

# PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING AT IG\_BH04/05/06 IGNACE AREA

*WP05 Data Report - Geophysical Well Logging for  
IG BH05*

**APM-REP-01332-0366**

**May 2023**

**WSP Canada Inc.**

**nwmo**

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**REPORT**

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*WP05 Data Report - Geophysical Well Logging for IG BH05*

Submitted to:

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## WP05 DATA REPORT

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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 WSP Canada Inc. (WSP) on behalf of the NWMO. The IG\_BH05 program is described in the Borehole Characterization Plan (BCP) for IG\_BH05 (Golder 2021a).

This data report describes the methodology, activities, and reporting for Work Package 5 (WP05): Geophysical Well Logging for IG\_BH05. 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<sup>2</sup>. 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\_BH05 is located within an investigation area of approximately 19 km<sup>2</sup> 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  $\pm$  1.1 Ma and 2725  $\pm$  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  $2734.2 \pm 0.8$  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  $2732.3 \pm 0.8$  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  $2694.0 \pm 0.9$  Ma (Stone et al. 2010).

The bedrock surrounding IG\_BH05 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  $1887 \pm 13$  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).

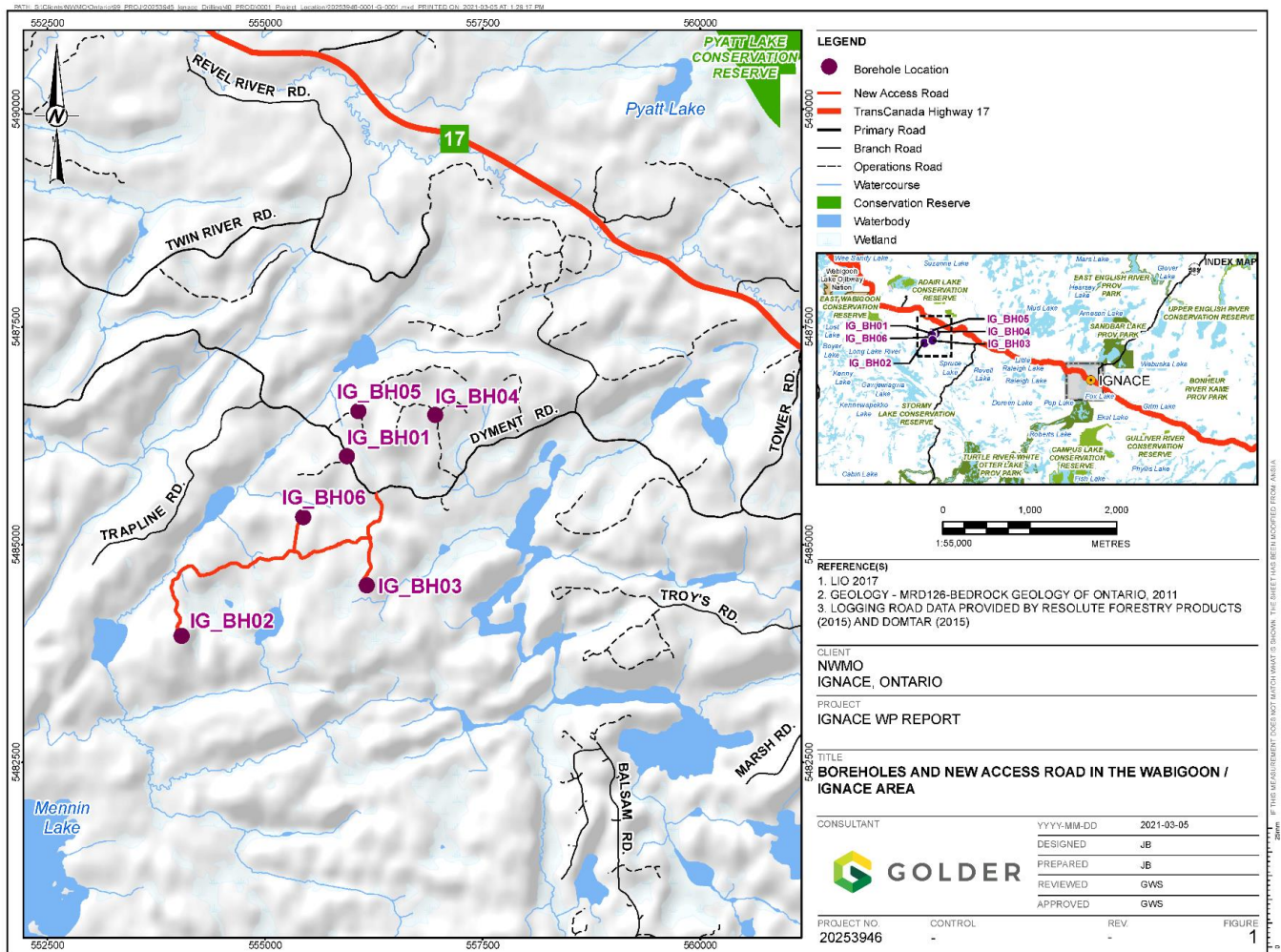
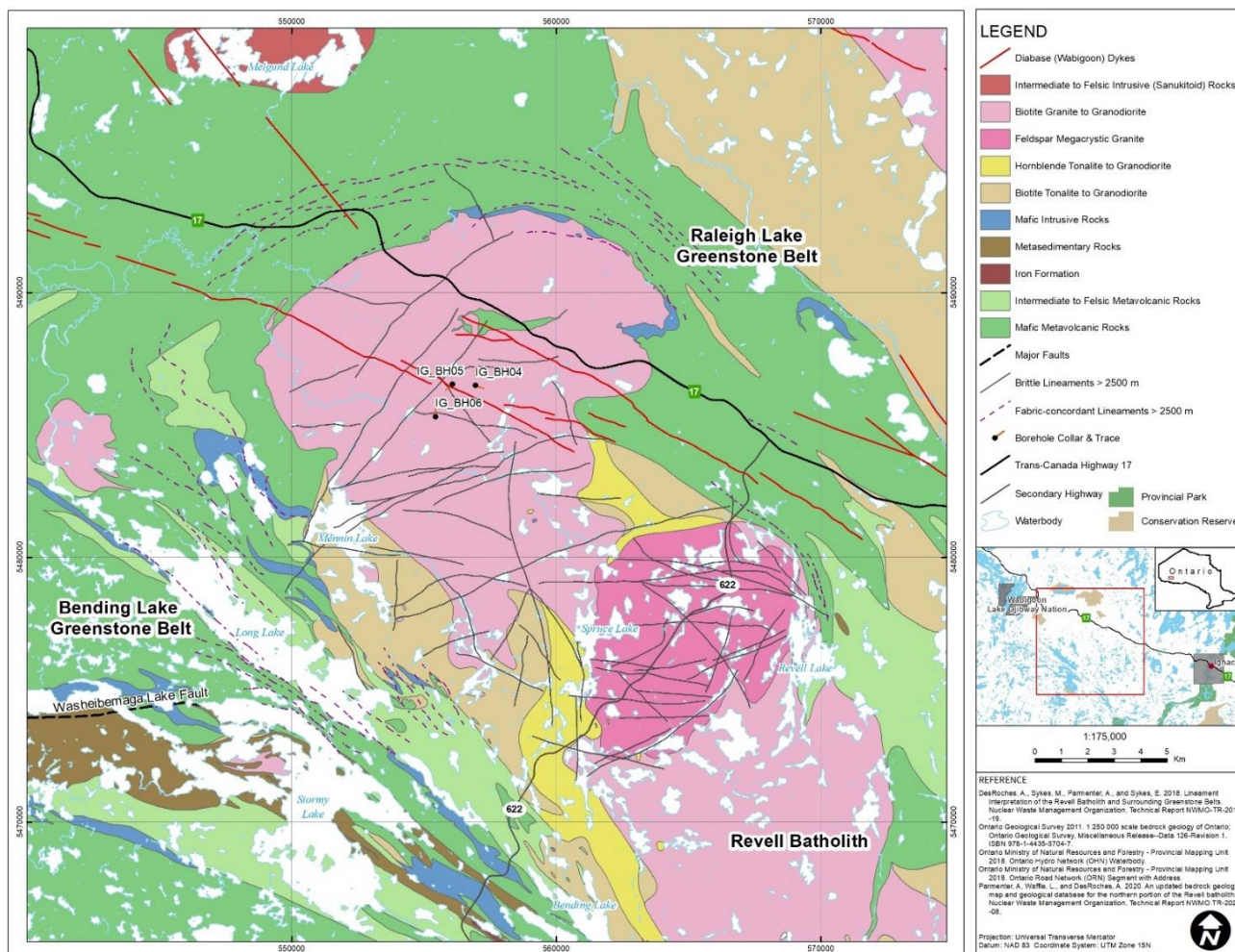


Figure 1: Location of IG\_BH05 in relation to the Wabigoon / Ignace Area



**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

WSP completed the geophysical logging in two stages. The geophysical logging team was mobilized to site on May 22, 2021 to collect optical and acoustic televiwer data from the upper 100 m portion of the borehole prior to the surface casing being set. The main geophysical logging program from the bottom of the finished borehole to the bottom of the steel casing was conducted from August 17 to 25, 2021 immediately after completion of drilling and flushing the borehole.

The main geophysical logging program was completed by WSP and its subconsultants DGI Geoscience (DGI) and Posiva Solutions Oy (Posiva). WSP personnel carried out the majority of the geophysical logs, and DGI carried out gamma-gamma, sonic, neutron and resistivity logs, under WSP supervision. Posiva carried out the Posiva flow logging, under WSP's supervision. The geophysical logging acquisition took place within the IG\_BH05 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: Winch bolted to ground and setup for IG\_BH05.**

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 vertically above ground surface. 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.

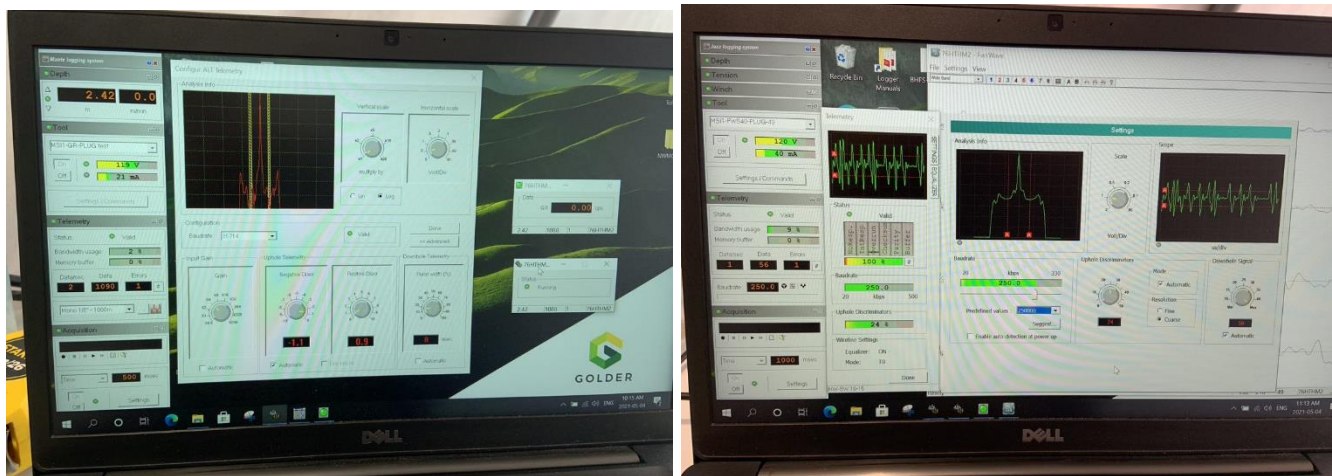


Figure 4: Laptop computer with ALT LoggerSuite software (left) and Jazz Logging System (right)



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:



- Televue, deviation, and caliper logging was carried out to help assess structural properties of the rock, in conjunction with WP03, rock core logging and photography.
- 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.
- 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.
- 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 | 2CAA-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 Televue                      | 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       | 2CAA-1000       | 0.05                | 10 / 20               | Down / Up         |
| Magnetic Susceptibility               | HMI-453         | 0.05                | 4.5                   | Up                |
| Optical Televue                       | QL40-OBI-2G     | 0.02                | 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.

