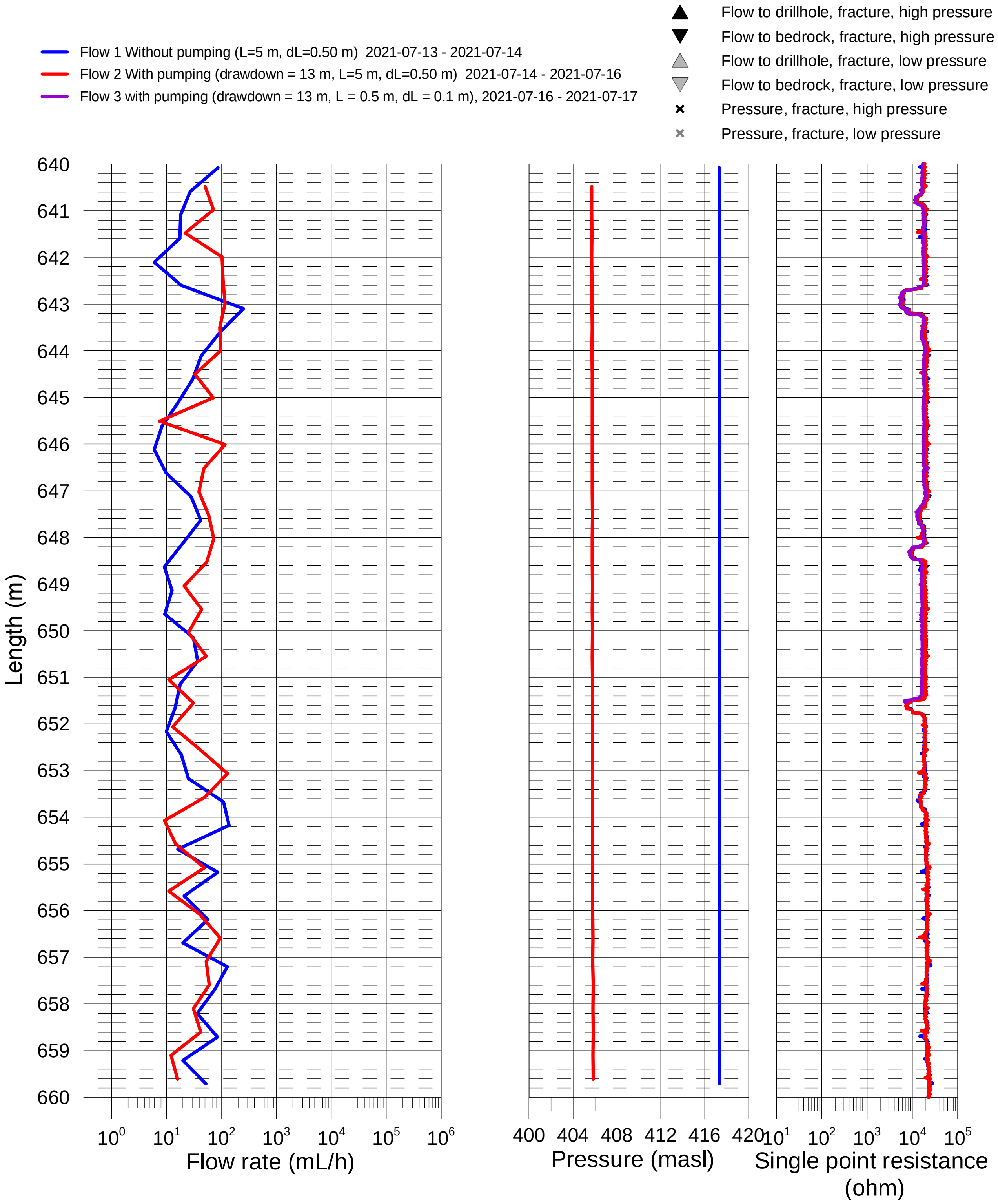
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



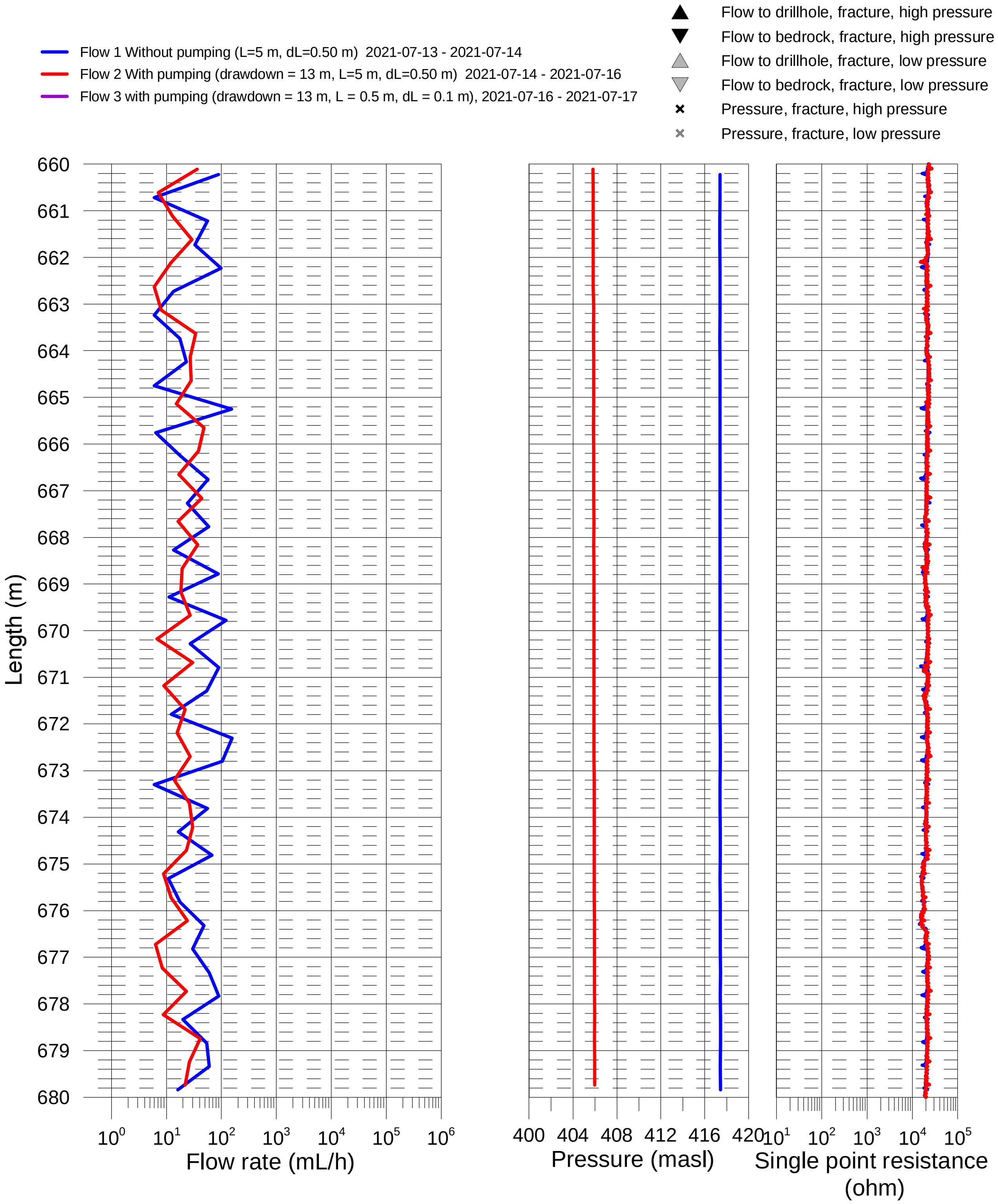
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



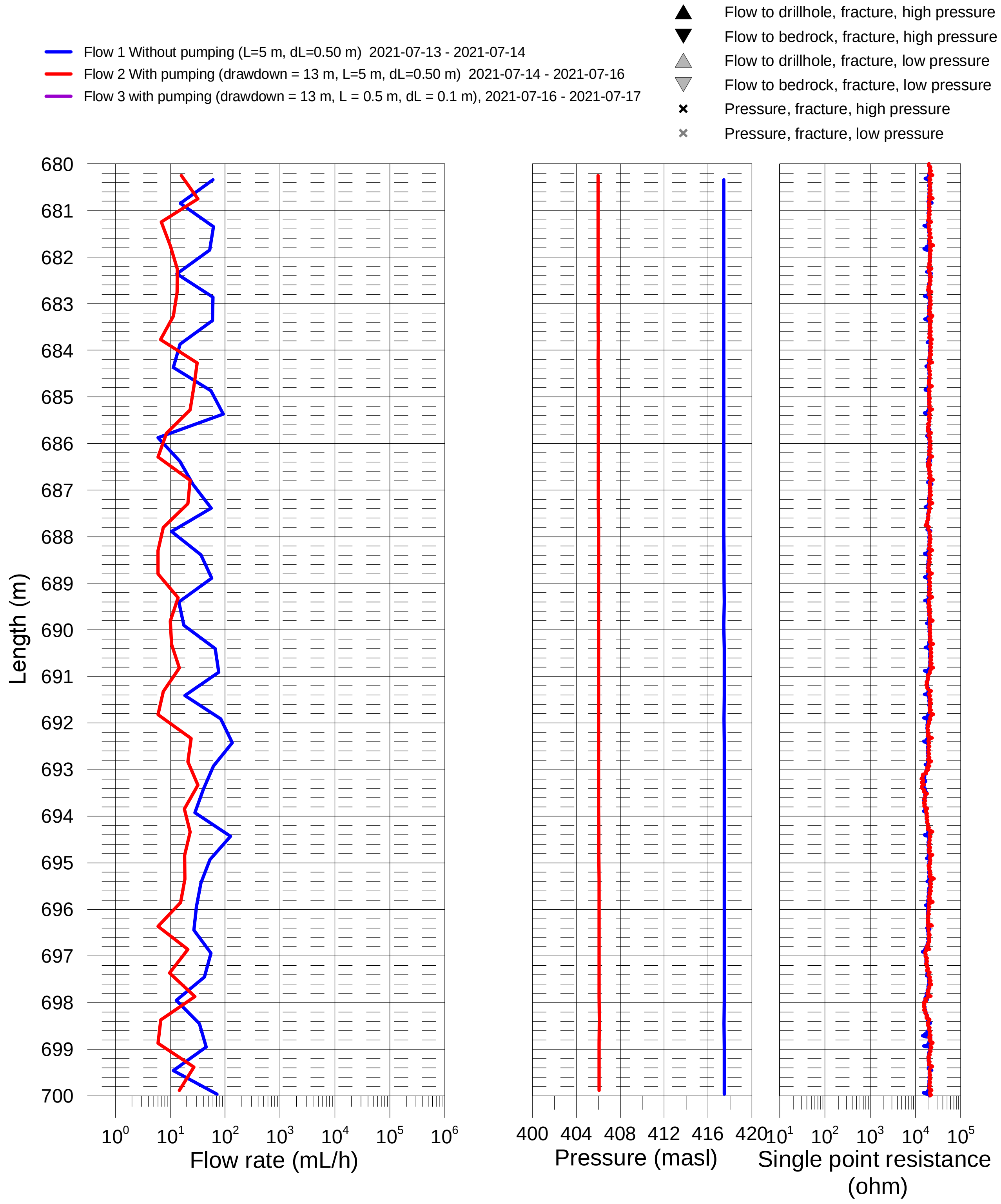
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