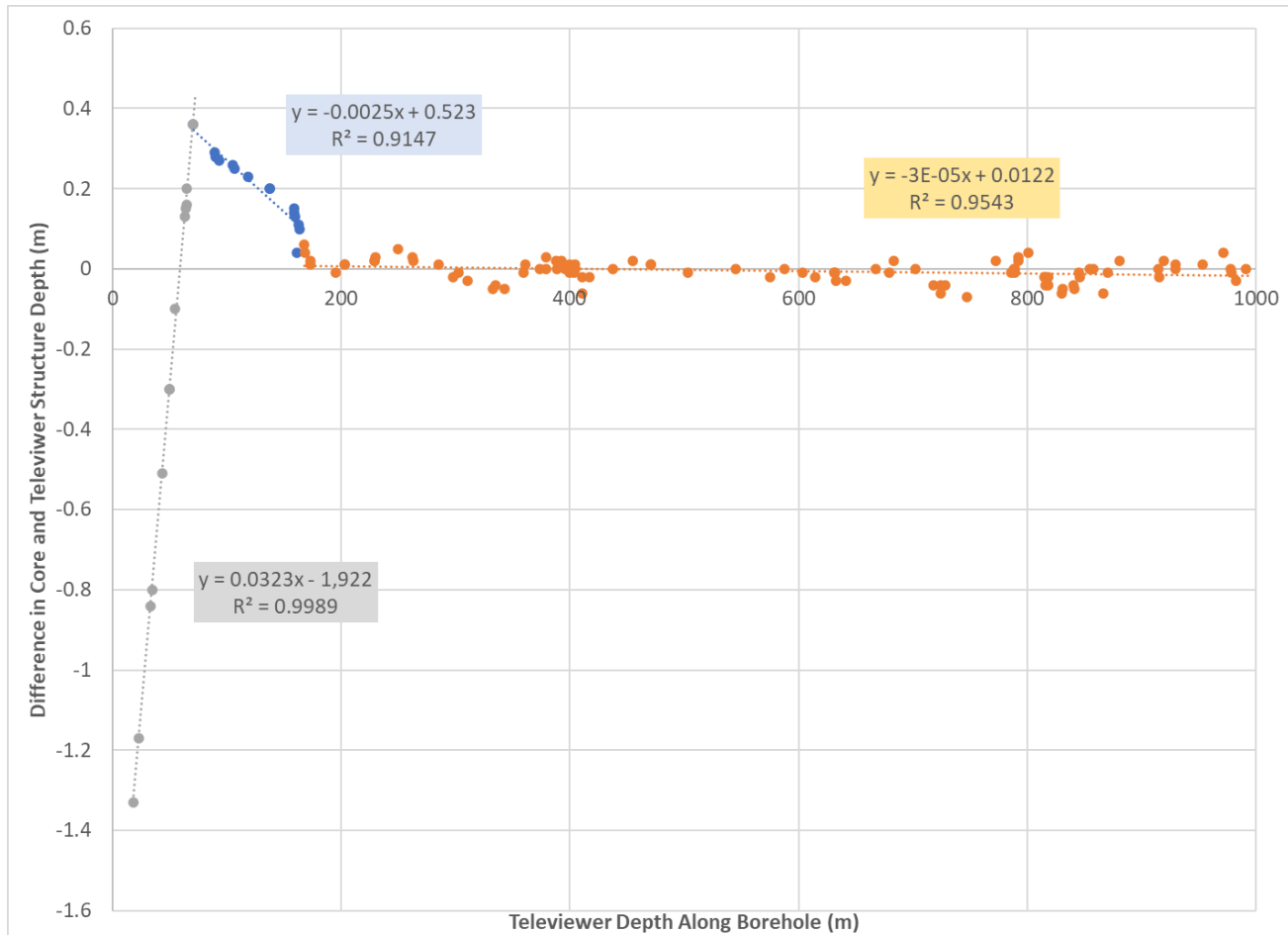
#### **3.4.1.1 Wireline Cable Stretch Correction**

After carefully analysing all processing procedures, and in consultation with NWMO, it was decided to not apply a cable stretch factor for IG\_BH05 data. Final depth corrections were applied to all BH05 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 and/or mismatching of structures between the two datasets.

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 televiwer (acoustic and optical) data**

As there were three general trends in the dataset it was decided to apply this correction factor to the geophysical logs, according to the relationship:

$$D < 60m: \quad \text{Final Depth (m)} = D * 0.0323 - 1.922$$

$$D = 60 \text{ to } 170m: \quad \text{Final Depth (m)} = D * -0.0025 + 0.523$$

$$D > 170m: \quad \text{Final Depth (m)} = D * -0.00003 + 0.0122$$

where:

$$D = \text{Corrected Depth (m)}$$

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, and errors in the initial depth correction to core structures, done at a coarse level. The remaining discrepancies between core and televiwer structure

depths, typically in the range of  $\pm 0.1$  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) |
|---|------------------------------|
| Electromagnetic Induction (Apparent Conductivity) | -0.88                        |
| Gamma-Gamma Density                               | 0.01                         |
| Acoustic Televiwer                                | -0.84                        |
| Natural Gamma                                     | -0.88                        |
| Neutron   | -0.96                        |
| Full Waveform Sonic                               | 0.33                         |
| Resistivity (E-LOG)                               | 0.30                         |
| Mechanical Caliper                                | 0.00                         |
| Spectral Gamma                                    | -0.98                        |
| Fluid Temperature / Resistivity                   | -0.59                        |
| Magnetic Susceptibility                           | -0.92                        |
| Optical Televiwer (Deviation Run)                 | -0.25                        |
| Optical Televiwer                                 | 0.15                         |
| Heat-Pulse Flowmeter                              | 0.65                         |

### 3.4.2 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 500 m, turned on and the first log was started. The QA/QC log was recorded for 10% of the borehole depth, from 500 m to 400 m at 4.5 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 500 m to 400 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 7.36 mS/m to 23.35 mS/m. The average value is 18.33 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, 624 to 625 m, 857 to 858 m, 915 to 920 m and 983 to 985 m correspond with dykes and veins apparent in the optical televiewer log and seen in natural gamma, gamma-gamma density, and neutron logs.

### 3.4.3 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<sup>3</sup>) and a test borehole in rock with a known density of 2.942 g/cm<sup>3</sup>. The gamma-gamma density probe achieved calibration status with  $\pm 0.08$  g/cm<sup>3</sup> in near and far density measurements of the aluminium block and  $\pm 0.001$  g/cm<sup>3</sup> 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 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 2.01 g/cc to 3.18 g/cc (below the casing), with an average of 2.77 g/cc. The Far Density log ranges from 2.41 g/cc to 3.20 g/cc (below the casing), and has an average value of 2.75 g/cc. There is a large area of increase from 285 to 335 m, as well as ten spikes ranging in thickness from 0.7 to 4.0 m are apparently associated with discrete changes in rock type as observed in optical televiewer logs and through geological core logging (WP03: Golder, 2020b), and typically range from 2.91 g/cc to 3.11 g/cc, or 0.07 g/cc to 0.3 g/cc above background. There are five spikes, ranging in thickness from 0.14 to 0.5 m, with a densities ranging from of 2.01 g/cc to 2.63 g/cc, or 0.14 g/cc to 0.75 g/cc below background at depths of 451.6 to 452.1 m, 575.05 to 575.52 m, 577.33 to 577.76 m, 818.20 to 819.9 m and 958.65 to 959.11 m which also appears to be associated with a discrete change in rock type as observed in optical televiewer logs and through geological core logging (WP03: Golder, 2023).

### **3.4.4 Televiewer Logging**

#### **3.4.4.1 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, 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. 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 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 10 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 2 m to 995 m. Once the QA/QC log was finished, the QA/QC file was terminated. The ABI40-2G was run up the borehole at 2.0 m per minute, sampling every 0.002 m with 288 ppt (points per turn) azimuthal resolution. A constant logging speed was used throughout entire length of borehole to ensure consistency. The probe was then lowered and select intervals relogged where there was poor resolution



or data collection errors in the main log. Once this was completed an additional log was recorded up the borehole, sampling at 0.05 m to record deviation.

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, -0.84 m, was recorded as the After-Survey Depth Error (ASDE).

The .TFD files were imported into WellCAD then depth shifted and merged accordingly. For the primary log data curves, an interpolation function was applied to remove data spikes and gaps smaller than 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.

#### **3.4.4.2 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), sampling every 0.002 m with 900 ppt azimuthal resolution.

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.

The .TFD files were imported into WellCAD then depth shifted and merged accordingly. 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.

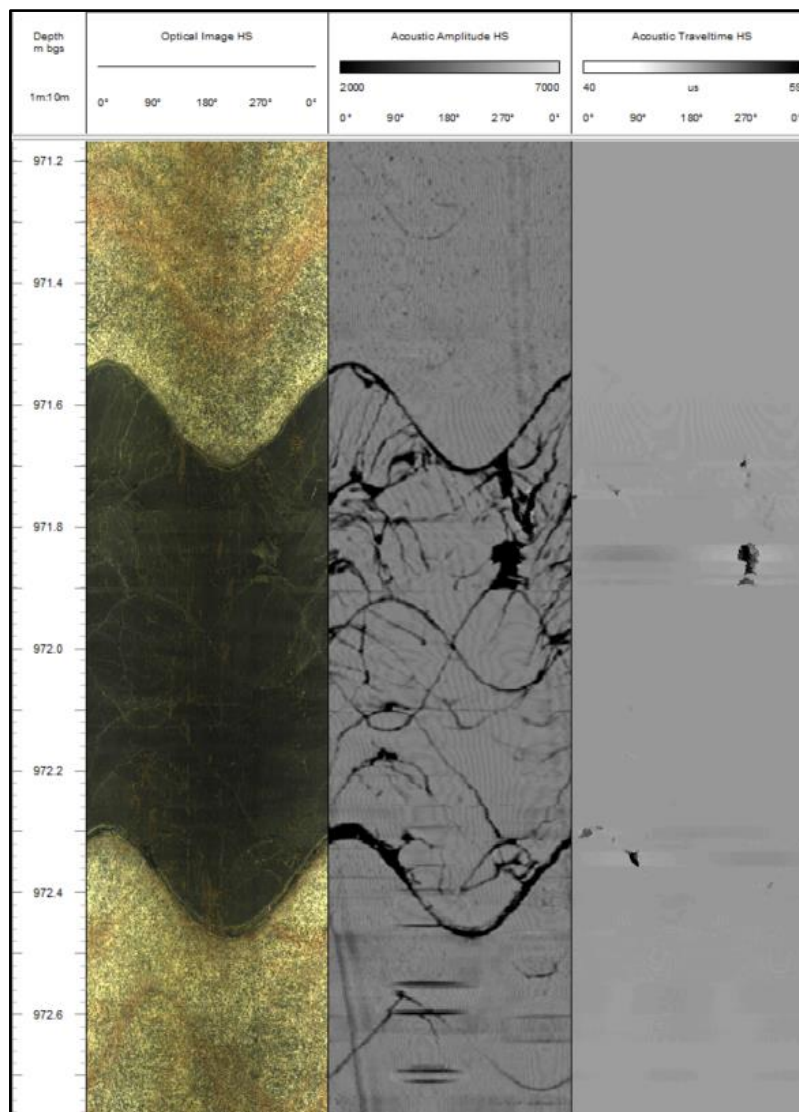
One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2. The optical televiewer image is displayed for reference in the Structural Log, Lithology Log, Engineering Log, and Hydrogeology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

During the flushing of the borehole, as part of Work Package 3, which was conducted prior to starting the borehole geophysical logging flocculent was added to the flushing water to improve clarity of the borehole fluid and increase quality of the optical televiewer log. The optical televiewer data collected in IG\_BH05 was significantly clearer than the televiewer data collected in IG\_BH04, indicating that the flocculent worked for its intended purpose, although it caused issues for the flow logs (HPFM and Posiva logs).

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 3.4.4.3.

#### 3.4.4.3 *Televiewer Structural Interpretation*

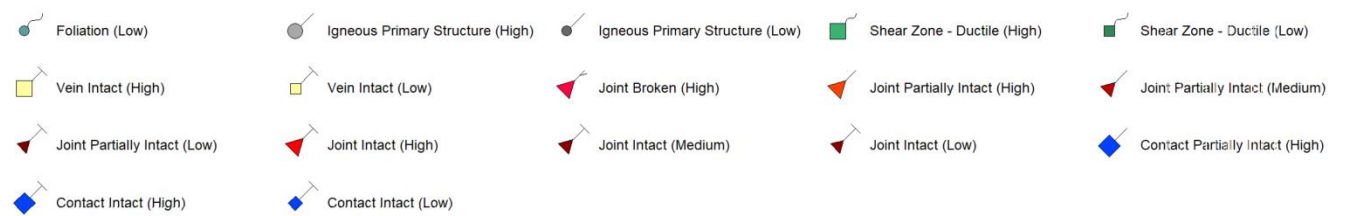
Once the optical and acoustic televiewer logs were finalized, a structural analysis was completed using the structural interpretation module in WellCAD to obtain the depth, apparent dip, and dip direction (i.e., orientations relative to high side) of each interpreted structure (Figure 8).



**Figure 8: 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 (see Figure 9) 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.



**Figure 9: 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 diameter, 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. Three breakout zones were observed in the borehole log, between 451.4 and 451.9 m, between 626.8 and 627.1 m, and between 856.8 and 857.2 m, which are shown in Figures 10, 11, and 12.

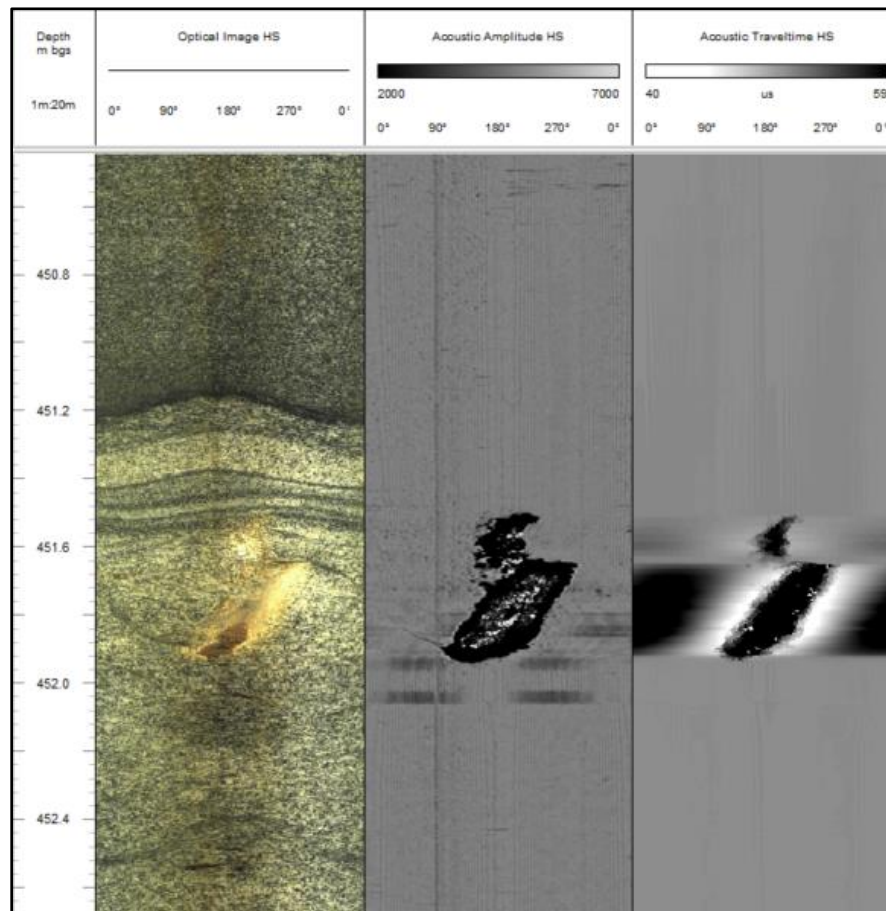


Figure 10: Breakout zone observed between 451.4 and 451.9 m.

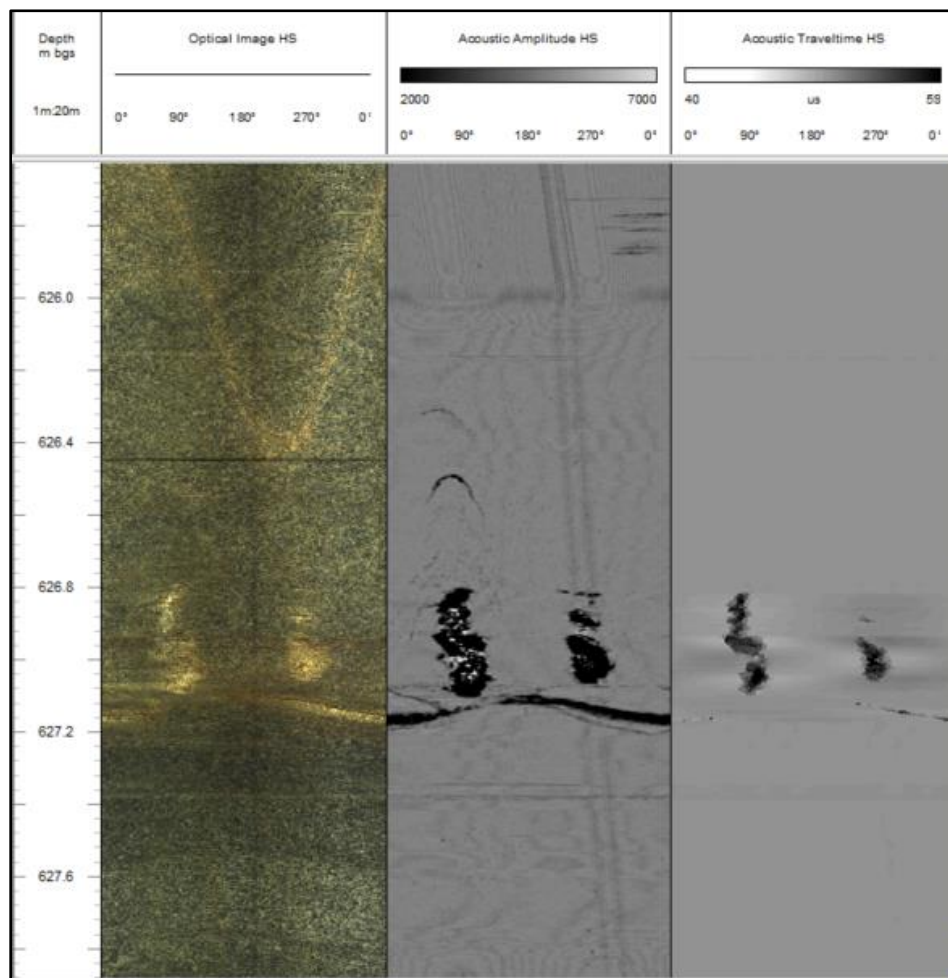
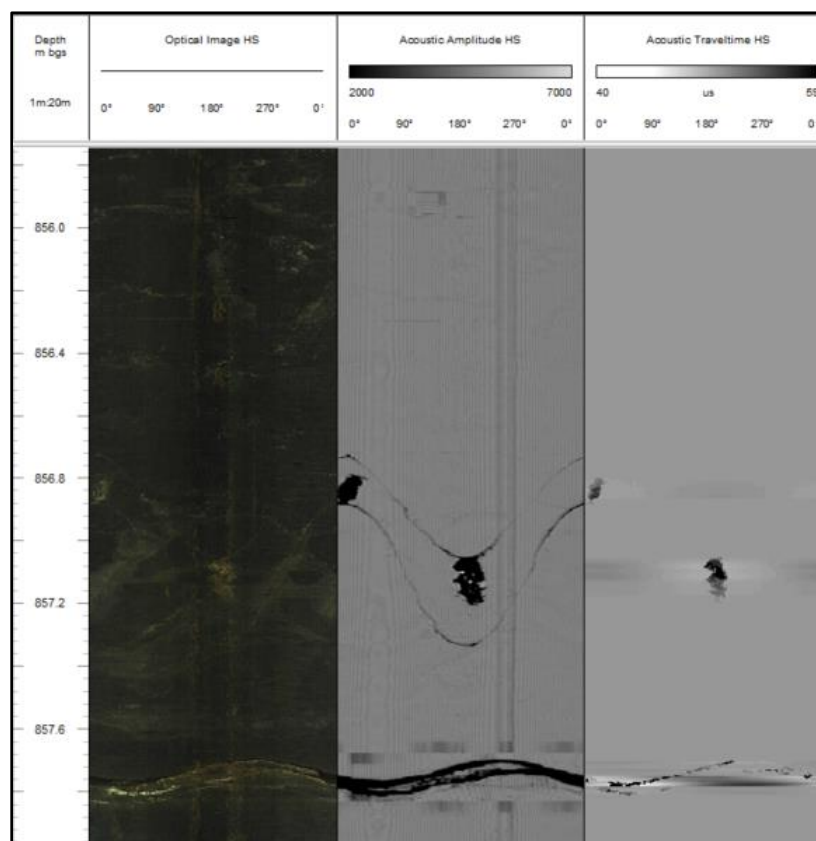


Figure 11: Breakout zone observed between 626.8 and 627.1 m.





**Figure 12: Breakout zone observed between 856.8 and 857.2 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 ( $1.361^{\circ}\text{W}$ ), 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 1.26 counts/m. The frequency of Veins ranges from 0 counts/m to 9 counts/m, with an average of 0.32 counts/m.

Five equal-angle (Wulff) stereonet, 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 stereonet, are displayed in the Structural Log, included in Appendix E.

### 3.4.5 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 sodium iodide crystal configured to be a scintillation detector to measure the incoming natural gamma radiation from the borehole walls. The gamma-emitting radioisotopes 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 with 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 18.51 cps to 282.60 cps, with an average value is 73.36 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. The most apparent anomalies in the data tend to be associated with sharp changes in total counts associated with changes in biotite concentration. There is a large area of decrease in Natural Gamma response from 285 to 335 m with values of ~50 cps which is associated with



diabase. Elsewhere in the borehole more localized anomalies are also associated with intervals that have undergone alteration.

### 3.4.6 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 3800.2 cps to 10,686.9 cps with an average value of 9,182.5 cps. and the LS data ranging from 70.9 cps to 1,939.3 cps, with an average value of 1,005.6 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 seven biggest anomalies at 285 m to 335 m, 360 m to 362 m, 715 m

to 719 m, 785 m to 790 m, 854 m to 859 m, and 915 m to 921 m. These depth intervals are similarly reflected in the gamma-gamma density and total gamma curves. Based on core logging data (WP03: Golder, 2020b), this interval is associated with an increase in biotite within the tonalite bedrock. Numerous high-frequency anomalies, reflected as sharp 200 cps to 800 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 0.63% to 47.75%, with a median Porosity of 1.41% in the open rock section of the borehole. The median is chosen as a better representation of the data due to the effect of large porosity values (at fractured zones) on the mean. 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 zone of increased porosity is over the depth interval of 285 to 335 m, correlation with average porosity increases to 25%. Other spikes are locally present at depth intervals of 359 m to 362 m, 391 m to 393 m, 404 m to 406 m, 410 m to 412 m, 716 m to 719 m, 785 m to 791 m, 854 m to 859 m, 915 m to 921 m, 953 m to 955 m, and 4 local spikes between 971 m to 984 m. Many of these spikes are associated with lithology (dykes).

### 3.4.7 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 999.71 to 32.96 m.

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):

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

where:

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

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

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

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

where:

$\mu = \text{Shear Modulus (MPa)}$

$\nu = \text{Poisson's Ratio}$

The Bulk Modulus was calculated according to the formula:

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

where:

$\rho_b = \text{Bulk Density (g/cc)}$

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

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

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:

$$\text{Characteristic Acoustic Impedance (Rayls}_{MKS}) = \rho_n \times v_p$$

where:

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

$$v_p = \text{Compression Wave Velocity (m/s)}$$

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 3 lists the FWS logs, along with their units, minimum and maximum values, as well as average values (where applicable).

**Table 3: FWS Log Details**

| Log Name                          | Units       | Min Value            | Max Value            | Average Value        |
|-----------------------------------|-------------|----------------------|----------------------|----------------------|
| Compression Wave Slowness         | μs/m        | 155                  | 215                  | 176                  |
| Shear Wave Slowness               | μs/m        | 267                  | 375                  | 296                  |
| Compression Wave Velocity         | m/s         | 4656                 | 6434                 | 5704                 |
| Shear Wave Velocity               | m/s         | 2666                 | 3750                 | 3378                 |
| Poisson's Ratio                   | -           | 0.1110               | 0.3961               | 0.2289               |
| Shear Modulus                     | MPa         | 19729                | 42312                | 31649                |
| Young's Modulus                   | MPa         | 52788                | 104635               | 77808                |
| Bulk Modulus                      | MPa         | 28182                | 90913                | 48178                |
| Characteristic Acoustic Impedance | Rayls (MKS) | 1.19*10 <sup>7</sup> | 2.04*10 <sup>7</sup> | 1.58*10 <sup>7</sup> |

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. Six spikes on Compression and Shear Wave Velocity curves correspond to spikes on Near and Far Density curves at 165m to 170 m, 285 m to 335 m, 785 m to 790 m, 854 m to 859 m, 915 m to 920 m, and 982 m to 985 m where average Compression and Shear Wave Velocities changes 10% to 30%, accordingly.

### 3.4.8 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 (10.2 cm and 15.2 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 primary caliper log was run up from the bottom of the borehole to 54.11 m (into the casing), at 2.5 m per minute, sampling every 1 cm. The probe was then closed, descended to 160 m and logged up to 60 m to collect the QA/QC log.

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 92.93 mm to 110.78 mm, with an average value 96.13 mm. The Mechanical Caliper and Acoustic Caliper logs match well for their ranges, showing the same pattern along the length of the borehole.

### 3.4.9 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  $\Omega$ m, 100  $\Omega$ m, 1,000  $\Omega$ m and 10,000  $\Omega$ m (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 BH05\_MSI\_BRIDLE\_GAM506\_IP5579.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 600 m and the tool was turned on, Depth Mode was selected, and the first log was started. The QA/QC log was recorded up from 600 m to 500 m. The probe was run at 2.2 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 probe was inside the casing at a depth of 60 m the log was stopped, 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 4, 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 with primary examples at 403 m, 623 to 632 m, 714 to 719 m, 786 to 793 m, 855 to 861 m, 916 to 922 m, and 977 to 990 m.

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 primary examples at 622 to 638 m, 714 to 728 m, 784 to 800 m, 851 to 870 m, 953 to 965 m, 975 to 990 m. There are downward spikes 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 4: ELOG Log Details**

| Log Name                | Units            | Min Value | Max Value | Average Value |
|-------------------------|------------------|-----------|-----------|---------------|
| Self-Potential          | mV               | -111      | 355       | 240           |
| Single Point Resistance | $\Omega$         | 236       | 32,377    | 18,047        |
| 8" Resistivity          | $\Omega\text{m}$ | 344       | 3,877     | 2,162         |
| 16" Resistivity         | $\Omega\text{m}$ | 619       | 6,703     | 3,671         |

| Log Name        | Units            | Min Value | Max Value | Average Value |
|-----------------|------------------|-----------|-----------|---------------|
| 32" Resistivity | $\Omega\text{m}$ | 1,213     | 10,809    | 5,673         |
| 64" Resistivity | $\Omega\text{m}$ | 1,841     | 14,491    | 7,283         |

### 3.4.10 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 sodium iodide crystal configured to be a scintillation detector, 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 radioisotopes 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 500 m and turned on and the first log was started. The QA/QC log was recorded up 10% of the borehole depth, from 500 m to 400 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 5, along with their units, minimum and maximum values, as well as average and estimated background values (where applicable).

**Table 5: Spectral Gamma Log Details**

| Log Name           | Units     | Min Value | Max Value | Average Value |
|--------------------|-----------|-----------|-----------|---------------|
| Spectral Gamma     | total cps | 1.17      | 100.20    | 28.93         |
| K – Stacked – 2m   | cps       | 0.12      | 1.07      | 0.51          |
| Th – Stacked – 2m  | cps       | 0.00      | 0.23      | 0.04          |
| U – Stacked – 2m   | cps       | 0.00      | 0.38      | 0.14          |
| K – Stacked – 10m  | cps       | 0.23      | 0.81      | 0.51          |
| Th – Stacked – 10m | cps       | 0.00      | 0.10      | 0.04          |
| U – Stacked – 10m  | cps       | 0.04      | 0.26      | 0.14          |

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.