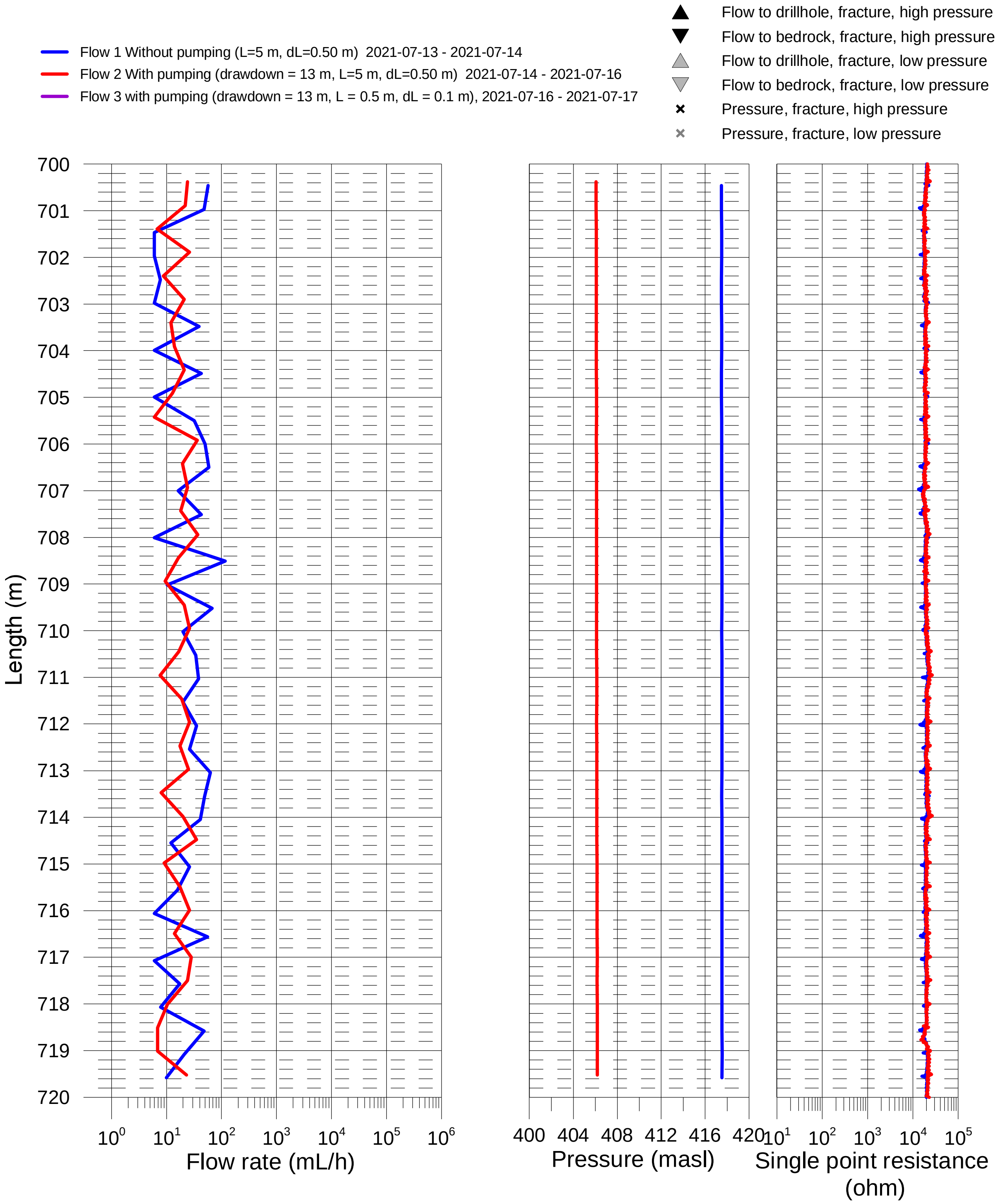
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



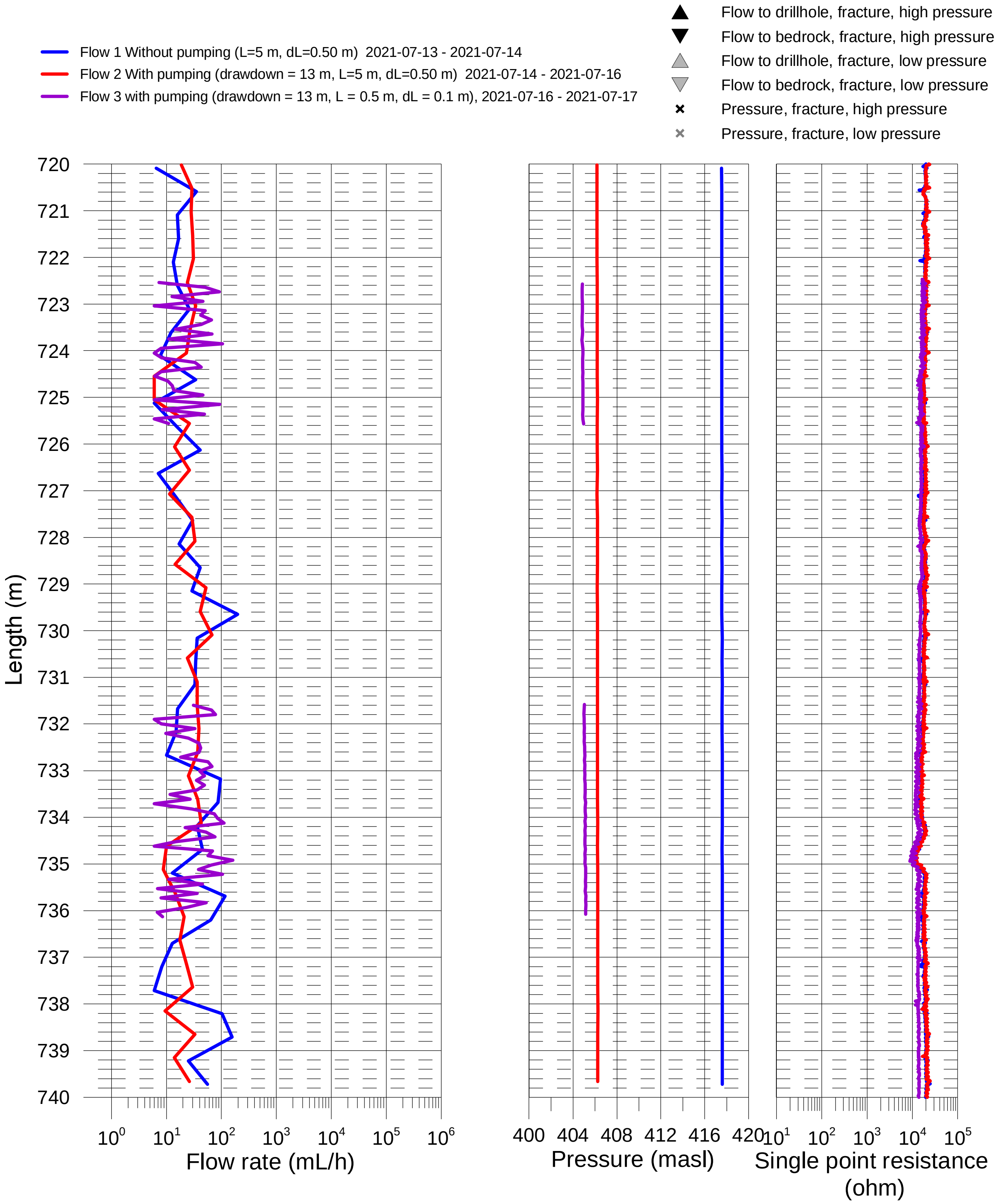
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



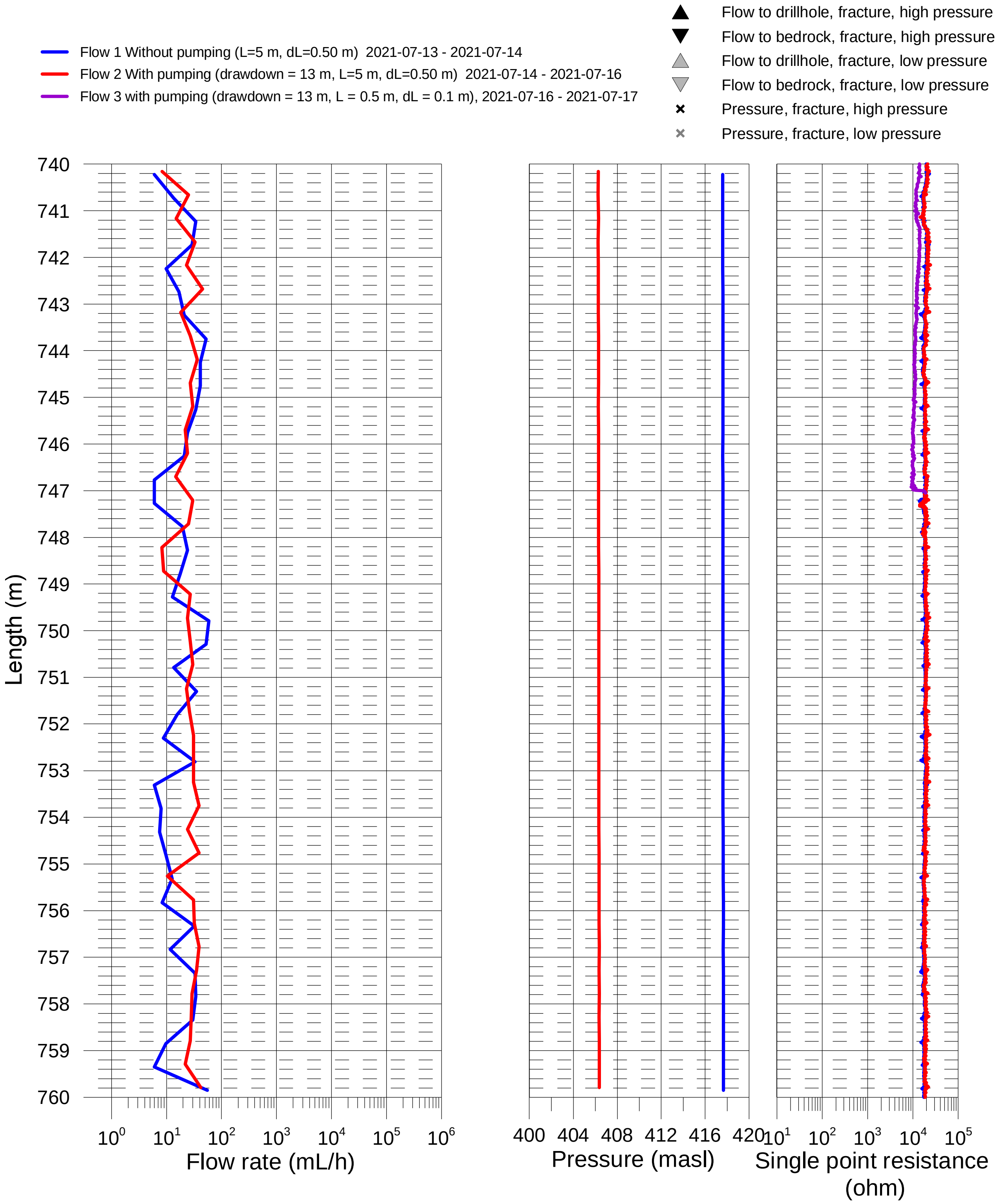
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



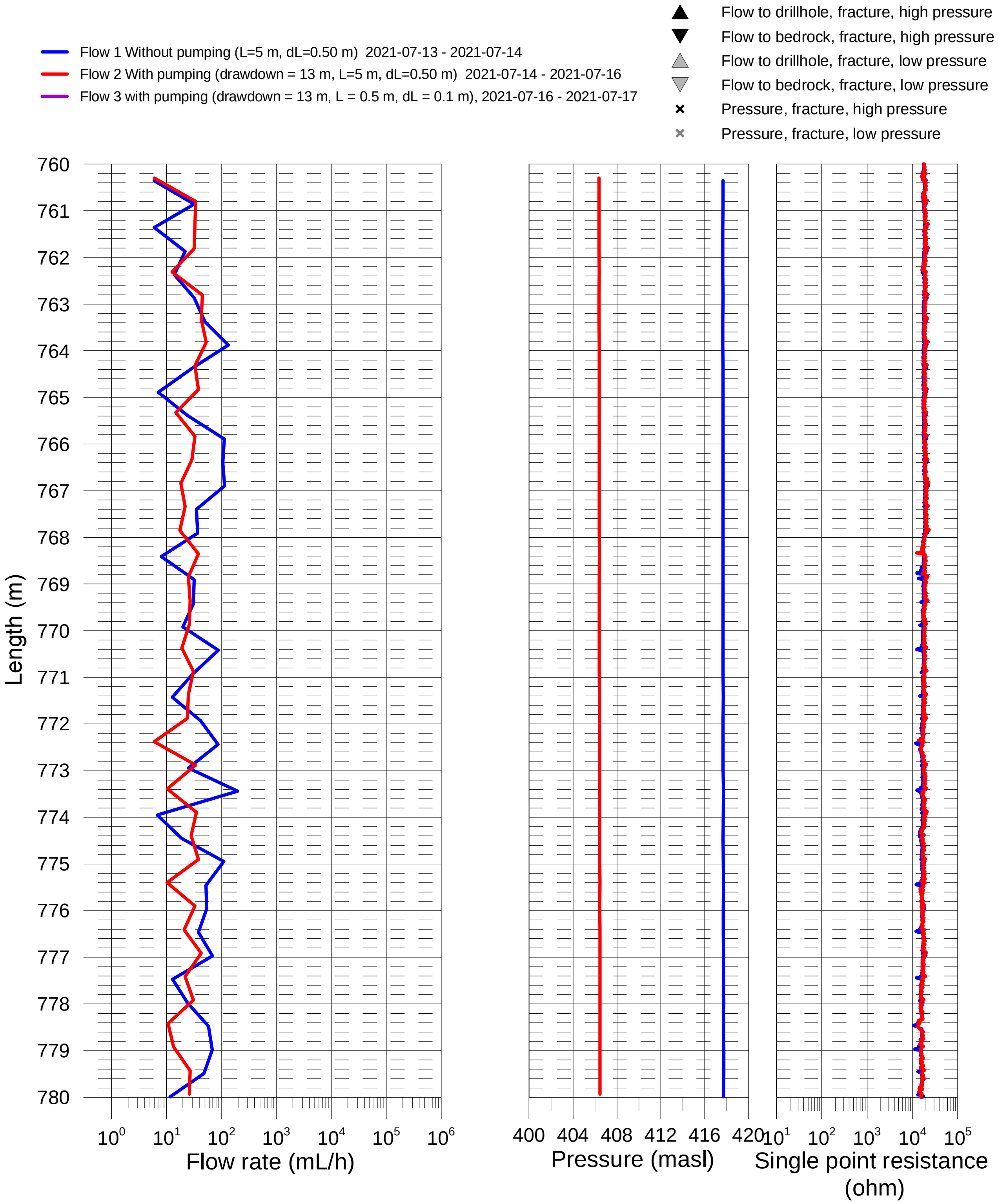
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



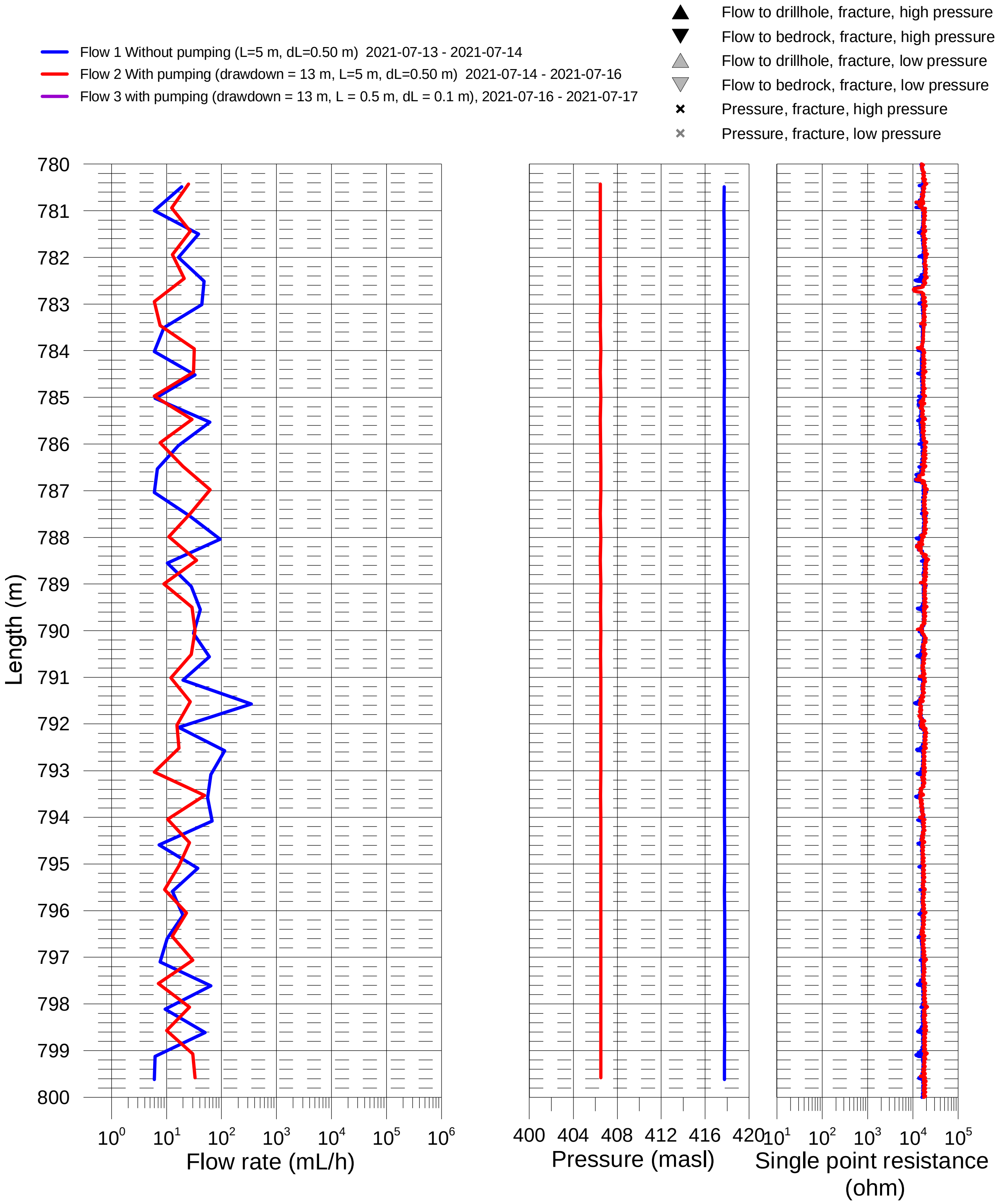
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



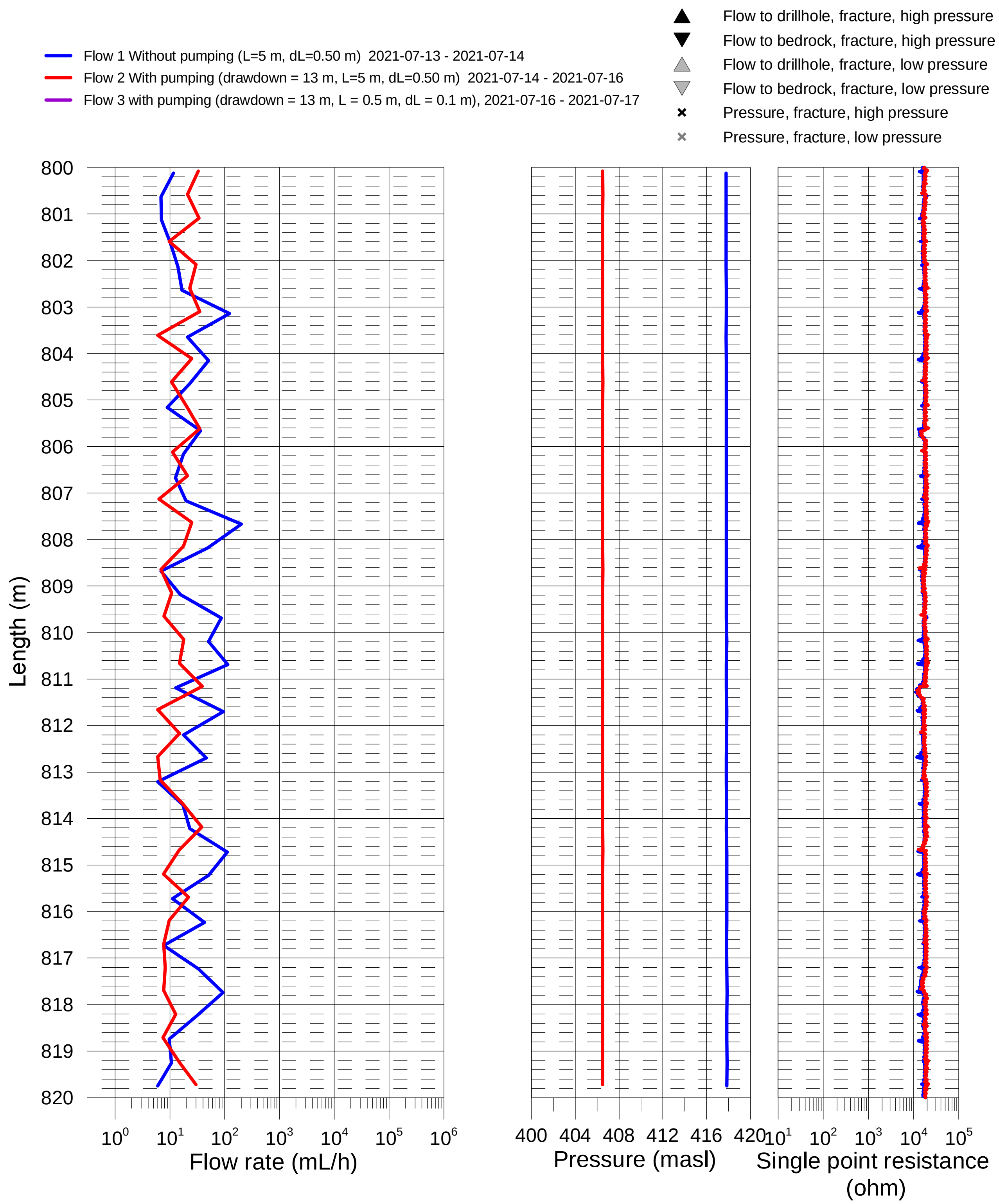
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