### 3.4.11 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  $\Omega\text{m}$  and 88.5  $\Omega\text{m}$ ). 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. A repeat log, for QA/QC purposes, was collected up the entire borehole at a speed of 15 m per minute.

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  $\Omega\text{m}$  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 6, along with their units, minimum and maximum values, as well as average values. The Fluid Temperature curve shows a steady increase from approximately 9.3°C at the water table, to 16.0°C at the bottom of the borehole.

**Table 6: FTR Log Details**

| Log Name                  | Units            | Min Value | Max Value | Average Value |
|---------------------------|------------------|-----------|-----------|---------------|
| Fluid Temperature         | °C               | 9.15      | 15.98     | 12.25         |
| Fluid Resistivity         | $\Omega\text{m}$ | 0.07      | 110.19    | 17.56         |
| Static Fluid Conductivity | mS/m             | 9.08      | 13749.7   | 211.37        |

### 3.4.12 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 ( $0.02262 \times 10^{-3}$  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  $0.08 \times 10^{-3}$  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  $0.41 \times 10^{-3}$  SI to  $56.82 \times 10^{-3}$  SI, with an average value of  $2.65 \times 10^{-3}$  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, diabase, and amphibolite lenses at depth intervals of 285 m to 335 m, 359 m to 362 m, 391 m to 393 m, 404 to 407 m, 574 to 576 m, 680 to 682 m, 715 m to 719 m, 854 m to 859 m, 915 m to 921 m, 971 to 973 m, and 977 to 982 m.

### 3.4.13 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 50 m bgs. A drawdown to 24 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.

The addition of flocculent to the borehole fluid as part of Work Package 2 is believed to have resulted in sedimentation of suspended solids from the water column which collected on the screen of the HPFM probe during testing. It is not believed to have affected the testing results, as operation of the HPFM probe was checked inside the casing at the start and end of testing. The probe was cleaned thoroughly between probe runs.

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.

#### **3.4.14 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\_BH05 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 3.4.4.2, 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 four optical televiewer logs created and used to calculate the trajectory of the borehole from ground surface to the bottom of hole (Table 7).

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.

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. 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 7, along with their logging direction, sampling rates, units, minimum and maximum values, as well as average values (where applicable).

**Table 7: Deviation Log Details**

| Log Name                    | Sampling Rate (m) | Units | Min Value | Max Value | Average Value |
|-----------------------------|-------------------|-------|-----------|-----------|---------------|
| ABI Azimuth 03-08           | 0.05              | Deg   | 212.43    | 232.42    | 220.21        |
| OTV Azimuth 08-09           | 0.016             | Deg   | 213.00    | 232.91    | 220.45        |
| OTV Azimuth 08-03 and 08-04 | 0.016             | Deg   | 213.91    | 233.78    | 220.08        |
| OTV Azimuth 01-02           | 0.016             | Deg   | 217.24    | 224.93    | 220.84        |
| ABI Azimuth 01-05           | 0.01              | Deg   | 219.04    | 227.64    | 221.03        |
| ABI Tilt 03-08              | 0.05              | Deg   | 19.49     | 22.39     | 21.00         |
| OTV Tilt 08-09              | 0.016             | Deg   | 17.86     | 24.18     | 20.87         |
| OTV Tilt 08-03 and 08-04    | 0.016             | Deg   | 19.72     | 21.75     | 20.84         |
| OTV Tilt 01-02              | 0.016             | Deg   | 19.34     | 21.46     | 20.31         |
| ABI Tilt 01-05              | 0.01              | Deg   | 19.61     | 22.25     | 20.28         |

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 ( $\pm 0.5^\circ$  of tilt,  $\pm 1.2^\circ$  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 8: Details of the Averaged Deviation Log**

| Log Name           | Units | Min Value | Max Value | Average Value |
|--------------------|-------|-----------|-----------|---------------|
| Azimuth Average TN | Deg   | 213.94    | 233.11    | 220.29        |
| Tilt Average       | Deg   | 19.69     | 23.25     | 20.95         |

**Table 9: Results of Eastings, Northings, and True Vertical Depth (TVD) Recorded at Bottom of Borehole**

| Log Name | Units | Total Value |
|----------|-------|-------------|
| Easting  | m     | -236.19     |
| Northing | m     | -265.53     |
| TVD      | m     | 928.26      |

### 3.4.15 Posiva Flow

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

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.

The addition of flocculent to the borehole fluid as part of Work Package 2 is believed to have resulted in sedimentation of suspended solids from the water column which collected on the Posiva probe during testing. As testing progressed some anomalies were noted in the data collection, as discussed in Appendix F, believed to be due to accumulation of sediment on the sensors. Based on results of the final detailed Posiva log it was determined that the sediment present in the borehole and on the probe did not affect the reported results.

Four water flowing fractures were identified during the Posiva Flow Logging. Fractures were identified at depths of 93.30, 155.87, 159.61, 165.18, 165.59, 227.67, 311.92, 317.70, 392.44, 795.39, and 857.10 m along the borehole. The largest flow was encountered at a depth of 93.30 m, where flow was 130 mL/hr in unpumped conditions and 3,810 mL/hr while pumped drawdown was approximately 13 metres in the borehole. The highest transmissivity, also at a depth of 93.30 m, was calculated to be  $7.00 \times 10^{-8} \text{ m}^2/\text{s}$ . The complete Posiva report presenting the testing, interpretation and results is provided in Appendix F.



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**APPENDIX A**

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

## QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

**TO:** Maria Sánchez-Rico Castejón  
Sarah Hirschorn

**Date / Shift:** May-22-2021 - Shift 01  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_2PCA_01-01.tfd   | 05/22    | OF        | 100.66   | 1.89   | 98.77            | 05/22       | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_01-04.tfd | 05/22    | OF        | 99.96    | 13.70  | 86.26            | 05/22       | CRP         | Acceptable   |
| IG_BH05_WP05_GAMAB1_01-06.tfd | 05/22    | OF        | 100.01   | 14.56  | 85.45            | 05/22       | CRP         | Acceptable   |
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Olga Fomenko May 22, 2021  
 Print name Signature Date

**Client:** NWMO **Job Number:** 20253946-5050  
**Location:** Ignace – IG\_BH05 **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  
Sarah Hirschorn

**Date / Shift:** Aug-17-2021 - Shift 02  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_2SFA_02-01.tfd  | Aug 17   | CM        | 1.99     | 355.61  | 353.62           | 18 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SFA_02-02.tfd  | Aug 17   | CM        | 350.00   | 1000.71 | 650.71           | 18 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2PCAF_02-03.tfd | Aug 18   | PL        | 1000.71  | 54.11   | 946.60           | 18 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2PCAF_02-04.tfd | Aug 18   | PL        | 159.80   | 60.00   | 99.80            | 18 Aug 2021 | CRP         | Acceptable   |
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Olga Fomenko

Print name



Signature

Aug 18, 2021

Date

|                     |                         |                     |  |
|---------------------|-------------------------|---------------------|--|
| <b>Client:</b>      | <u>NWMO</u>             | <b>Job Number:</b>  | <u>20253946-5050</u>                     |
| <b>Location:</b>    | <u>Ignace – IG_BH05</u> | <b>Project:</b>     | <u>Phase 2 Initial Borehole Drilling</u> |
| <b>Prepared by:</b> | <u>Olga Fomenko</u>     | <b>Verified by:</b> | <u>Christopher Phillips</u>              |



FORM: NWMO-IGNACE-20253946-WP05-F004

Distributed By: Email

[illegible]

Aug 19, 2021  
Date

**Job Number:** 20253946-5050

**Project:** Phase 2 Initial Borehole Drilling

**Verified by:** Christopher Phillips

## QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

**TO:** Maria Sánchez-Rico Castejón  
Sarah Hirschorn

**Date / Shift:** Aug-19-2021 - Shift 04  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_ABI_04-01.tfd | Aug 19   | OF        | 454.52   | 50.00  | 404.52           | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-02.tfd | Aug 19   | CM        | 265.00   | 280.01 | 15.01            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-03.tfd | Aug 19   | CM        | 300.01   | 321.00 | 20.99            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-04.tfd | Aug 19   | CM        | 360.00   | 387.01 | 27.01            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-05.tfd | Aug 19   | CM        | 409.75   | 417.00 | 7.25             | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-06.tfd | Aug 19   | CM        | 444.04   | 442.02 | 2.02             | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-07.tfd | Aug 19   | CM        | 461.04   | 449.01 | 12.03            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-08.tfd | Aug 19   | CM        | 511.14   | 499.50 | 11.64            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-09.tfd | Aug 20   | PL        | 601.10   | 562.95 | 38.15            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-10.tfd | Aug 20   | PL        | 651.01   | 624.03 | 26.98            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-11.tfd | Aug 20   | PL        | 716.01   | 689.02 | 26.99            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-12.tfd | Aug 20   | PL        | 796.07   | 729.91 | 66.16            | 20 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_ABI_04-13.tfd | Aug 20   | PL        | 838.63   | 994.40 | 155.77           | 20 Aug 2021 | CRP         | Acceptable   |

Olga Fomenko  
Print name

  
Signature

Aug 20, 2021  
Date

**Client:** NWMO  
**Location:** Ignace – IG\_BH05  
**Prepared by:** Olga Fomenko

**Job Number:** 20253946-5050  
**Project:** Phase 2 Initial Borehole Drilling  
**Verified by:** Christopher Phillips



# GOLDER

## QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

**TO:** Maria Sánchez-Rico Castejón  
Sarah Hirschorn

**Date / Shift:** Aug-20-2021 - Shift 05  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_ABI_05-01.tfd      | Aug-20   | OF        | 994.40   | 2.22   | 992.18           | 21 Aug 2021 | CRP         | Acceptable     |
| IG_BH05_WP05_GAM2NUA_05-02.tfd  | Aug-20   | DGI       | 301.02   | 2.55   | 298.47           | 21 Aug 2021 | CRP         | Acceptable     |
| IG_BH05_WP05_2PGA2PIA_05-03.tfd | Aug-20   | CM        | 500.02   | 399.97 | 100.05           | 21 Aug 2021 | CRP         | Acceptable     |
| IG_BH05_WP05_2PGA2PIA_05-04.tfd | Aug-20   | CM        | 1000.72  | 167.00 | 833.72           | 21 Aug 2021 | CRP         | Not Acceptable |
| IG_BH05_WP05_2PGA2PIA_05-05.tfd | Aug-20   | PL        | 200.03   | 60.02  | 140.01           | 21 Aug 2021 | CRP         | Not Acceptable |
| IG_BH05_WP05_2FSA_05-06.tfd     | Aug-21   | PL        | 1.95     | 992.01 | 990.06           | 21 Aug 2021 | CRP         | Acceptable     |
| IG_BH05_WP05_2FSA_05-07.tfd     | Aug-21   | PL        | 992.01   | 2.54   | 989.47           | 21 Aug 2021 | CRP         | Acceptable     |

Olga Fomenko

Aug 21, 2021

Print name

Signature

Date

**Client:** NWMO

**Job Number:** 20253946-5050

**Location:** Ignace – IG\_BH05

**Project:** Phase 2 Initial Borehole Drilling

**Prepared by:** Olga Fomenko

**Verified by:** Christopher Phillips

## QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

|            |                             |                        |                                     |
|------------|-----------------------------|------------------------|-------------------------------------|
| <b>TO:</b> | Maria Sánchez-Rico Castejón | <b>Date / Shift:</b>   | Aug-21-2021 - Shift 06              |
|            | Sarah Hirschorn             | <b>Work Package:</b>   | WP05 – Borehole Geophysical Logging |
|            | Mostafa Khorshidi           |                        |                                     |
| <b>CC:</b> | George Schneider            | <b>Distributed By:</b> | Email                               |
|            |                             |                        |                                     |

### Borehole Geophysical Logs:

| Log Name                                  | Log Date | Logged By | From (m) | To (m) | Total Length (m) | Review Date | Reviewed By | Data Quality |
|---|----------|-----------|----------|--------|------------------|-------------|-------------|--------------|
| IG_BH05_WP05_GAM2NUA_06-01.tfd            | Aug-21   | DGI       | 995.04   | 199.01 | 796.03           | 23 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAM2DEN_06-02.tfd REPEAT RUN | Aug-21   | DGI       | 301.05   | 198.98 | 102.07           | 23 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2PGA2PIA_06-04.tfd           | Aug-21   | CM        | 1000.70  | 60.01  | 940.69           | 23 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMHMI_06-06.tfd REPEAT RUN  | Aug-22   | PL        | 400.05   | 299.81 | 100.24           | 23 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMHMI_06-08.tfd             | Aug-22   | PL        | 1000.68  | 64.36  | 936.32           | 23 Aug 2021 | CRP         | Acceptable   |

|                            |  |                      |
|----------------------------|--|----------------------|
| Olga Fomenko<br>Print name | <br>Signature | Aug 22, 2021<br>Date |
|----------------------------|--|----------------------|

|                     |                  |                     |                                   |
|---------------------|------------------|---------------------|-----------------------------------|
| <b>Client:</b>      | NWMO             | <b>Job Number:</b>  | 20253946-5050                     |
| <b>Location:</b>    | Ignace – IG_BH05 | <b>Project:</b>     | Phase 2 Initial Borehole Drilling |
| <b>Prepared by:</b> | Olga Fomenko     | <b>Verified by:</b> | Christopher Phillips              |