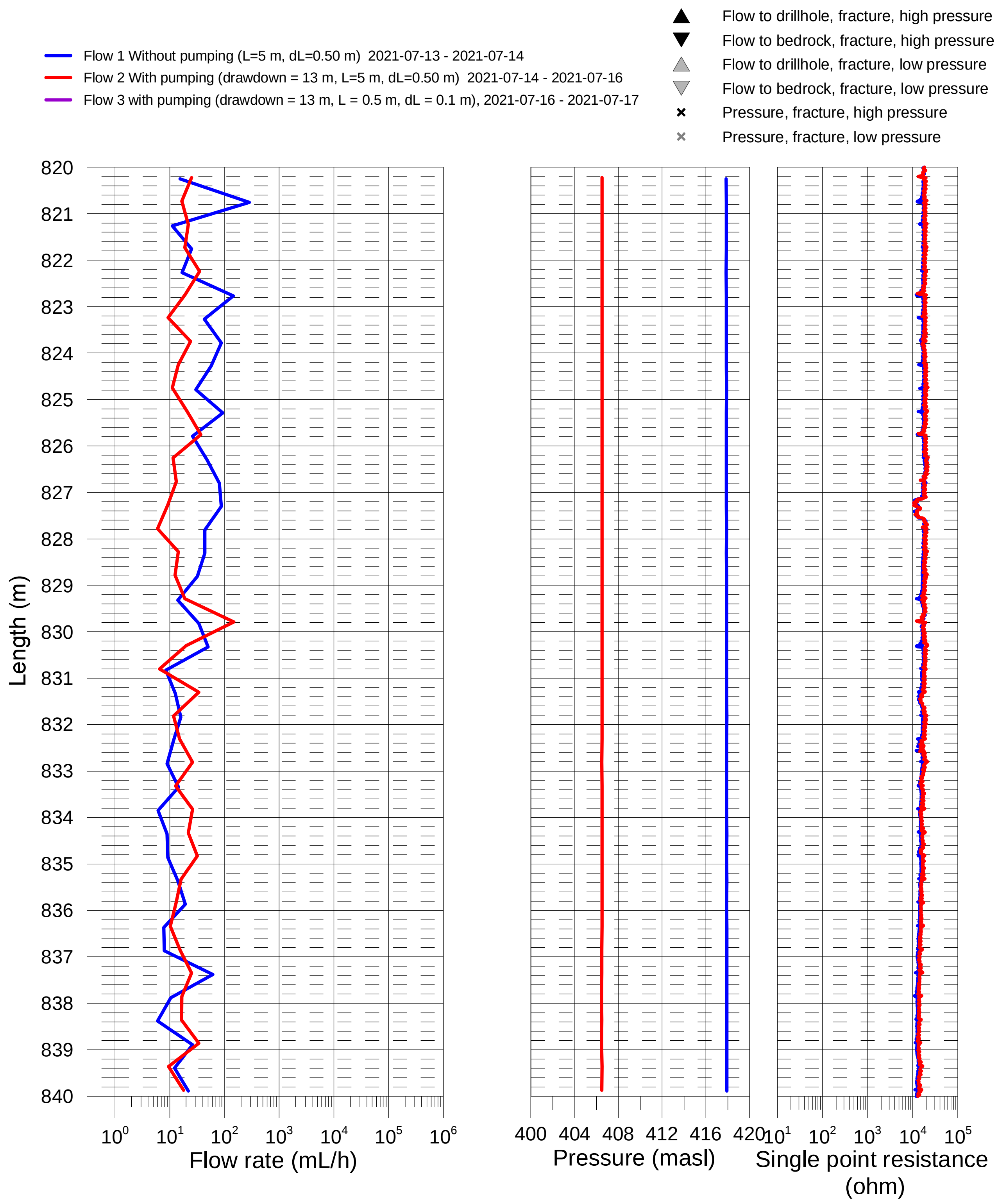
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



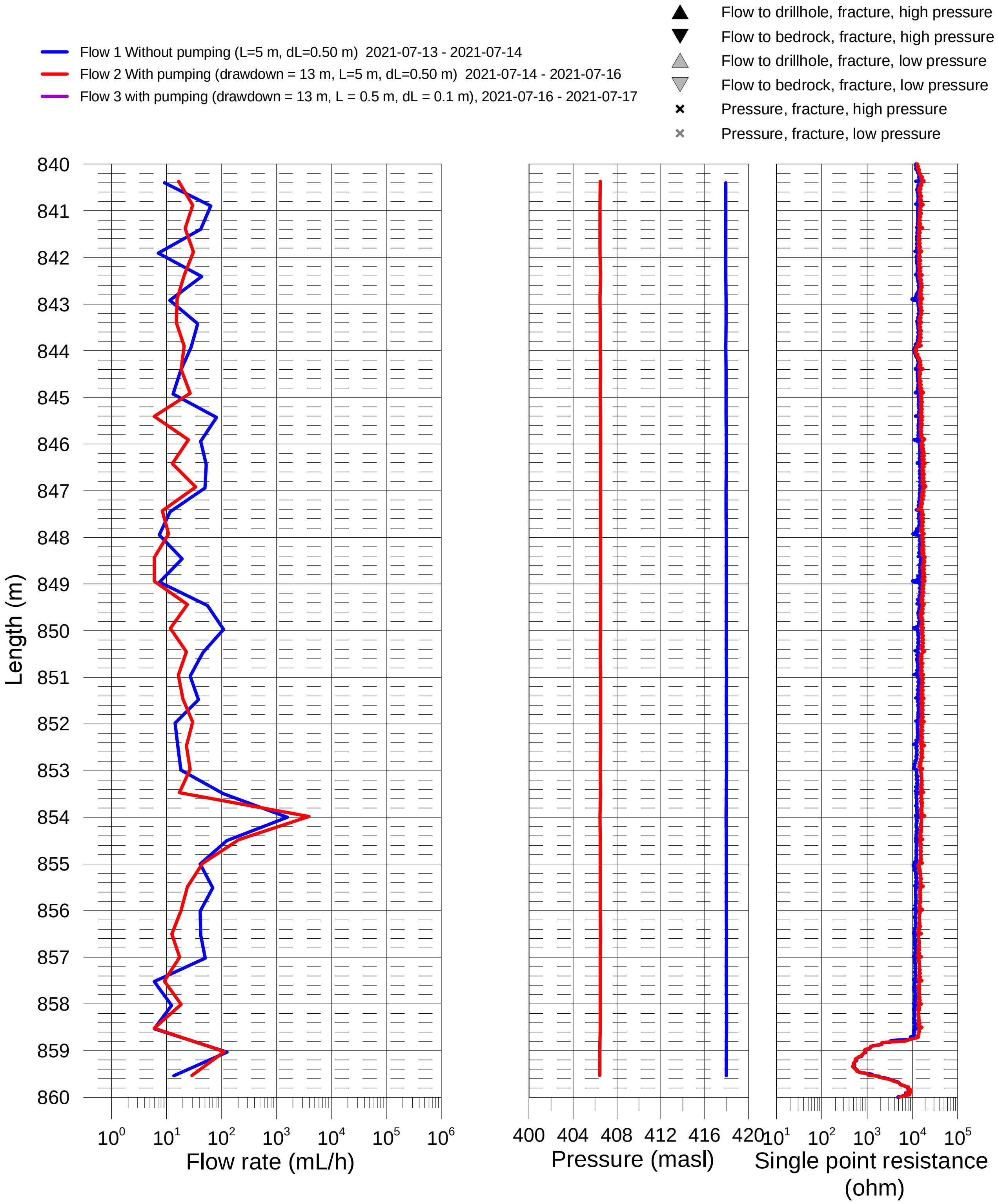
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



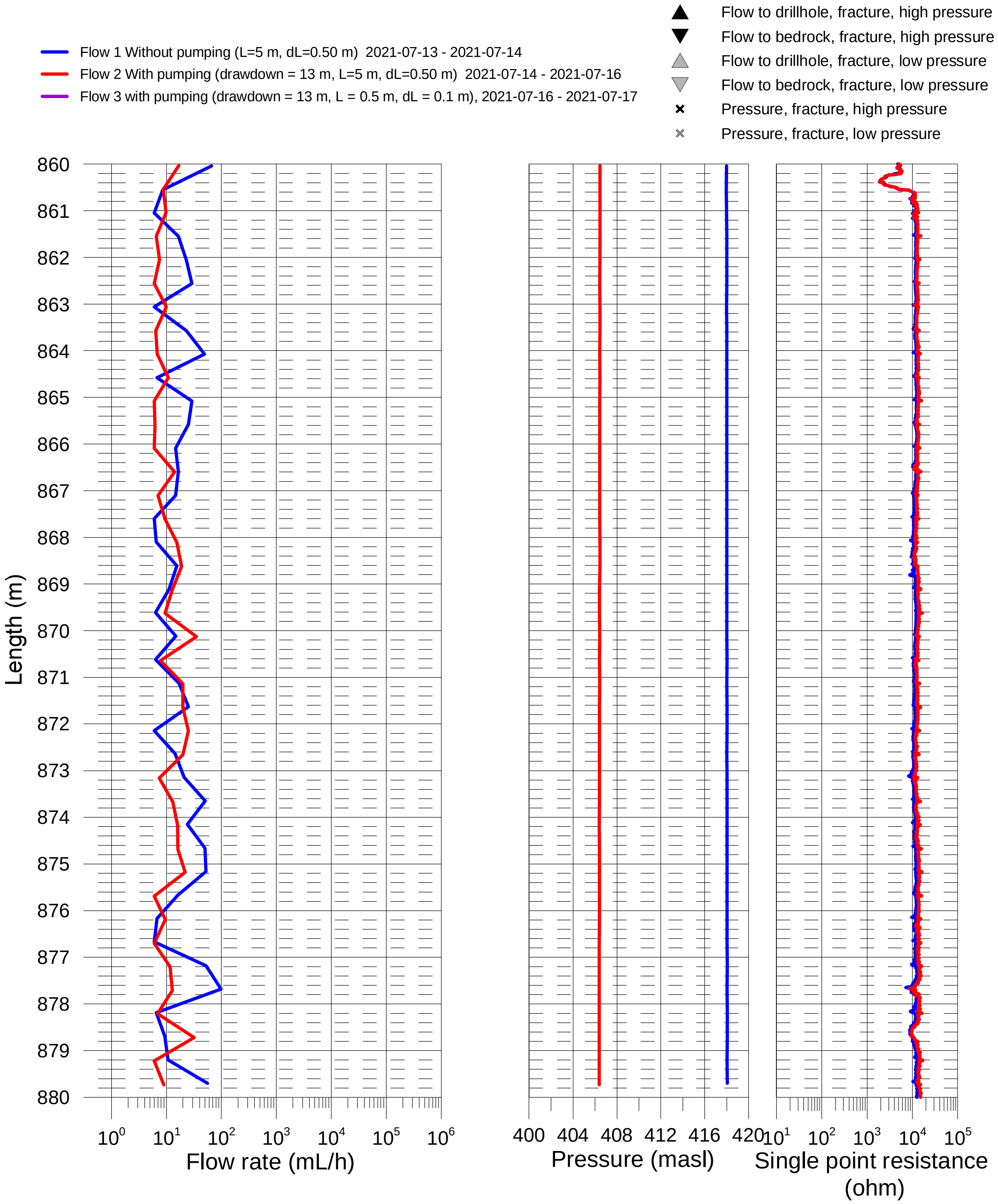
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



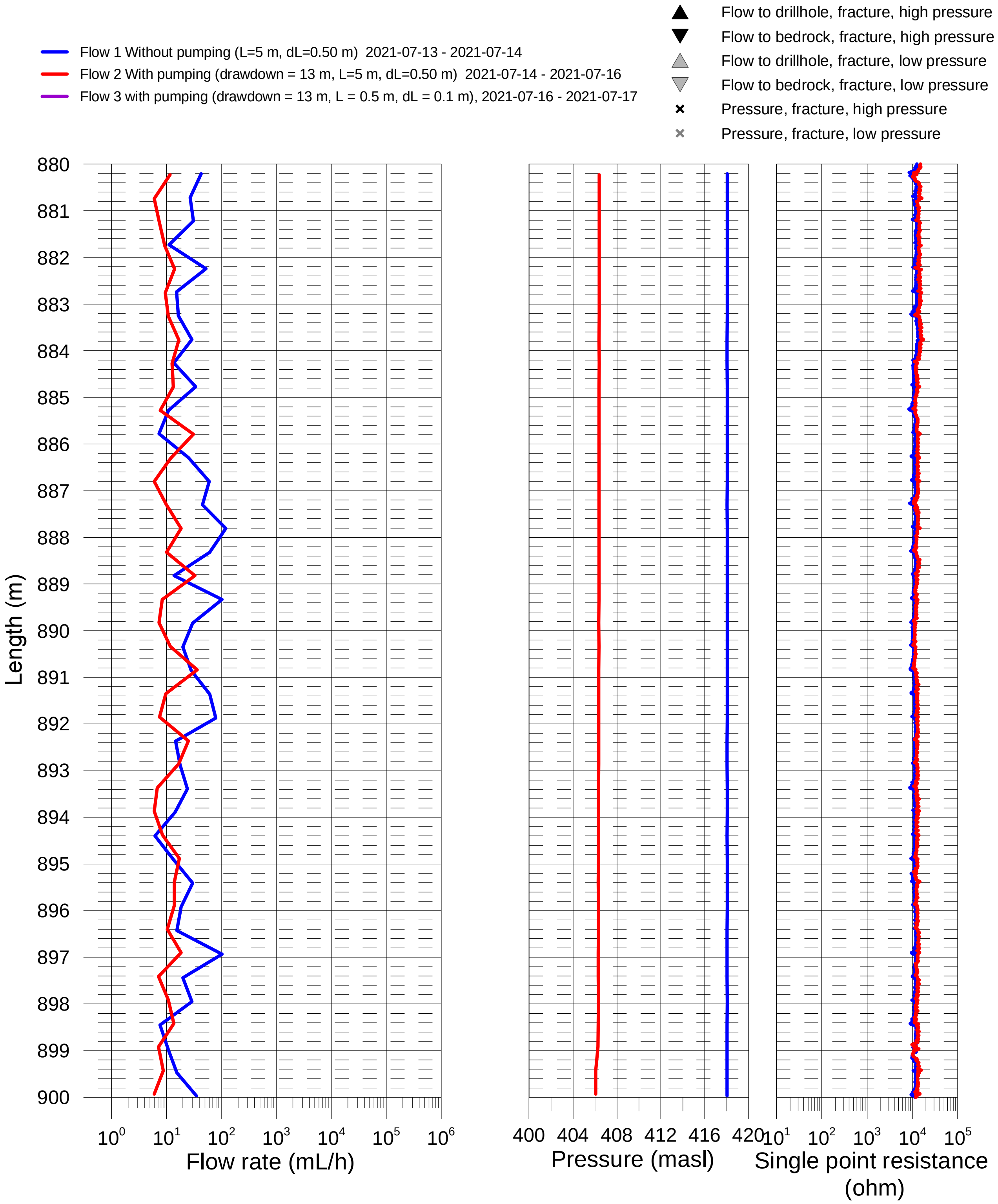
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



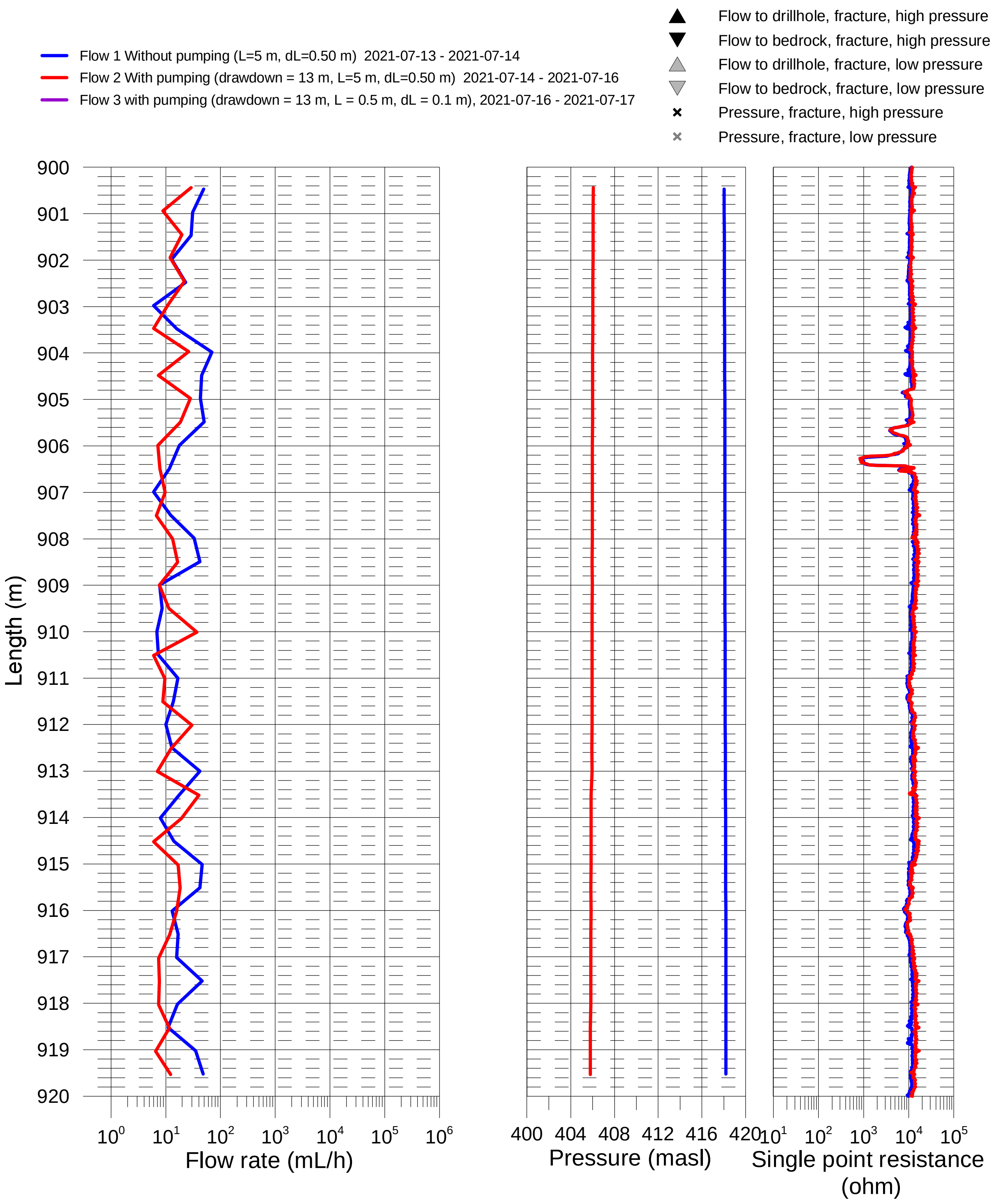
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



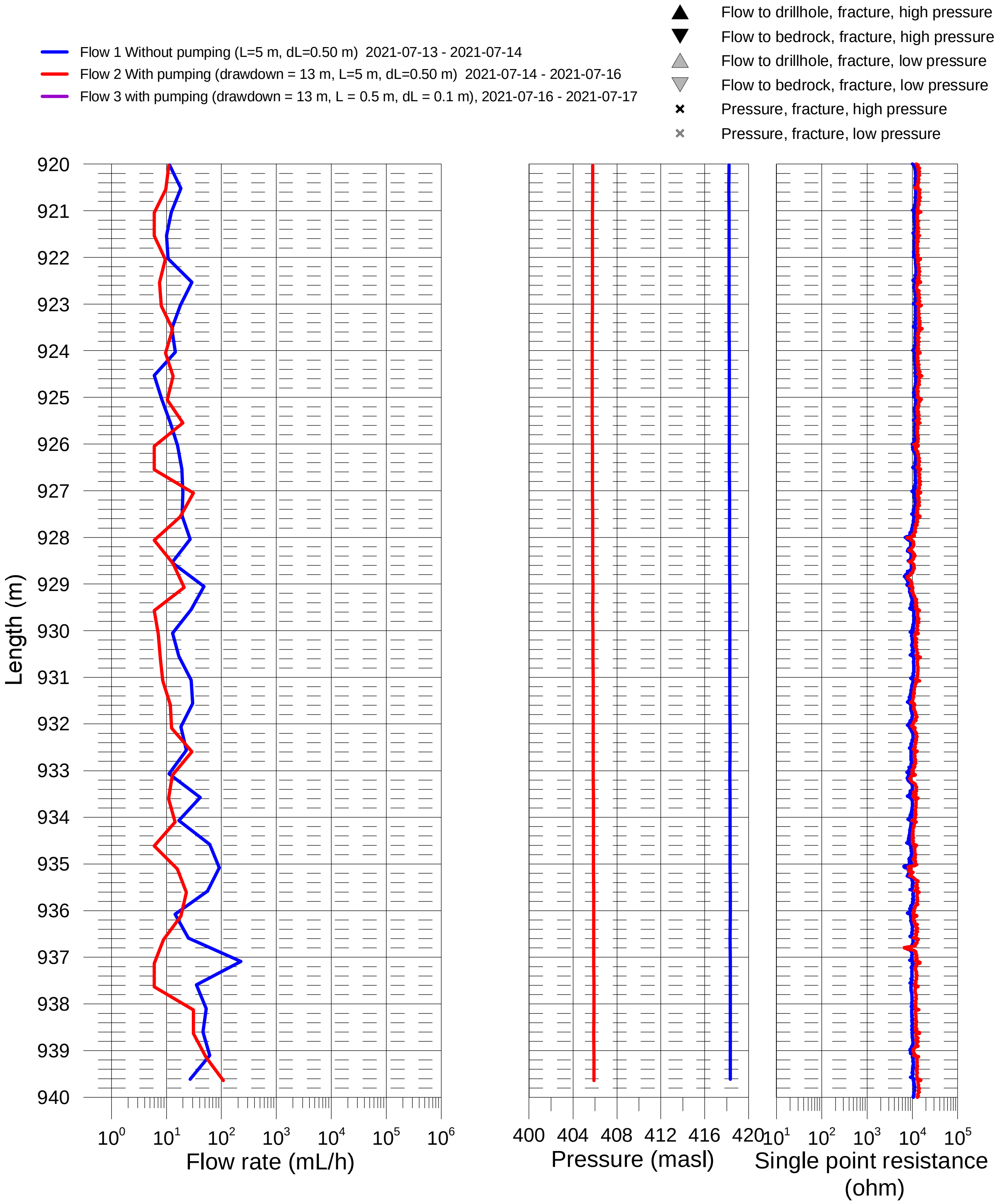
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



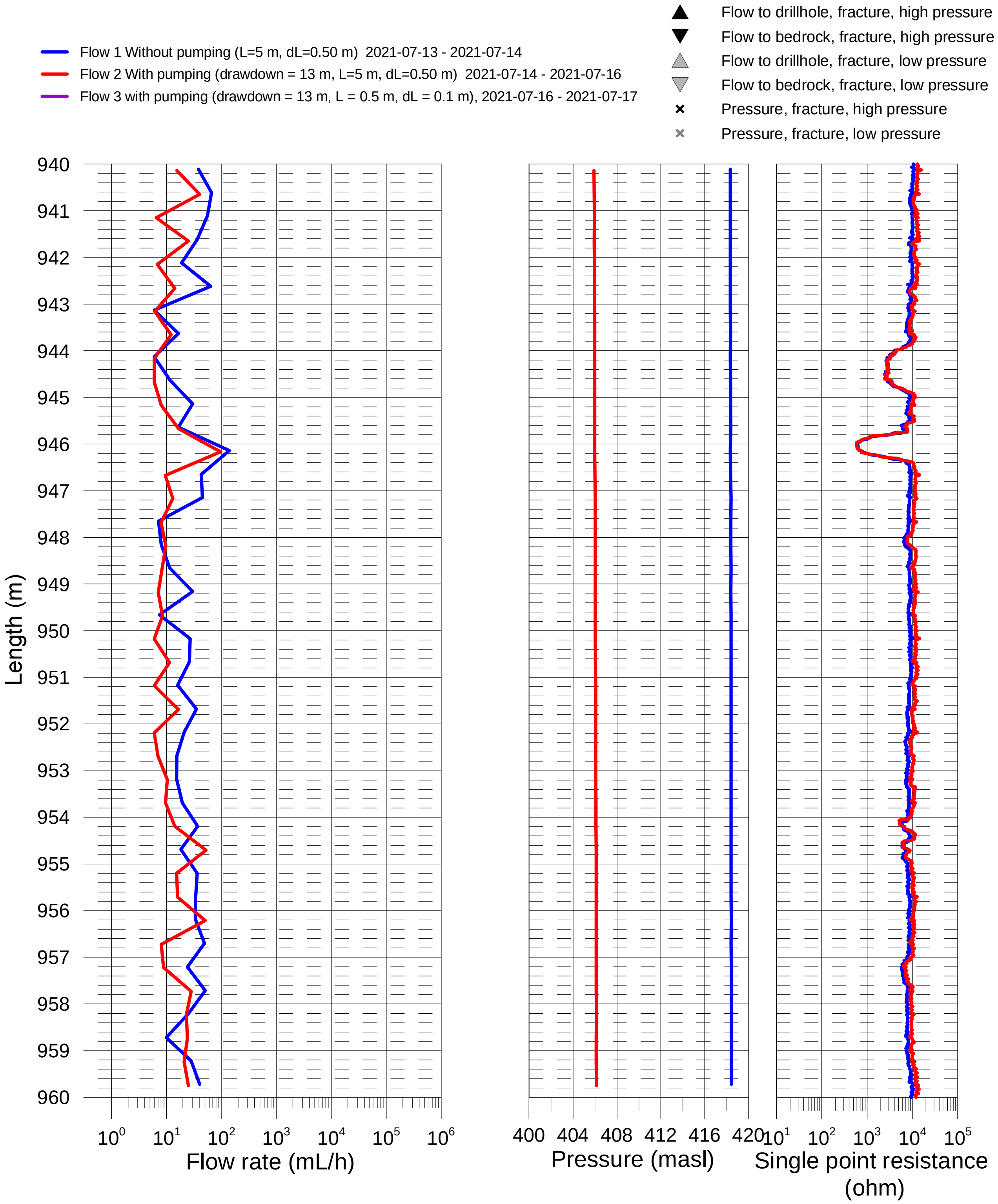
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