# GOLDER

## QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-20253946-WP05-F004

**TO:** Maria Sánchez-Rico Castejón  
Sarah Hirschorn

**Date / Shift:** Aug-22-2021 - Shift 07  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_GAM2DEN_07-01.tfd         | Aug-22   | DGI       | 995.03   | 2.93   | 992.10           | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_07-02.tfd REPEAT RUN | Aug-22   | CM        | 500.00   | 400.00 | 100.00           | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_07-03.tfd            | Aug-22   | CM        | 1000.71  | 973.00 | 27.71            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_07-04.tfd            | Aug-22   | CM        | 980.00   | 966.98 | 13.02            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_07-05.tfd            | Aug-22   | CM        | 972.00   | 2.76   | 969.24           | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_FWS_07-07.tfd REPEAT RUN  | Aug-23   | PL        | 500.77   | 395.13 | 105.64           | 24 Aug 2021 | CRP         | Acceptable   |
|  |          |           |          |        |                  |             |             |              |

Olga Fomenko  
Print name

Olga Fomenko  
Signature

Aug 23, 2021  
Date

**Client:** NWMO

**Job Number:** 20253946-5050

**Location:** Ignace – IG\_BH05

**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  
Sarah Hirschorn

**Date / Shift:**

Aug-23-2021 - Shift 08

**Work Package:**

WP05 – Borehole Geophysical  
Logging

**CC:**

Mostafa Khorshidi

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_BH05_WP05_FWS_08-02.tfd    | Aug-23   | OF        | 999.71   | 32.96  | 966.75           | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_08-03.tfd | Aug-23   | CM        | 2.61     | 726.80 | 724.19           | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_08-04.tfd | Aug-23   | PL        | 690.10   | 985.01 | 294.91           | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_08-05.tfd | Aug-24   | PL        | 977.00   | 987.54 | 10.54            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_08-06.tfd | Aug-24   | PL        | 977.02   | 990.01 | 12.99            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_08-07.tfd | Aug-24   | PL        | 977.00   | 992.51 | 15.51            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_08-08.tfd | Aug-24   | PL        | 977.02   | 994.30 | 17.28            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMOB1_08-09.tfd | Aug-24   | PL        | 994.07   | 2.46   | 991.61           | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_08-10.tfd   | Aug-24   | PL        | 60.00    | 80.00  | 20.00            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_08-11.tfd   | Aug-24   | PL        | 330.00   | 350.00 | 20.00            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_08-12.tfd   | Aug-24   | PL        | 580.01   | 611.41 | 31.40            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_08-13.tfd   | Aug-24   | PL        | 609.01   | 630.00 | 20.99            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_08-14.tfd   | Aug-24   | PL        | 710.00   | 740.19 | 30.19            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_08-15.tfd   | Aug-24   | PL        | 805.01   | 825.00 | 19.99            | 24 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_2SNA_08-16.tfd   | Aug-24   | PL        | 910.02   | 950.00 | 39.98            | 24 Aug 2021 | CRP         | Acceptable   |

Olga Fomenko



Aug 24, 2021

Print name

Signature

Date

**Client:** NWMO

**Job Number:**

20253946-5050

**Location:** Ignace – IG\_BH05

**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

**Date / Shift:** Aug-24-2021 - Shift 09  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_2SNA_09-01.tfd             | Aug-24   | OF        | 1000.50  | 937.85 | 62.65            | 25 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMIP_09-03.tfd REPEAT RUN | Aug-24   | OF        | 600.12   | 499.81 | 100.31           | 25 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMIP_09-05.tfd            | Aug-24   | CM        | 1000.01  | 672.20 | 327.81           | 25 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMIP_09-06.tfd            | Aug-24   | CM        | 739.97   | 516.45 | 223.52           | 25 Aug 2021 | CRP         | Acceptable   |
| IG_BH05_WP05_GAMIP_09-07.tfd            | Aug-24   | CM        | 650.01   | 60.00  | 590.01           | 25 Aug 2021 | CRP         | Acceptable   |
|   |          |           |          |        |                  |             |             |              |

Olga Fomenko  
Print name

Signature

Aug 25, 2021  
Date

**Client:** NWMO

**Job Number:** 20253946-5050

**Location:** Ignace – IG\_BH05

**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

**Date / Shift:** Aug-25-2021 - Shift 10  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_HPFM_09-08.tfd | Aug-25   | PL/OF     | 70       | 990.0  | 920              | 26 Aug 2021 | CRP         | Acceptable     |
| IG_BH05_WP05_HPFM_10-01.tfd | Aug-25   | OF        | 990.0    | 70.0   | 920.0            | 26 Aug 2021 | CRP         | Not Acceptable |
|                             |          |           |          |        |                  |             |             |                |
|                             |          |           |          |        |                  |             |             |                |
|                             |          |           |          |        |                  |             |             |                |
|                             |          |           |          |        |                  |             |             |                |

Olga Fomenko  
Print name

  
Signature

Aug 25, 2021  
Date

**Client:** NWMO

**Job Number:** 20253946-5050

**Location:** Ignace – IG\_BH05

**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

**Date / Shift:** Aug-26-2021 - Shift 11  
**Work Package:** WP05 – Borehole Geophysical Logging

**CC:** Mostafa Khorshidi  
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_BH05_WP05_HFPM_11-01.tfd | Aug-26   | OF        | 51.1     | 410.1  | 360.0            | 26 Aug 2021 | CRP         | Not Acceptable<br>– Probe clogged with sediments |
|                             |          |           |          |        |                  |             |             |  |

Olga Fomenko  
Print name

Olga Fomenko  
Signature

Aug 27, 2021  
Date

**Client:** NWMO


**Job Number:** 20253946-5050

**Location:** Ignace – IG\_BH05

**Project:** Phase 2 Initial Borehole Drilling

**Prepared by:** Olga Fomenko

**Verified by:** Christopher Phillips

|   |  |
|---|--|
|  | <b>NWMO IGNACE DRILLING - DATA QUALITY CONFIRMATION (REV 0)</b><br>DAILY INSTRUMENT CALIBRATION FORM FOR WP05<br>20253946 (5050)<br>Form No.: NWMO-IGNACE-20253946-WP02-F007 |
|   | Borehole IG_BH05   |

Calibration by: O.Fomenko  
 Calibration date and time: 2021-08-17 16:30



**Calibration Details**

| Instrument /<br>Serial Number | Parameter                    | Units       | Calibration Standard   |                       | Measured Value | Calibration<br>Required? | Calibration<br>Performed? | Measured Value<br>after Calibration |
|-------------------------------|------------------------------|-------------|------------------------|-----------------------|----------------|--------------------------|---------------------------|-------------------------------------|
|                               |                              |             | Lot No. /<br>Exp. Date | Target<br>Measurement |                |                          |                           |                                     |
| AquaFluor                     | Fluorescein<br>Concentration | ppb         | 1F0652<br>Sept-2022    | -                     | -              | -                        | -                         | -                                   |
| Horiba U-52                   | pH                           | -           | 0GH332<br>Aug-2021     | 4                     | 4              | N                        | Y                         | 4                                   |
|                               | Conductivity                 | mS/cm       | 0GH332<br>Aug-2021     | 4.49                  | 5.89           | N                        | Y                         | 4.5                                 |
|                               | Turbidity                    | NTU         | 0GH332<br>Aug-2021     | 0                     | 14.8           | N                        | N                         | 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





## NWMO IGNACE DRILLING - DATA QUALITY CONFIRMATION (REV 0)

DAILY INSTRUMENT CALIBRATION FORM FOR WP05

20253946 (5050)

Form No.: NWMO-IGNACE-20253946-WP02-F007

Borehole

IG\_BH05

Calibration by: P.Leith  
Calibration date and time: 2021-08-21 1:50

### Calibration Details

| Instrument /<br>Serial Number | Parameter                    | Units       | Calibration Standard   |                       | Measured Value | Calibration<br>Required? | Calibration<br>Performed? | Measured Value<br>after Calibration |
|-------------------------------|------------------------------|-------------|------------------------|-----------------------|----------------|--------------------------|---------------------------|-------------------------------------|
|                               |                              |             | Lot No. /<br>Exp. Date | Target<br>Measurement |                |                          |                           |                                     |
| AquaFluor                     | Fluorescein<br>Concentration | ppb         | 1F0652<br>Sept-2022    | -                     | -              | -                        | -                         | -                                   |
| Horiba U-52                   | pH                           | -           | 0GH332<br>Aug-2021     | 4                     | 4              | N                        | Y                         | 4.01                                |
|                               | Conductivity                 | mS/cm       | 0GH332<br>Aug-2021     | 4.49                  | 4.69           | N                        | Y                         | 4.5                                 |
|                               | Turbidity                    | NTU         | 0GH332<br>Aug-2021     | 0                     | 0.5            | N                        | N                         | 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

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | MECHANICAL CALIPER |
| <b>Serial Number</b>   | 2649               |
| <b>Date</b>            | MARCH 11, 2021     |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | 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.<br>2PCA_Caliper_2649_03112021.tfd<br>Caliper cal file: Caliper_2649_Calibration_03112021.txt |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 11, 2021<br>Date |
|--------------------------------------|--|------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | MECHANICAL CALIPER |
| <b>Serial Number</b>   | 4354               |
| <b>Date</b>            | MARCH 11, 2021     |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | 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.<br>2PCA_Caliper_4354_03112021.tfd<br>Caliper cal file: Caliper_4354_Calibration_03112021.txt |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 11, 2021<br>Date |
|--------------------------------------|--|------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | MECHANICAL CALIPER |
| <b>Serial Number</b>   | 5032               |
| <b>Date</b>            | MARCH 11, 2021     |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | 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.<br>2PCA_Caliper_5032_03112021.tfd<br>Caliper cal file: Caliper_5032_Calibration_03112021.txt |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 11, 2021<br>Date |
|--------------------------------------|--|------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                            |
|------------------------|----------------------------|
| <b>Equipment Model</b> | ABI 2G ACOUSTIC TELEVIEWER |
| <b>Serial Number</b>   | 190404                     |
| <b>Date</b>            | MARCH 11, 2021             |
| <b>Operator</b>        | OLGA FOMENKO               |
| <b>Location</b>        | MISSISSAUGA LAB            |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / AZI    | 0                 | 0.2 / 359.8    | 0.2 / -0.2 |
| DEG ROLL / AZI    | 90                | 94.2 / 96.7    | 4.2 / 6.7  |
| 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. |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 11, 2021<br>Date |
|--------------------------------------|--|------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                              |
|------------------------|------------------------------|
| <b>Equipment Model</b> | QL40 FWS FULL WAVEFORM SONIC |
| <b>Serial Number</b>   | 210306                       |
| <b>Date</b>            | Aug 22, 2021                 |
| <b>Operator</b>        | OLGA FOMENKO                 |
| <b>Location</b>        | MISSISSAUGA LAB              |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| US                | na                | responding     | na         |
| US                | na                | responding     | na         |
| US                | na                | responding     | na         |
| US                | na                | responding     | na         |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on the bench. Used metal tape measure to check direct signal from transmitter to rec 1, rec2, rec3, rec4.<br>IG_BH05_WP05_FWS_PreUseCheck 07Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | Aug 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | QLGAM ATV STACK    |
| <b>Serial Number</b>   | 6752+190404        |
| <b>Date</b>            | APRIL 7, 2021      |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | 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.<br>QLGR6752_ATV190404_Gamma_040721.tfd |

|                                      |  |                       |
|--------------------------------------|--|-----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | April 7, 2021<br>Date |
|--------------------------------------|--|-----------------------|



## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                       |
|------------------------|-----------------------|
| <b>Equipment Model</b> | HEAT PULSE FLOW METER |
| <b>Serial Number</b>   | 2293                  |
| <b>Date</b>            | Aug 25, 2021          |
| <b>Operator</b>        | PETER LEITH           |
| <b>Location</b>        | NWMO BH05 site        |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| n/a               | FLOW              | FLOW           | n/a        |
| n/a               | NO FLOW           | NO FLOW        | n/a        |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

|  |
|--|
| <b>Testing Notes</b>   |
| Probe checked using bucket with water.<br><br>IG_BH05_WP05_HFPM_PreUseCheck_09Shift.mh |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | Aug 25, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                       |
|------------------------|-----------------------|
| <b>Equipment Model</b> | HEAT PULSE FLOW METER |
| <b>Serial Number</b>   | 4736                  |
| <b>Date</b>            | Aug 18, 2021          |
| <b>Operator</b>        | OLGA FOMENKO          |
| <b>Location</b>        | NWMO BH05 site        |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| n/a               | FLOW              | FLOW           | n/a        |
| n/a               | NO FLOW           | NO FLOW        | n/a        |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

|   |
|---|
| <b>Testing Notes</b>  |
| Probe checked using bucket with water.<br>IG_BH05_WP05_HFPM_PreUse_03Shift.mh |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | Aug 18, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                  |
|------------------------|----------------------------------|
| <b>Equipment Model</b> | <i>OBI 2G OPTICAL TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>160403</i>                    |
| <b>Date</b>            | <i>MARCH 11, 2021</i>            |
| <b>Operator</b>        | <i>OLGA FOMENKO</i>              |
| <b>Location</b>        | <i>MISSISSAUGA LAB</i>           |

| Calibration Units | Calibration Value | Measured Value | Difference                 |
|-------------------|-------------------|----------------|----------------------------|
| DEG ROLL / AZI    | 0                 | 356.7 / 357.7  | -3.7 / -2.3                |
| DEG ROLL / AZI    | 90                | 90.3 / 93.1    | 0.3 / 3.1                  |
| DEG ROLL / AZI    | 180               | 180.1 / 182.4  | 0.8 / 2.4                  |
| 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 |

Check 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<br>Calibration Operator | <br>Signature | March 11, 2021<br>Date |
|--------------------------------------|--|------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                 |
|------------------------|-----------------|
| <b>Equipment Model</b> | QL40 Gamma      |
| <b>Serial Number</b>   | 5484            |
| <b>Date</b>            | MAY 14, 2021    |
| <b>Operator</b>        | CHRIS PHILLIPS  |
| <b>Location</b>        | MISSISSAUGA LAB |

| Calibration Units | Calibration Value    | Measured Value | Difference |
|-------------------|----------------------|----------------|------------|
| CPS               | n/a - air            | 15-21          | n/a        |
| CPS               | n/a - bentonite clay | 51-72          | n/a        |
|                   |                      |                |            |
|                   |                      |                |            |
|                   |                      |                |            |
|                   |                      |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on the bench. Background response and bentonite clay bag response.<br>GAM_5484_05142021.tfd |



Christopher Phillips  
Calibration Operator

Signature

May 14, 2021  
Date

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                 |
|------------------------|-----------------|
| <b>Equipment Model</b> | 4MXC-1000       |
| <b>Serial Number</b>   | 1699            |
| <b>Date</b>            | MARCH 11, 2021  |
| <b>Operator</b>        | OLGA FOMENKO    |
| <b>Location</b>        | MISSISSAUGA 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<br>Calibration Operator | <br>Signature | March 11, 2021<br>Date |
|--------------------------------------|--|------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                 |
|------------------------|-----------------|
| <b>Equipment Model</b> | 4MXC-1000       |
| <b>Serial Number</b>   | 2323            |
| <b>Date</b>            | MARCH 11, 2021  |
| <b>Operator</b>        | OLGA FOMENKO    |
| <b>Location</b>        | MISSISSAUGA 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<br>Calibration Operator | <br>Signature | March 11, 2021<br>Date |
|--------------------------------------|--|------------------------|

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

| #  | Probe                                 | Probe model  | Parametr 1  | Parameter 2                            | Parameter 3       | Comments  |
|----|---------------------------------------|--------------|---|--|-------------------|---|
| 1  | Fluid Temperature / Res               | 2SFA/QLFTC   | Temperature Cal - Water with Ice and Boiled water, Using Horiba | Cond Cal ( to solutions), Using Horiba |                   | Horiba  |
| 2  | Flowing Fluid Electrical Conductivity | 2SFA/QLFTC   |   |  |                   |   |
|    |                                       |              |   |  |                   |   |
| 3  | Mechanical Caliper                    | 2PCA         | Cal Jig 10.2cm  | Cal Jig 15.2cm                         |                   | After arms are open, slightly pull the Caliper UP to let them fully open  |
| 4  | ATV                                   | QLABI        | Roll 0,90,180,270,0   | Tilt 0, 90                             | Az 0,90,180,270,0 |   |
|    |                                       | QLABI        |   |  |                   |   |
|    | Natural Gamma                         | 2PGA/QLGAM   | background air  | bentonite                              | na                |   |
| 5  | Apparent Conductivity                 | 2PIA         | Cond ring 0   | Cond ring 463                          |                   | Probe has to be stabilized in bh below the casing (at least 20 m) fo 20-45 min  |
| 6  | Fluid Temperature/ Res                | 2SFA/QLFTC   | Temperature Cal - Water with Ice and Boiled water, Using Horiba | Cond Cal ( to solutions), Using Horiba |                   |   |
| 7  | MagSus                                | QL HMI       | Caj Jig air   | Caj Jig 0.6                            | Caj Jig 5         | Probe has to be stabilized in bh below the casing (at least 20 m) fo 20-45 min  |
| 8  | Spectral Gamma                        | 2SNA         | background air  | bentonite                              | na                | Probe has to be stabilized in the water for 15 min  |
| 9  | Neutron DGI                           | 2NUA-1000/2C |   |  |                   |   |
| 10 | Gamma-Gamma DGI                       | 2DEN         |   |  |                   |   |
| 11 | FWS                                   | QL FWS       | na  | na                                     | na                |   |
| 12 | E-log Res/SP/SPR                      | QL IP        | Cal box 1,100,1000,10000  | na                                     | na                | DO NOT TERN the Probe on in casing. Lower below at least 10-20 m, then tern on. Let the probe warm up for 20 min on surface before calibratong. |
| 13 | Heat Pulse Flow Meter                 | HFPM         | bucket with water   | bucket with water - stirring           | na                |   |
| 14 | OTV                                   | QLOBI        | Roll 0,90,180,270,0   | Tilt 0, 90                             | colour wheel      |   |
|    |                                       | QLOBI        |   |  |                   |   |



## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                |
|------------------------|--------------------------------|
| <b>Equipment Model</b> | <i>2PCA Mechanical Caliper</i> |
| <b>Serial Number</b>   | <i>5032</i>                    |
| <b>Date</b>            | <i>August 18, 2021</i>         |
| <b>Operator</b>        | <i>O Fomenko</i>               |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>       |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| CM                | 10.2              | 10.20          | 0.00       |
| CM                | 15.2              | 15.02          | 0.18       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench. Files saved for each of the tests for reference.<br>IG_BH05_WP05_2PCA_PostUse_02Shift.tfd<br>Calibration file: IG_BH05_WP05_2PCA 5032 Calibration 02 shift.txt |

|                                      |  |                         |
|--------------------------------------|--|-------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | August 18, 2021<br>Date |
|--------------------------------------|--|-------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | MECHANICAL CALIPER |
| <b>Serial Number</b>   | 5032               |
| <b>Date</b>            | MARCH 22, 2021     |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | NWMO BH05 site     |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| cm                | 15.2              | 14.94          | 0.26       |
| cm                | 10.2              | 10.01          | 0.19       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

|  |
|--|
| <b>Testing Notes</b>   |
| Probe checked using calibration jig.<br>IG_BH05_WP05_2PCA_PostUseCheck_01Shift.tfd<br>Caliper cal file: Caliper 5032_Calibration_01ShiftBH05.txt |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 22, 2021<br>Date |
|--------------------------------------|--|------------------------|

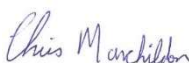
## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | 2PGA 2PIA STACK NATURAL GAMMA+ APPARENT CONDUCTIVITY |
| <b>Serial Number</b>   | 2622+2618  |
| <b>Date</b>            | Aug 20, 2021   |
| <b>Operator</b>        | CHRIS MARCHILDON                                     |
| <b>Location</b>        | NWMO BH05 site                                       |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| mS                | 102.0             | 115.0          | 15.0       |
| mS                | 0.0               | 22.0           | 22.0       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on the bench, reading background noise and DGI NUA source.<br>IG_BH05_WP05_2PIA_PostUse_05Shift.tfd<br>IG_BH05_WP05_2PIA_Calibration_05Shift.txt    2PIA calibration file |

|                      |   |              |
|----------------------|---|--------------|
| Chris Marchildon     |  | Aug 20, 2021 |
| Calibration Operator | Signature   | Date         |

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | 2PGA 2PIA STACK NATURAL GAMMA+ APPARENT CONDUCTIVITY |
| <b>Serial Number</b>   | 2622+2618  |
| <b>Date</b>            | Aug 22, 2021   |
| <b>Operator</b>        | PETER LEITH  |
| <b>Location</b>        | NWMO BH05 site                                       |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| mS                | 102.0             | 107.4-107.7    | 5.4-5.7    |
| mS                | 0.0               | 7.6-7.8        | 7.6-7.8    |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on the bench, using calibration ring.<br>IG_BH05_WP05_2PIA_PostUse_06Shift.tfd<br>IG_BH05_WP05_2PIA_Calibration_06Shift.txt    2PIA calibration file |

Peter Leith  
 Calibration Operator



Signature

Aug 22, 2021  
 Date

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                    |
|------------------------|------------------------------------|
| <b>Equipment Model</b> | 2SFA Fluid Temperature/Resistivity |
| <b>Serial Number</b>   | 5032                               |
| <b>Date</b>            | August 18, 2021                    |
| <b>Operator</b>        | O Fomenko                          |
| <b>Location</b>        | NWMO_IG_BH05 site                  |

| Calibration Units | Calibration Value | Measured Value | Difference  |
|-------------------|-------------------|----------------|-------------|
| DED               | 2.50 - 3.20       | -0.72 - -0.79  | 1.78 - 2.41 |
| DEG               | 29.00 - 31.50     | 30.52- 31.50   | 0.00 - 1.52 |
| OHM*M             | 4.10              | 1.55-1.67      | 2.55        |
| OHM*M             | 106.00            |                |             |
|                   |                   |                |             |
|                   |                   |                |             |
|                   |                   |                |             |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on bench. Files saved for each of the tests for reference.<br>IG_BH05_WP05_2SFA_CondPostUse_02Shift.tfd<br>IG_BH05_WP05_2SFA_TempPostUse_02Shift.tfd<br>Calibration file: IG_BH05_WP05_2SFA 5032 CalibrationTempCond 02 shift.txt |

|                                      |  |                         |
|--------------------------------------|--|-------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | August 18, 2021<br>Date |
|--------------------------------------|--|-------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                    |
|------------------------|------------------------------------|
| <b>Equipment Model</b> | 2SFA Fluid Temperature/Resistivity |
| <b>Serial Number</b>   | 5032                               |
| <b>Date</b>            | August 21, 2021                    |
| <b>Operator</b>        | OLGA FOMENKO                       |
| <b>Location</b>        | NWMO_IG_BH05 site                  |

| Calibration Units | Calibration Value (Horiba) | Measured Value (2SFA) | Difference |
|-------------------|----------------------------|-----------------------|------------|
| DED               | 6.3-7.4                    | 6.9-7.3               | 0.1-0.3    |
| DEG               | 24.2-27.5                  | 25.9-26.7             | 0.8-1.7    |
| DEG               | air                        | 17.49                 | na         |
| OHM*M             | 135.5                      | 147.0-148.0           | 11.5-12.5  |
| OHM*M             | 4.21-4.27                  | 2.3-2.7               | 1.91-1.57  |
| OHM*M             | air                        | 172.0                 | na         |
|                   |                            |                       |            |
|                   |                            |                       |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench. Files saved for each of the tests for reference.<br>IG_BH05_WP05_2SFA_CondPostUse 06Shift.tfd<br>IG_BH05_WP05_2SFA_TempPostUse 06Shift.tfd<br>Calibration file: IG_BH05_WP05_2SFA5032 CalibrationTempCond 05 shift.txt |

|                      |   |                 |
|----------------------|---|-----------------|
| Olga Fomenko         |  | August 21, 2021 |
| Calibration Operator | Signature   | Date            |

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                            |
|------------------------|----------------------------|
| <b>Equipment Model</b> | ABI 2G ACOUSTIC TELEVIEWER |
| <b>Serial Number</b>   | 190404                     |
| <b>Date</b>            | May 22, 2021               |
| <b>Operator</b>        | OLGA FOMENKO               |
| <b>Location</b>        | NWMO_IG_BH05 site          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.8            | 0.8        |
| DEG ROLL / DEG    | 90                | 90.4           | 0.4        |
| DEG ROLL / DEG    | 180               | 179.9          | -0.1       |
| DEG ROLL / DEG    | 270               | 269.6          | -0.4       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH04_WP05_ABI_PostRollCeck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|



## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                            |
|------------------------|----------------------------|
| <b>Equipment Model</b> | ABI 2G ACOUSTIC TELEVIEWER |
| <b>Serial Number</b>   | 190404                     |
| <b>Date</b>            | August 20, 2021            |
| <b>Operator</b>        | Olga Fomenko               |
| <b>Location</b>        | NWMO_IG_BH05 site          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| ROLL / DEG        | 0                 | 0.3            | 0.3        |
| ROLL / DEG        | 90                | 90.3           | 0.3        |
| ROLL / DEG        | 180               | 180.2          | 0.2        |
| ROLL / DEG        | 270               | 270.4          | 0.4        |
| TILT / DEG        | 90                | 88.8           | 1.2        |
| TILT / DEG        | 0                 | 1.1            | 1.1        |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
    ☐ Needs Recalibration

|  |
|--|
| <b>Testing Notes</b>   |
| Probe checked on bench, rolling by hand. Ground is not even.<br><br>IG_BH05_WP05_ABI_PostRoll_05Shift.tfd<br><br>IG_BH05_WP05_ABI_PostTilt_05Shift.tfd |

|                      |  |                 |
|----------------------|--|-----------------|
| Olga Fomenko         | <br>Signature | August 20, 2021 |
| Calibration Operator |  | Date            |