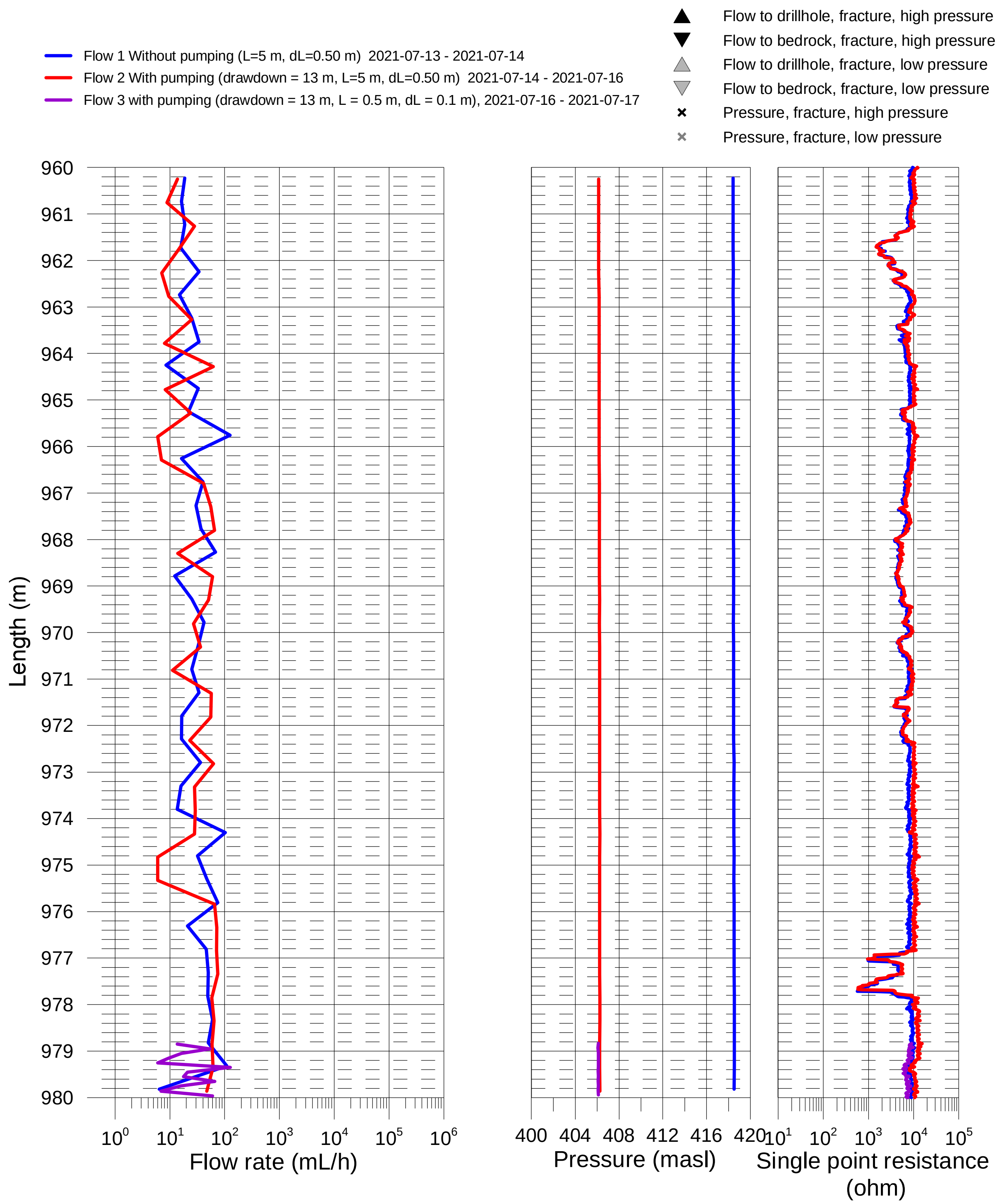
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



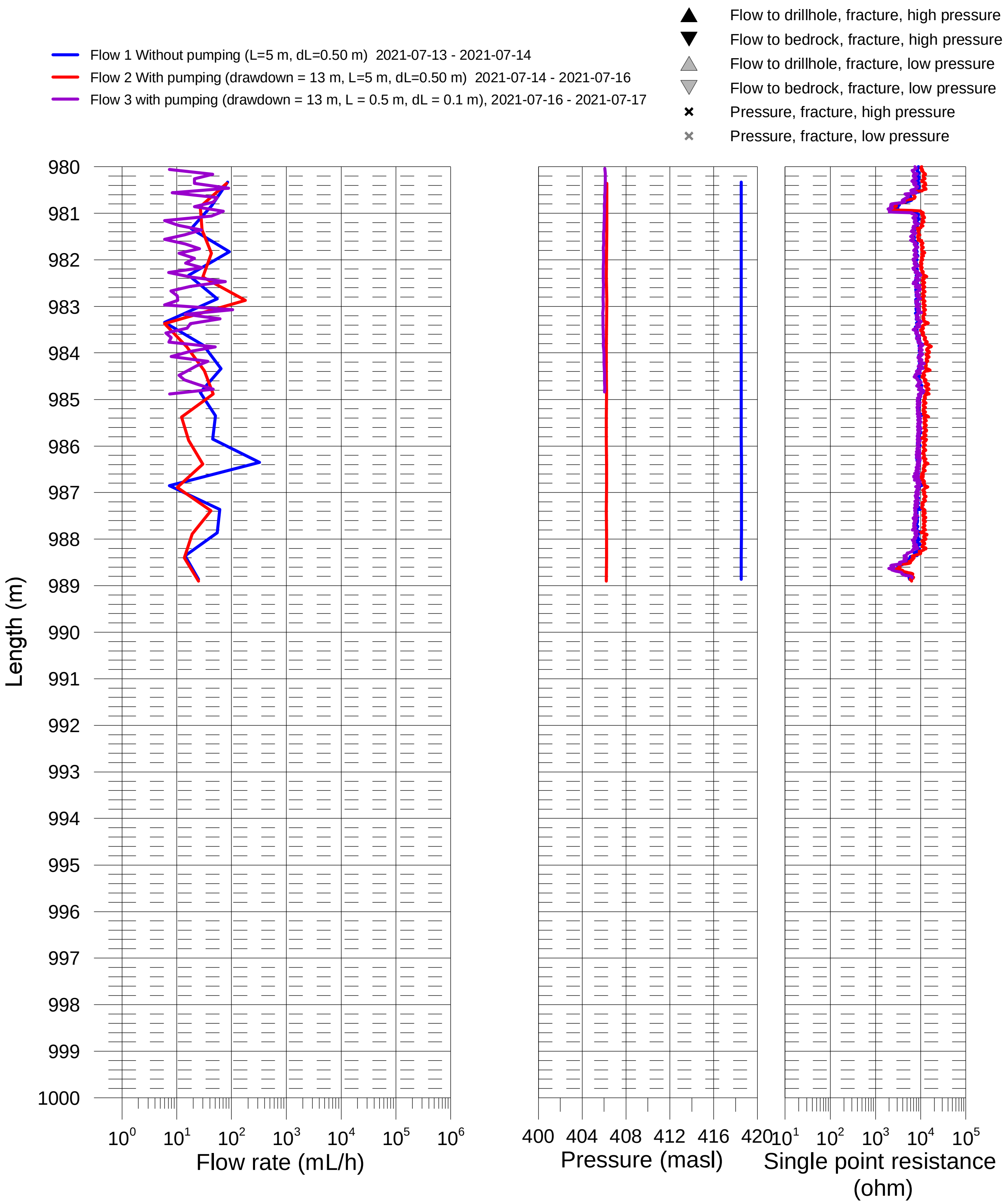
Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance

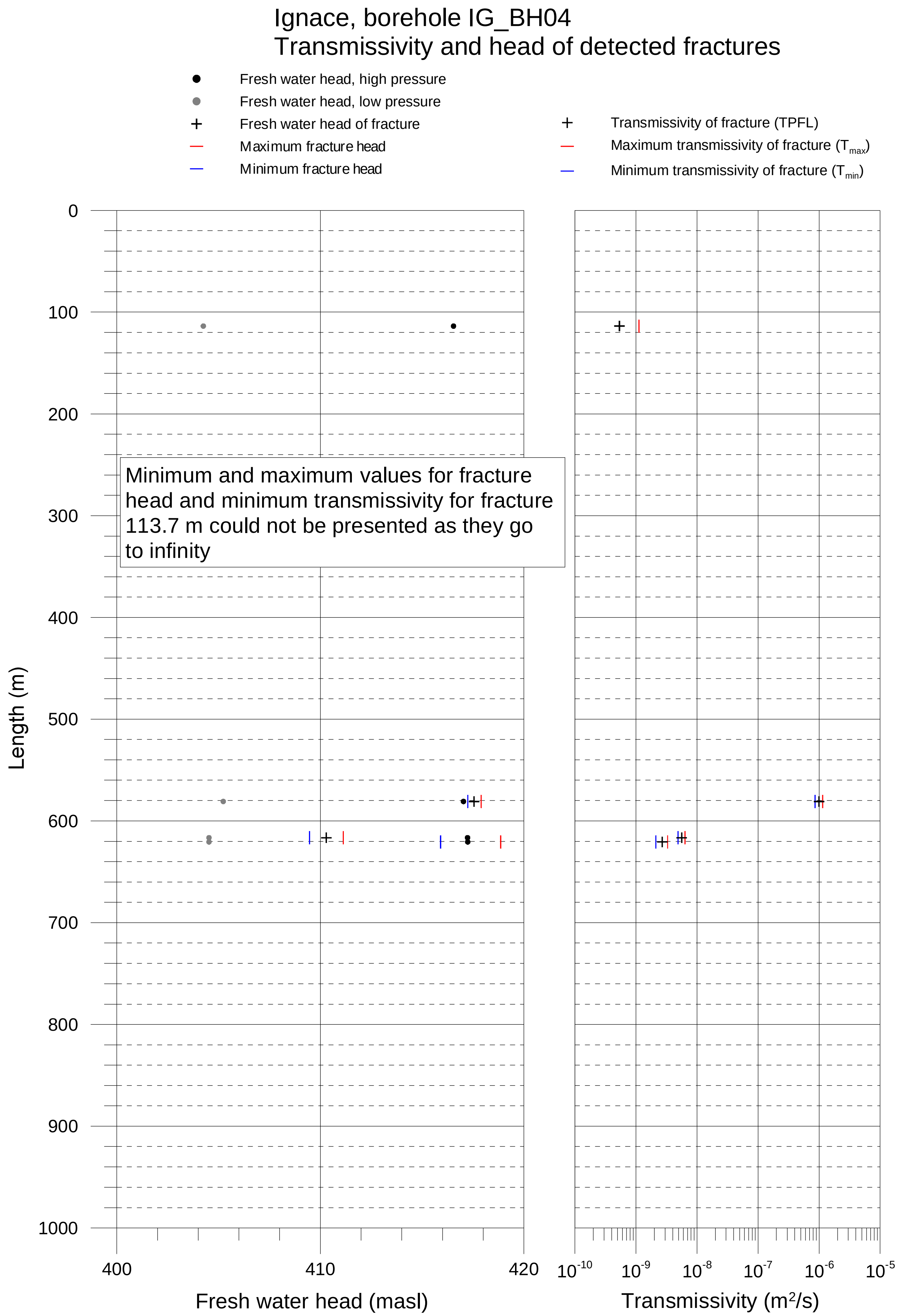


Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance



Ignace, borehole IG_BH04
Flow rate, pressure and single point resistance





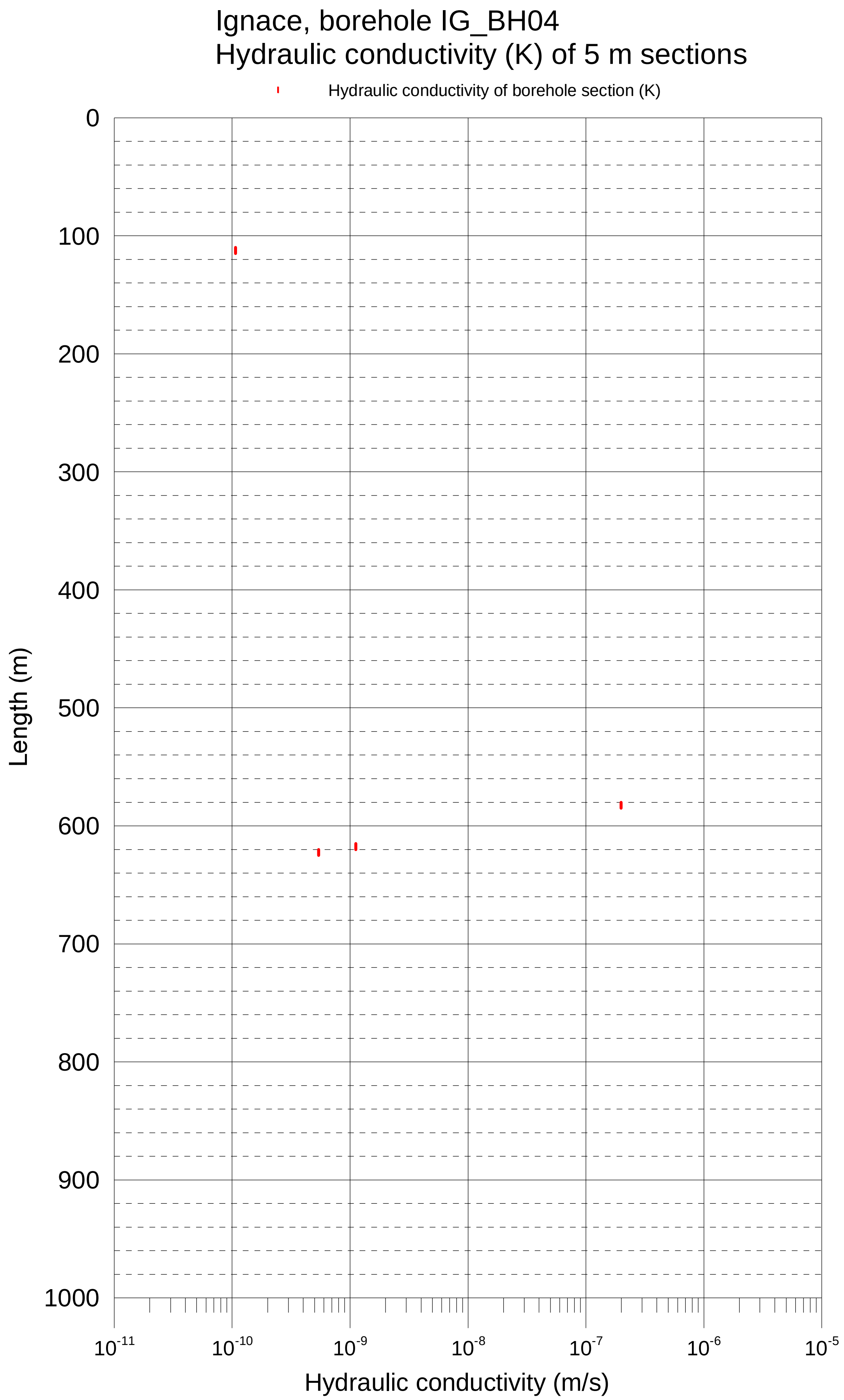
Ignace, borehole IG_BH04
Transmissivity and head of detected fractures
Fresh water head, high pressure
Fresh water head, low pressure
Fresh water head of fracture
Maximum fracture head
Minimum fracture head
Transmissivity of fracture (TPFL)
Maximum transmissivity of fracture (T_{max})
Minimum transmissivity of fracture (T_{min})
Minimum and maximum values for fracture head and minimum transmissivity for fracture 113.7 m could not be presented as they go to infinity
Length (m)
0
100
200
300
400
500
600
700
800
900
1000
400
410
420
Fresh water head (masl)
10^{-10}
10^{-9}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
Transmissivity (m^2/s)

Ignace, borehole IG_BH04
Table of transmissivity and head of detected fractures

Description of columns:

Length (m) = Distance from the reference to the fracture (m)
FW Head$_H$ (masl) = Fresh water head in the drillhole (meter above sea level), higher drillhole pressure
Flow$_H$ (mL/h) = Flow rate of the fracture, higher drillhole pressure
FW Head$_L$ (masl) = Fresh water head in the drillhole (meter above sea level), lower drillhole pressure
Flow$_L$ (mL/h) = Flow rate of the fracture, lower drillhole pressure
T_{PFL} (m^2/s) = Transmissivity of the fracture
FW Head of fracture (masl) = Fresh water head of the fracture
T_{max} (m^2/s) = Upper limit for T_{PFL} based on uncertainty in flow and pressure measurements
T_{min} (m^2/s) = Lower limit for T_{PFL} based on uncertainty in flow and pressure measurements
FW HeadOfF$_{max}$ (masl) = Upper limit for FW head of fracture based on uncertainty in flow and pressure measurements
FW HeadOfF$_{min}$ (masl) = Lower limit for FW head of fracture based on uncertainty in flow and pressure measurements

Length (m)	FW HeadH (masl)	FlowH (mL/h)	FW HeadL (masl)	FlowL (mL/h)	T_{PFL} (m^2/s)	FW Head of fracture (masl)	T_{max} (m^2/s)	T_{min} (m^2/s)	FW HeadOfF$_{max}$ (masl)	FW HeadOfF$_{min}$ (masl)
113.7	416.54	±20	404.25	24	5.37E-10	-	1.12E-09	-	-	-
580.9	417.03	1900	405.23	44700	9.97E-07	417.55	1.14E-06	8.59E-07	417.90	417.24
616.5	417.23	-142	404.53	118	5.62E-09	410.29	6.39E-09	4.91E-09	411.13	409.47
620.6	417.24	±10	404.53	125	2.70E-09	-	3.31E-09	2.13E-09	418.86	415.91



Ignace, borehole IG_BH04
Hydraulic conductivity (K) of 5 m sections
Hydraulic conductivity of borehole section (K)
0
100
200
300
400
500
600
700
800
900
1000
Length (m)
10^{-11}
10^{-10}
10^{-9}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
Hydraulic conductivity (m/s)

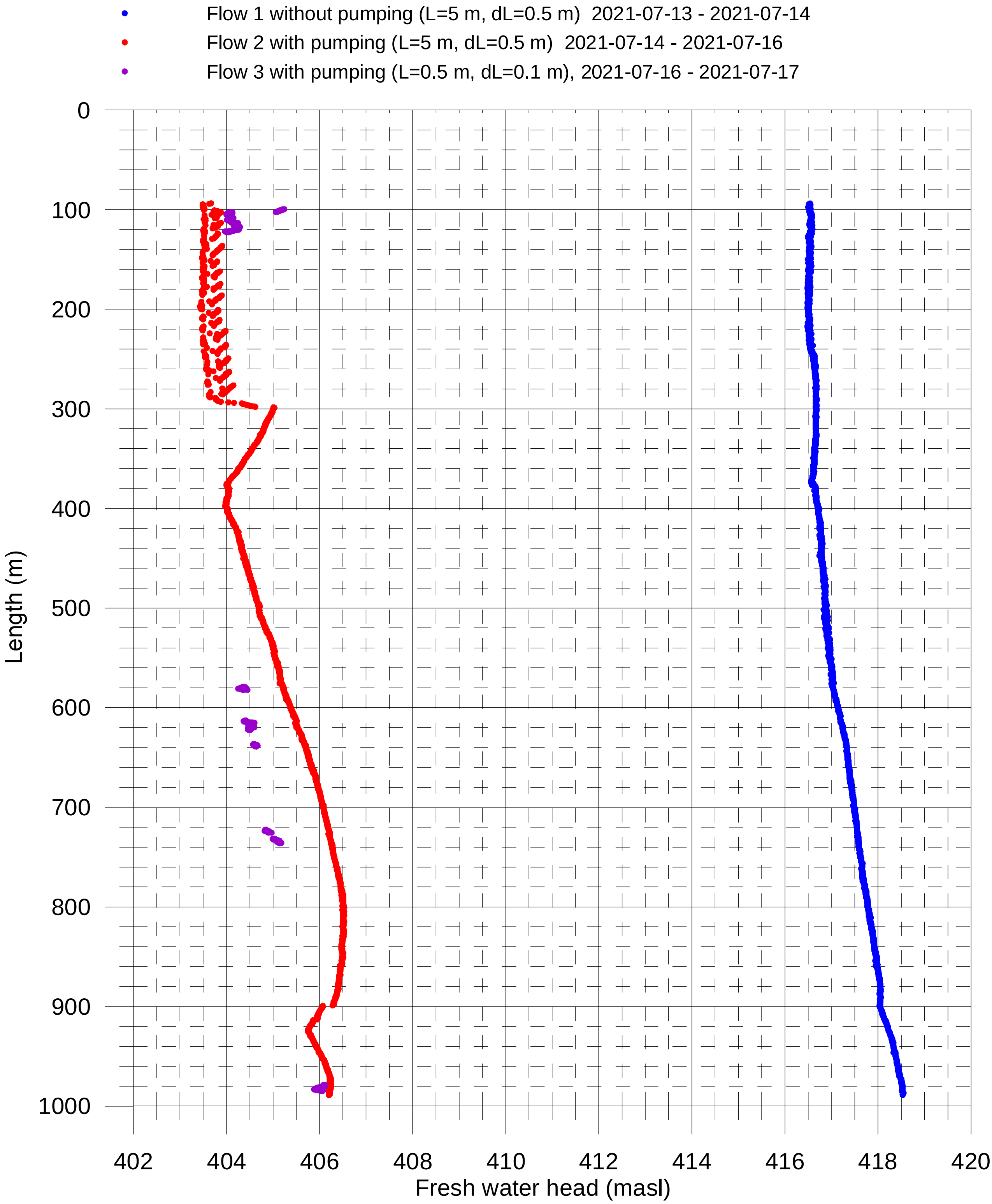
Ignace, borehole IG_BH04
Table of hydraulic conductivity of 5 m sections

Description of columns:

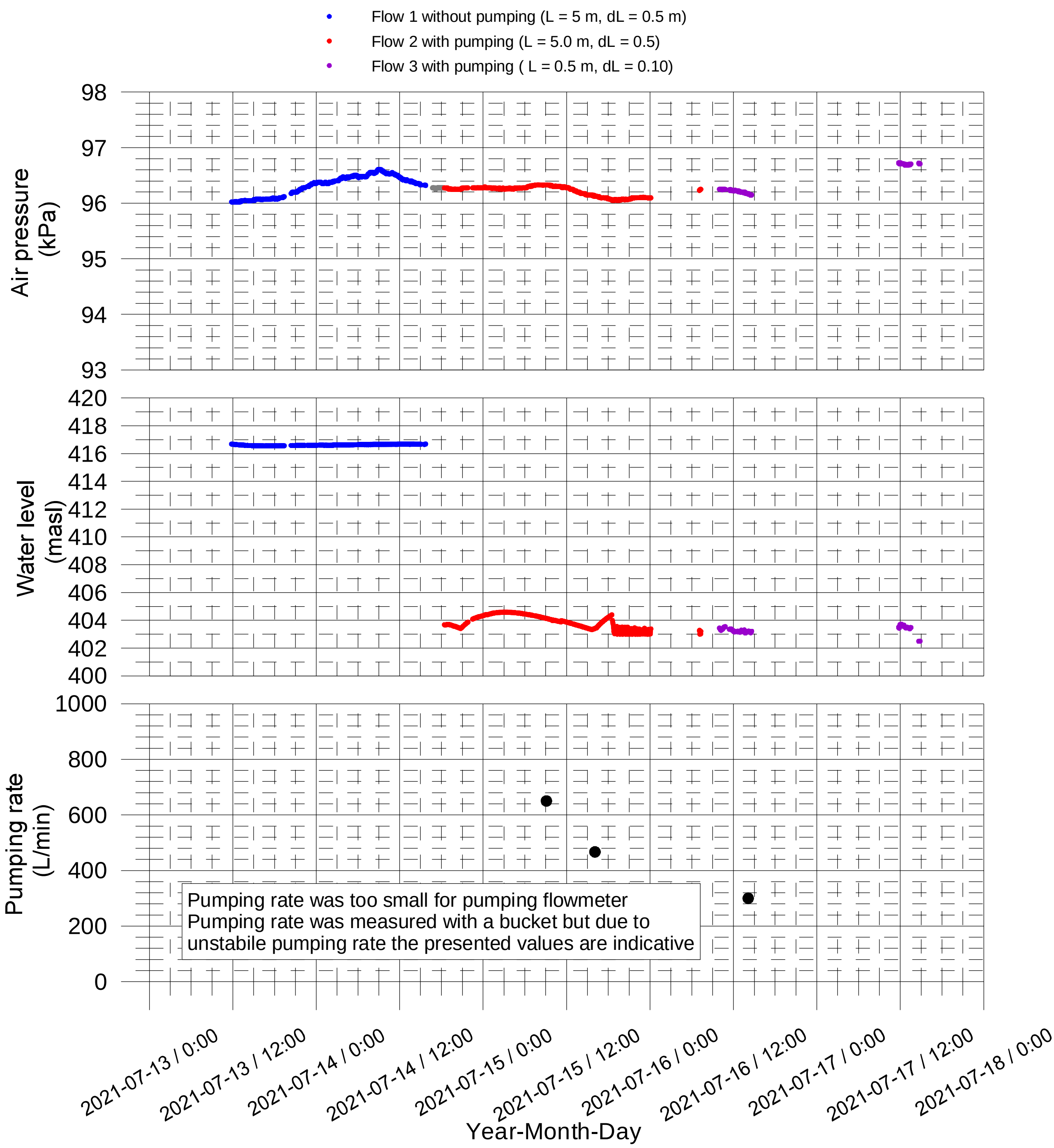
Sec Up (m) = Depth from reference depth to the upper end of the section
Sec Low (m) = Depth from reference depth to the lower end of the section
Tsum (m2/s) = Calculated transmissivity of the section
L (m) = Length of borehole section
K (m/s) = Calculated hydraulic conductivity of the section

Sec Up (m)	Sec Low (m)	Tsum (m^2/s)	L (m)	K (m/s)	Comment
100	110				No fractures found
110	115	5.37E-10	5	1.07E-10	
115	580				No fractures found
580	585	9.97E-07	5	1.99E-07	
585	615				No fractures found
615	620	5.62E-09	5	1.12E-09	
620	625	2.70E-09	5	5.40E-10	
625	990				No fractures found

Ignace, borehole IG_BH04
Fresh water head in the borehole

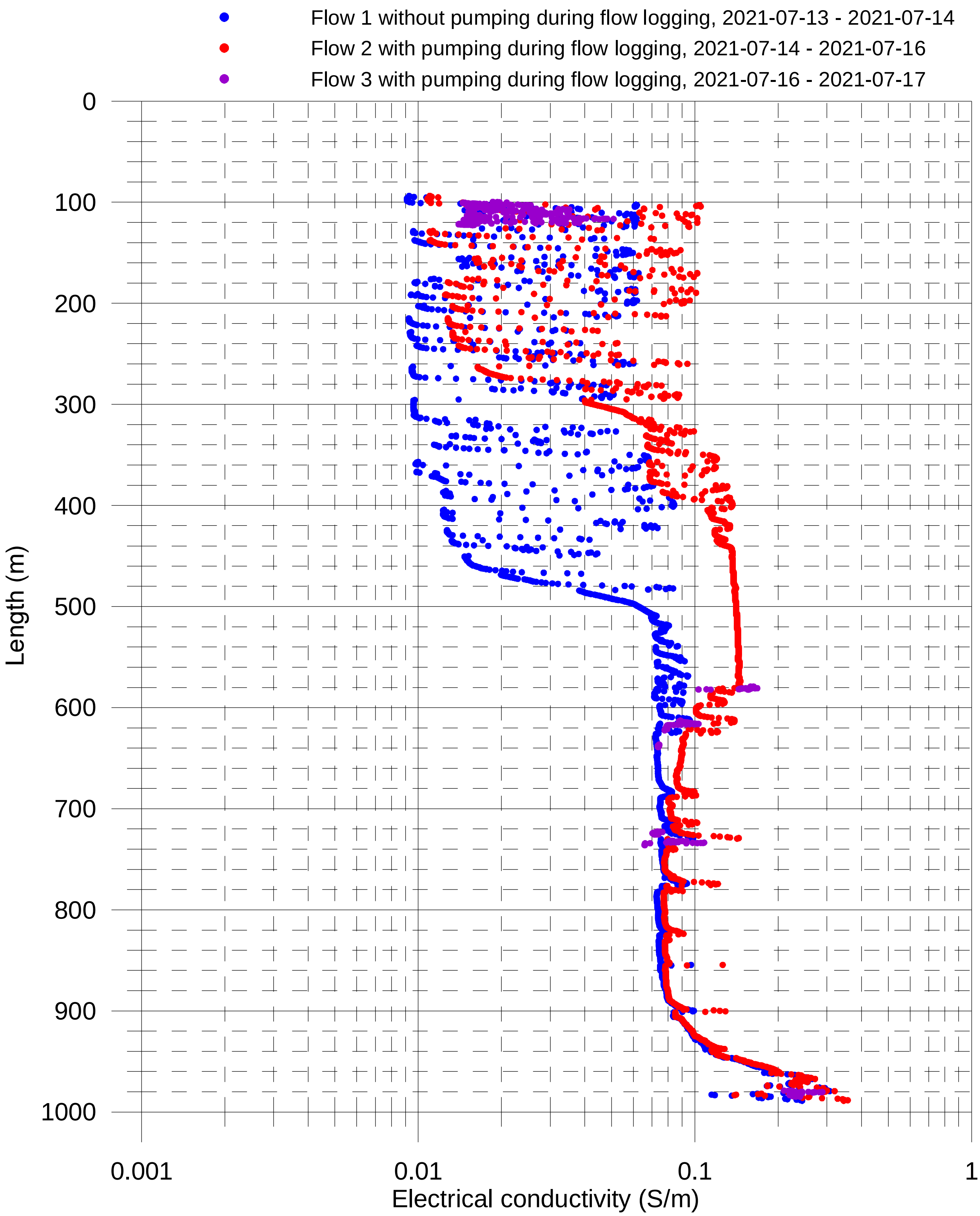


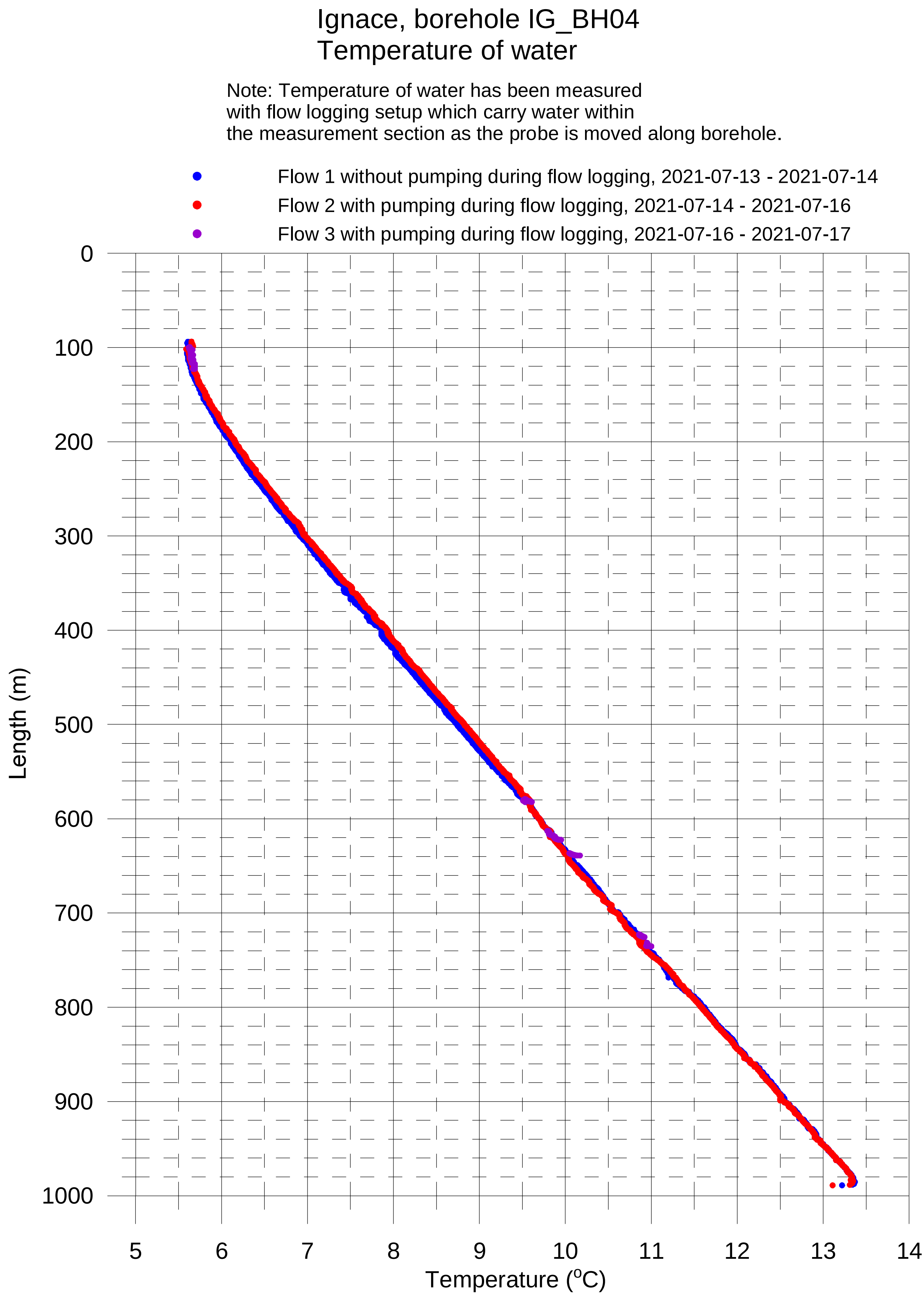
Ignace, borehole IG_BH04
Air pressure, water level in the borehole and pumping rate during flow logging



Ignace, borehole IG_BH04
Electrical conductivity of water

Note: Electrical conductivity of water has been measured
with flow logging setup which carry water within
the measurement section as the probe is moved along borehole.




Ignace, borehole IG_BH04
Temperature of water
Note: Temperature of water has been measured
with flow logging setup which carry water within
the measurement section as the probe is moved along borehole.
Flow 1 without pumping during flow logging, 2021-07-13 - 2021-07-14
Flow 2 with pumping during flow logging, 2021-07-14 - 2021-07-16
Flow 3 with pumping during flow logging, 2021-07-16 - 2021-07-17
Length (m)
0
100
200
300
400
500
600
700
800
900
1000
5
6
7
8
9
10
11
12
13
14
Temperature (°C)

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