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | <i>N GAMMA NORMAL RESISTIVITY, INDUCED POTENTIAL ELOG/IP</i> |
| <b>Serial Number</b>   | <i>5602_5579</i>   |
| <b>Date</b>            | <i>Aug 25, 2021</i>  |
| <b>Operator</b>        | <i>PETER LEITH</i>   |
| <b>Location</b>        | <i>NWMO BH05 site</i>  |

| Calibration Units | Calibration Value | Measured Value |        |        |        |     |       | Difference |       |       |       |
|-------------------|-------------------|----------------|--------|--------|--------|-----|-------|------------|-------|-------|-------|
|                   |                   | N8             | N16    | N32    | N64    | SPR | GAM   |            |       |       |       |
| Ohm*m             | 1                 | 0.99           | 0.99   | 0.98   | 0.98   | na  | na    | 0.99       | 0.99  | 0.98  | 0.98  |
| Ohm*m             | 100               | 105.4          | 105.2  | 104.9  | 106.5  | na  | na    | 5.4        | 5.2   | 4.9   | 6.5   |
| Ohm*m             | 1000              | 1051.0         | 1050.0 | 1052.3 | 1054.2 | na  | na    | 51.0       | 50.0  | 52.0  | 54.2  |
| Ohm*m             | 10000             | 9842.7         | 9822.0 | 9844.0 | 9822.0 | na  | na    | 157.3      | 178.0 | 158.0 | 178.0 |
| cps               | background        |                |        |        |        |     | 12-26 |            |       |       |       |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Calibration and Calibration check is done using ALT calibration box SN 155101<br>IG_BH05_WP05_GAMIP_PostUseCheck_09Shift.tfd<br>Calibration_IP_5579_09Shift.txt |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | Aug 25, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | QL40 HMI INDUCTION MAGNETIC SUSCEPTIBILITY |
| <b>Serial Number</b>   | 6766                                       |
| <b>Date</b>            | Aug 22, 2021                               |
| <b>Operator</b>        | OLGA FOMENKO                               |
| <b>Location</b>        | NWMO_IG_BH05 site                          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| mS/m              | 1000              | 1038.89        | 38.89      |
| mS/m              | 200               | 202.37         | 2.37       |
| SI*10-3           | 0.6               | 0.91           | 0.31       |
| SI*10-3           | 5                 | 5.31           | 0.31       |
| SI*10-3           | 5.6               | 5.87           | 0.27       |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on the bench outside, stabilized in water at 80.0 depth for 30 min.<br>HMI_Calibration_factory_220321.txt    Factory (MSI) Calibrated in March 22,2021.<br>IG_BH05_WP05_HMI_Stabilization_06Shift.tfd    Stabilization file<br>IG_BH05_WP05_HMI_CondPostUseCheck_06Shift.tfd<br>IG_BH05_WP05_HMI_MagPostUseCheck_06Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | Aug 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                  |
|------------------------|----------------------------------|
| <b>Equipment Model</b> | <i>OBI 2G OPTICAL TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>160304</i>                    |
| <b>Date</b>            | <i>May 22, 2021</i>              |
| <b>Operator</b>        | <i>OLGA FOMENKO</i>              |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>         |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.3            | 0.3        |
| DEG ROLL / DEG    | 90                | 90.2           | 0.2        |
| DEG ROLL / DEG    | 180               |                |            |
| DEG ROLL / DEG    | 270               | 270.3          | 0.3        |
| TILT / DEG        | 90                | 90.3           | 0.3        |
| TILT / DEG        | 0                 | 0.1            | 0.1        |
| COLOUR WHEEL      | NA                | NA             | NA         |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH05_WP05_OBI_PostColourCheck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET


|                        |                                  |
|------------------------|----------------------------------|
| <b>Equipment Model</b> | <i>OBI 2G OPTICAL TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>160403</i>                    |
| <b>Date</b>            | <i>August 18, 2021</i>           |
| <b>Operator</b>        | <i>Peter Leith</i>               |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>         |

| Calibration Units | Calibration Value | Measured Value | Difference                 |
|-------------------|-------------------|----------------|----------------------------|
| ROLL / DEG        | 0                 | 0.9            | 0.9                        |
| ROLL / DEG        | 90                | 89.9           | 0.1                        |
| ROLL / DEG        | 180               | 180.0          | 0.0                        |
| ROLL / DEG        | 270               | 270.2          | 0.2                        |
| Image Colour      | Colour Wheel      | Recorded File  | n/a – Image quality passed |
| TILT / DEG        | 90                | 89.6           | 0.4                        |
| TILT / DEG        | 0                 | 0.3            | 0.3                        |

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.<br><br>IG_BH05_WP05_OBI_PostTilt_03Shift.tfd<br>IG_BH05_WP05_OBI_PostColour_03Shift.tfd<br>IG_BH05_WP05_OBI_PostRoll_03Shift.tfd |

Peter Leith  
 Calibration Operator

  
 Signature

August 19, 2021  
 Date

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                |
|------------------------|--------------------------------|
| <b>Equipment Model</b> | <i>2PCA Mechanical Caliper</i> |
| <b>Serial Number</b>   | <i>5032</i>                    |
| <b>Date</b>            | <i>August 17, 2021</i>         |
| <b>Operator</b>        | <i>O Fomenko</i>               |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>       |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| CM                | 10.2              | 10.25          | 0.05       |
| CM                | 15.2              | 15.19          | 0.01       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on bench. Files saved for each of the tests for reference.<br>IG_BH05_WP05_2PCA_PreUse_02Shift.tfd<br>Calibration file: IG_BH05_WP05_2PCA 5032 Calibration 02 shift.txt |

|                                      |  |                         |
|--------------------------------------|--|-------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | August 17, 2021<br>Date |
|--------------------------------------|--|-------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | MECHANICAL CALIPER |
| <b>Serial Number</b>   | 5032               |
| <b>Date</b>            | MARCH 22, 2021     |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | NWMO BH05 site     |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| cm                | 15.2              | 15.2           | 0          |
| cm                | 10.2              | 10.21          | 0.01       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked using calibration jig.<br>IG_BH05_WP05_2PCA_PreUseCheck_01Shift.tfd<br>Caliper cal file: Caliper 5032_Calibration_01ShiftBH05.txt |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 22, 2021<br>Date |
|--------------------------------------|--|------------------------|




## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | 2PGA 2PIA STACK NATURAL GAMMA+ APPARENT CONDUCTIVITY |
| <b>Serial Number</b>   | 2622+2618  |
| <b>Date</b>            | Aug 20, 2021   |
| <b>Operator</b>        | CHRIS MARCHILDON                                     |
| <b>Location</b>        | NWMO BH05 site                                       |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| CPS               | background        | 18-32          | na         |
| CPS               | DGI NUA Source    | 2000-2200      | na         |
| mS                | 463.0             | 458.6          | 4.4        |
| mS                | 0.0               | 6.7            | 6.7        |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on the bench, reading background noise and DGI NUA source.<br>IG_BH05_WP05_2PGA_PreUse_05Shift.tfd<br>IG_BH05_WP05_2PIA_PreUse_05Shift.tfd<br>IG_BH05_WP05_2PIA_Calibration_05Shift.txt    2PIA calibration file |

|                      |  |                      |
|----------------------|--|----------------------|
| Chris Marchildon     | <br>Signature | Aug 20, 2021<br>Date |
| Calibration Operator |  |                      |


## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | 2PGA 2PIA STACK NATURAL GAMMA+ APPARENT CONDUCTIVITY |
| <b>Serial Number</b>   | 2622+2618  |
| <b>Date</b>            | Aug 21, 2021   |
| <b>Operator</b>        | CHRIS MARCHILDON                                     |
| <b>Location</b>        | NWMO BH05 site                                       |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| CPS               | background        | 18-32          | na         |
| CPS               | DGI NUA Source    | 2000-2200      | na         |
| mS                | 102.0             | 98.9 - 102.3   | 0.3-3.1    |
| mS                | 0.0               | -0.6 - -0.9    | 0.6-0.9    |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on the bench, reading background noise and DGI NUA source.<br>IG_BH05_WP05_2PGA_PreUse_05Shift.tfd<br>IG_BH05_WP05_2PIA_PreUse_06Shift.tfd<br>IG_BH05_WP05_2PIA_Calibration_06Shift.txt    2PIA calibration file |

|  |  |                      |
|--|--|----------------------|
| Chris Marchildon<br>Calibration Operator | <br>Signature | Aug 21, 2021<br>Date |
|--|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                    |
|------------------------|------------------------------------|
| <b>Equipment Model</b> | 2SFA Fluid Temperature/Resistivity |
| <b>Serial Number</b>   | 5032                               |
| <b>Date</b>            | August 17, 2021                    |
| <b>Operator</b>        | O Fomenko                          |
| <b>Location</b>        | NWMO_IG_BH05 site                  |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DED               | 7.70              | 7.60           | 0.10       |
| DEG               | 42.00             | 40.50          | 1.50       |
| OHM*M             | 4.06              | 4.12           | 0.06       |
| OHM*M             | 100.00            | 92.05          | 7.50       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on bench. Files saved for each of the tests for reference.<br>IG_BH05_WP05_2SFA_CondPreUse_02Shift.tfd<br>IG_BH05_WP05_2SFA_TempPreUse_02Shift.tfd<br>Calibration file: IG_BH05_WP05_2SFA 5032 CalibrationTempCond 02 shift.txt |

|                                      |  |                         |
|--------------------------------------|--|-------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | August 17, 2021<br>Date |
|--------------------------------------|--|-------------------------|


## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                    |
|------------------------|------------------------------------|
| <b>Equipment Model</b> | 2SFA Fluid Temperature/Resistivity |
| <b>Serial Number</b>   | 5032                               |
| <b>Date</b>            | August 20, 2021                    |
| <b>Operator</b>        | Peter Leith                        |
| <b>Location</b>        | NWMO_IG_BH05 site                  |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DED               | 7.06              | 6.9-7.5        | 0.16-0.44  |
| DEG               | 55.0              | 57-63.0        | 3.0-8.0    |
| OHM*M             | 99.0              | 128.0          | 29.0       |
| OHM*M             | 4.04              | 3.4            | 0.64       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench. Files saved for each of the tests for reference.<br>IG_BH05_WP05_2SFA_CondPreUse_05Shift.tfd<br>IG_BH05_WP05_2SFA_TempPreUse_05Shift.tfd<br>Calibration file: IG_BH05_WP05_2SFA 5032 CalibrationTempCond 05Shift.txt |

|                                     |  |                         |
|-------------------------------------|--|-------------------------|
| Peter Leith<br>Calibration Operator | <br>Signature | August 20, 2021<br>Date |
|-------------------------------------|--|-------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                     |
|------------------------|---------------------|
| <b>Equipment Model</b> | 2SNA SPECTRAL GAMMA |
| <b>Serial Number</b>   | 4116                |
| <b>Date</b>            | Aug 22, 2021        |
| <b>Operator</b>        | OLGA FOMENKO        |
| <b>Location</b>        | NWMO BH05 site      |

| Calibration Units | Calibration Value        | Measured Value | Difference |
|-------------------|--------------------------|----------------|------------|
| CPS               | n/a - air                | 2-13           | n/a        |
| CPS               | n/a – DGI Neutron source | 1038-1138      | n/a        |
|                   |                          |                |            |
|                   |                          |                |            |
|                   |                          |                |            |
|                   |                          |                |            |

Calibration Check Results:     ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on the bench. Background response and DGI Neutron Source<br>IG_BH05_WP05_2SNA_PreUseCheck 07Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | Aug 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                            |
|------------------------|----------------------------|
| <b>Equipment Model</b> | ABI 2G ACOUSTIC TELEVIEWER |
| <b>Serial Number</b>   | 190404                     |
| <b>Date</b>            | May 22, 2021               |
| <b>Operator</b>        | OLGA FOMENKO               |
| <b>Location</b>        | NWMO_IG_BH05 site          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.0            | 0          |
| DEG ROLL / DEG    | 90                | 90.2           | 0.2        |
| DEG ROLL / DEG    | 180               | 180.4          | 0.4        |
| DEG ROLL / DEG    | 270               | 270.1          | 0.1        |
| TILT / DEG        | 90                | 90.8           | 0.8        |
| TILT / DEG        | 0                 | 0              | 0          |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH05_WP05_ABI_PreRollCeck_01Shift.tfd<br>IG_BH05_WP05_ABI_PreTiltCeck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

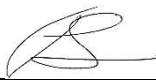
|                        |                                   |
|------------------------|-----------------------------------|
| <b>Equipment Model</b> | <i>ABI 2G ACOUSTIC TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>190404</i>                     |
| <b>Date</b>            | <i>August 19, 2021</i>            |
| <b>Operator</b>        | <i>Peter Leith</i>                |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| AZ / DEG          | 0                 | 3              | 3.0        |
| AZ / DEG          | 90                | 90.7           | 0.3        |
| AZ / DEG          | 180               | 181.1          | 1.1        |
| AZ / DEG          | 270               | 267.7          | 2.3        |
| TILT / DEG        | 90                | 89.5           | 0.5        |
| TILT / DEG        | 0                 | 0.5            | 0.5        |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
    ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench, rolling by hand.<br><br>IG_BH05_WP05_ABI_PreAz_03Shift.tfd<br><br>IG_BH05_WP05_ABI_PreTilt_03Shift.tfd |

Peter Leith  
 Calibration Operator

  
 Signature

August 19, 2021  
 Date

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | <i>N GAMMA NORMAL RESISTIVITY, INDUCED POTENTIAL ELOG/IP</i> |
| <b>Serial Number</b>   | <i>5602_5579</i>   |
| <b>Date</b>            | <i>Aug 24, 2021</i>  |
| <b>Operator</b>        | <i>OLGA FOMENKO</i>  |
| <b>Location</b>        | <i>NWMO BH05 site</i>  |

| Calibration Units | Calibration Value | Measured Value |         |         |         |     |       | Difference |      |      |      |
|-------------------|-------------------|----------------|---------|---------|---------|-----|-------|------------|------|------|------|
|                   |                   | N8             | N16     | N32     | N64     | SPR | GAM   |            |      |      |      |
| Ohm*m             | 1                 | 1.01           | 1.00    | 1.01    | 1.07    | na  | na    | 0.01       | 0.0  | 0.01 | 0.07 |
| Ohm*m             | 100               | 105.5          | 105.3   | 105.1   | 106.4   | na  | na    | 5.5        | 5.3  | 5.1  | 6.4  |
| Ohm*m             | 1000              | 1053.0         | 1052.0  | 1055.0  | 1055.0  | na  | na    | 53.0       | 52.0 | 55.0 | 55.0 |
| Ohm*m             | 10000             | 10008.0        | 10004.0 | 10010.0 | 10008.0 | na  | na    | 8.0        | 4.0  | 10.0 | 8.0  |
| cps               | background        |                |         |         |         |     | 17-23 |            |      |      |      |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes  |
|--|
| Calibration and Calibration check is done using ALT calibration box SN 155101<br>IG_BH05_WP05_GAMIP_PreUseCheck_09Shift.tfd<br>Calibration_IP_5579_09Shift.txt |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | Aug 24, 2021<br>Date |
|--------------------------------------|--|----------------------|



## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                   |
|------------------------|-------------------|
| <b>Equipment Model</b> | QL NATURAL GAMMA  |
| <b>Serial Number</b>   | 6752              |
| <b>Date</b>            | May 22, 2021      |
| <b>Operator</b>        | OLGA FOMENKO      |
| <b>Location</b>        | NWMO_IG_BH05 site |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| BACKGROUND        | 8-10              | NA             | NA         |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench. No radioactive source on site to check. Files saved for each of the tests for reference.<br>IG_BH05_WP05_GAM_PreUseCheck_01Shift |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|


## EQUIPMENT CALIBRATION CHECK SHEET

|                        |   |
|------------------------|---|
| <b>Equipment Model</b> | GAMOBİ GAMMA +2G OPTICAL TELEVIEWER stack |
| <b>Serial Number</b>   | 5602_160403                               |
| <b>Date</b>            | August 23, 2021                           |
| <b>Operator</b>        | CHRIS MARCHILDON                          |
| <b>Location</b>        | NWMO_IG_BH05 site                         |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| ROLL / DEG        | 0                 | 0.8            | 0.8        |
| ROLL / DEG        | 90                | 90.4           | 0.4        |
| ROLL / DEG        | 180               | 180.3          | 0.3        |
| ROLL / DEG        | 270               | 270.5          | 0.5        |
| cps               | Background value  | 10-36          | na         |
| Colour            | Colour wheel      | Colour wheel   | na         |
|                   |                   |                |            |

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.<br><br>IG_BH05_WP05_GAMOBİ_PreRoll_08Shift.tfd<br><br>IG_BH05_WP05_GAMOBİ_PreColour_08Shift.tfd |

|                      |   |                 |
|----------------------|---|-----------------|
| Chris Marchildon     |  | August 23, 2021 |
| Calibration Operator | Signature   | Date            |


## EQUIPMENT CALIBRATION CHECK SHEET

|                        |  |
|------------------------|--|
| <b>Equipment Model</b> | QL40 HMI INDUCTION MAGNETIC SUSCEPTIBILITY |
| <b>Serial Number</b>   | 6766                                       |
| <b>Date</b>            | Aug 22, 2021                               |
| <b>Operator</b>        | PETER LEITH                                |
| <b>Location</b>        | NWMO_IG_BH05 site                          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| mS/m              | 1000              | 1043.8         | 43.8       |
| mS/m              | 200               | 201.8          | 1.8        |
| SI*10-3           | 0.6               | 0.83           | 0.23       |
| SI*10-3           | 5                 | 5.2            | 0.2        |
| SI*10-3           | 5.6               | 5.77           | 0.17       |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on the bench outside, acclimatized in water at 80.0m for 30 min.<br>HMI_Calibration_factory_220321.txt Factory (MSI) Calibrated in March 22,2021.<br>IG_BH05_WP05_HMI_Stabilization_06Shift.tfd<br>IG_BH05_WP05_HMI_CondPreUseCheck_07Shift.tfd<br>IG_BH05_WP05_HMI_MagPreUseCheck_07Shift.tfd |

|                                     |  |                      |
|-------------------------------------|--|----------------------|
| Peter Leith<br>Calibration Operator | <br>Signature | Aug 22, 2021<br>Date |
|-------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                  |
|------------------------|----------------------------------|
| <b>Equipment Model</b> | <i>OBI 2G OPTICAL TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>160304</i>                    |
| <b>Date</b>            | <i>May 22, 2021</i>              |
| <b>Operator</b>        | <i>OLGA FOMENKO</i>              |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>         |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.4            | 0.4        |
| DEG ROLL / DEG    | 90                | 90.4           | 0.4        |
| DEG ROLL / DEG    | 180               |                |            |
| DEG ROLL / DEG    | 270               | 270.7          | 0.7        |
| TILT / DEG        | 90                | 90.2           | 0.2        |
| TILT / DEG        | 0                 | 0              | 0          |
| COLOUR WHEEL      | NA                | NA             | NA         |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH05_WP05_OBI_PreRollCeck_01Shift.tfd<br>IG_BH05_WP05_OBI_PreTiltCeck_01Shift.tfd<br>IG_BH05_WP05_OBI_PreColourCheck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

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## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                  |
|------------------------|----------------------------------|
| <b>Equipment Model</b> | <i>OBI 2G OPTICAL TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>160403</i>                    |
| <b>Date</b>            | <i>August 18, 2021</i>           |
| <b>Operator</b>        | <i>Peter Leith</i>               |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>         |

| Calibration Units | Calibration Value | Measured Value | Difference                 |
|-------------------|-------------------|----------------|----------------------------|
| ROLL / DEG        | 0                 | 359.9          | 0.1                        |
| ROLL / DEG        | 90                | 90.9           | 0.9                        |
| ROLL / DEG        | 180               | 180.4          | 0.4                        |
| ROLL / DEG        | 270               | 270.5          | 0.5                        |
| Image Colour      | Colour Wheel      | Recorded File  | n/a – Image quality passed |
| TILT / DEG        | 90                | 89.5           | 0.5                        |
| TILT / DEG        | 0                 | 0.4            | 0.4                        |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| <p>Probe checked on bench, rolling by hand. Colour wheel was used for Image colour check. Files saved for each of the tests for reference.</p> <p>IG_BH05_WP05_OBI_PreTilt_03Shift.tfd</p> <p>IG_BH05_WP05_OBI_PreColour_03Shift.tfd</p> <p>IG_BH05_WP05_OBI_PreRoll_03Shift.tfd</p> |

Peter Leith  
 Calibration Operator

  
 Signature

August 19, 2021  
 Date

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**CALIBRATION REPORT : 2PCA-F Caliper S/N: 5032**  
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**Name : Caliper**  
**Source : MChProc**  
**Alias : Caliper**  
**Units : cm**  
**Calibration Date : 22/05/21 11:03**  
**Calibration Type : Linear - 2 pts**  
**CalA : 0.00869242**  
**CalB : -26.1278**  
**Reference1 : 10.2**  
**Reference2 : 15.2**  
**Value1 : 4179.25**  
**Value2 : 4754.46**  
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## Winch Odometer Record Sheet

Project: L-675: NMWO - Golder

Client: Golder

Date: Aug 20th 2021

Completed by: R. Morrison

|   |                        |
|---|------------------------|
| <b>PARAMETER:</b>                                   |                        |
| <b>Winch Model:</b>                                 | Mount Sopris WFA 1800m |
| <b>Winch SN:</b>                                    | 1904                   |
| <b>Length of benchmark (measured with tape)</b>     | <del>10</del> meters   |
| <b>Odometer out length measured</b>                 | 1.00                   |
| <b>Odometer in length measured</b>                  | 1.01                   |
| <b>Difference between benchmark and out reading</b> | 0.01                   |
| <b>Difference between benchmark and in reading</b>  | 0.01                   |
| <b>Difference between in and out reading</b>        | 0.01                   |
| <b>Calibration Acceptable</b>                       | ✓ Yes   No             |
| <b><u>Comments:</u></b>                             |                        |



# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description  | Initials and date |
|----------------------------------|---|--|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05   | PEHE/11.8.        |
|                                  |   | Inclination: 70.1  | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm   | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl  | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63   | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xls</i> received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13  | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal   | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4  | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal   | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal   | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz   | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m  | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm  | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m   | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m  | PEHE/11.8.        |
|                                  |   | check the rubber disks   | PEHE/11.8.        |
|                                  |   | no coating on EC electrode   | PEHE/11.8.        |
|                                  |   | flow sensor clean  | PEHE/11.8.        |
|                                  |   | tubing clean   | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"   | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |  |                   |
|                                  |   | correct equipment setup  | -                 |
|                                  |   | check the rubber disks   | -                 |
|                                  |   | no coating on EC electrode   | -                 |
|                                  |   | flow sensor clean  | -                 |
|                                  |   | tubing clean   | -                 |
| <b>During loggings</b>           |   |  |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |  | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |  | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |  | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |  | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |  | PEHE/11.8.        |

|   |   |   |            |
|---|---|---|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.  |   |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m  |   | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming   |   | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.  |   | PEHE/11.8. |
| Additional comments and observations:       |   |   |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check  |   | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)   | Start, stop depths: 38.24 m - 988.69  | JERK/12.8. |
|   |   | Pressure data indicates correct depth correction: Yes   | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Entire length covered.   | JERK/12.8. |
|   |   |   |            |
|   | Flow rate   | The highest measured flow: -547 ml/h flow at depth of c. 790 m  | JERK/12.8. |
|   |   | Lower limit: 30 mL/h  | JERK/12.8. |
|   |   | Flow sum: -547 ml/h.  | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Measurement run is uncompleted   | JERK/12.8. |
|   | SPR   | Clear anomalies visible: Yes  | JERK/12.8. |
|   |   | Level indicates normal operation of rubber discs: Yes, normal level   | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Measurement run is uncompleted   | JERK/12.8. |
|   | Head  | Same level as water level at when close to water level: Measurement run is uncompleted  | JERK/12.8. |
|   |   | Water level stabile during measurement: No, water level has decreased slowly during the measurement run. About 0.45 m during first 400 m. | JERK/12.8. |
|   |   | Increasing as function of depth: Yes  | JERK/12.8. |
|   |   | Indications of flow resistance in flow sensor: No   | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Measurement run is uncompleted   | JERK/12.8. |
|   | EC/Temp   | Comparison of down and upwards runs: Similar  | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Measurement run is uncompleted   | JERK/12.8. |
|   | Start, stop depths: 987.65 m - 589.14 m (measurement run incompleted)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113000793059300.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |   |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m:<br>Water level and drawdown after 5 hours of pumping:  |   |            |

|   |   |   |  |
|---|---|---|--|
|   |   |   |  |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping   | <b>"Between loggings" check</b>   |   |  |
|   | EC/Temp<br>downwards  | Start, stop depths                                      |  |
|   |   | Pressure data indicates correct depth correction:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Flow rate   | The highest measured flow:                              |  |
|   |   | Lower limit:  |  |
|   |   | Flow sum:   |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | SPR   | Clear anomalies visible:                                |  |
|   |   | Level indicates normal operation of rubber discs:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Head  | Same level as water level at when close to water level: |  |
|   |   | Increasing as function of depth:                        |  |
|   |   | Indications of flow resistance in flow sensor:          |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | EC/Temp   | Comparison of down and upwards runs:                    |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Comparison with run 1:<br>Start, stop depths:<br>Reparations, fixes:<br>Filenames (.dat and .csv):<br>Additional comments and observations:<br>Pumping rate and drawdown stabile: |   |  |
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping | <b>"Between loggings" check</b>   |   |  |
|   | EC/Temp<br>downwards  | Start, stop depths:                                     |  |
|   |   | Pressure data indicates correct depth correction:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Flow rate   | The highest measured flow:                              |  |
|   |   | Lower limit:  |  |
|   |   | Flow sum:   |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | SPR   | Clear anomalies visible:                                |  |
|   |   | Level indicates normal operation of rubber discs:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Head  | Same level as water level at when close to water level: |  |

|                                      |   |  |  |
|--------------------------------------|---|--|--|
|                                      |   | Increasing as function of depth:                   |  |
|                                      |   | Indications of flow resistance in flow sensor:     |  |
|                                      |   | Data intact and entire measurement length covered: |  |
|                                      | EC/Temp   | Comparison of down and upwards runs:               |  |
|                                      |   | Data intact and entire measurement length covered: |  |
|                                      | Comparison with run 1 and 2:<br>Start, stop depths:<br>Reparations, fixes:<br>Filenames (.dat and .csv):<br><br>Additional comments and observations: |  |  |
| During data processing and reporting |   |  |  |
| Transmissivity                       | Highest and lowest detected T:  |  |  |
|                                      | Largest error limits:   |  |  |
|                                      | Fracture and section specific results consistent:   |  |  |
| Hydraulic head                       | Highest and lowest value:   |  |  |
|                                      | Largest error limits:   |  |  |

# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description  | Initials and date |
|----------------------------------|---|--|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05   | PEHE/11.8.        |
|                                  |   | Inclination: 70.1  | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm   | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl  | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63   | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xls</i> received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13  | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal   | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4  | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal   | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal   | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz   | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m  | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm  | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m   | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m  | PEHE/11.8.        |
|                                  |   | check the rubber disks   | PEHE/11.8.        |
|                                  |   | no coating on EC electrode   | PEHE/11.8.        |
|                                  |   | flow sensor clean  | PEHE/11.8.        |
|                                  |   | tubing clean   | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"   | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |  |                   |
|                                  |   | correct equipment setup  | -                 |
|                                  |   | check the rubber disks   | -                 |
|                                  |   | no coating on EC electrode   | -                 |
|                                  |   | flow sensor clean  | -                 |
|                                  |   | tubing clean   | -                 |
| <b>During loggings</b>           |   |  |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |  | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |  | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |  | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |  | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |  | PEHE/11.8.        |

|   |   |  |            |
|---|---|--|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.  |  |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m  |  | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming   |  | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.  |  | PEHE/11.8. |
| Additional comments and observations:       |   |  |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check  |  | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)   | Start, stop depths: 38.24 m - 988.69   | JERK/12.8. |
|   |   | Pressure data indicates correct depth correction: Yes  | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Entire length covered.  | JERK/12.8. |
|   | Flow rate   | The highest measured flow: -534 ml/h flow at depth of c. 790 m   | JERK/13.8. |
|   |   | Lower limit: 30 mL/h   | JERK/13.8. |
|   |   | Flow sum: +26 ml/h (+560 ml/h and -534 ml/h)   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | SPR   | Clear anomalies visible: Yes   | JERK/13.8. |
|   |   | Level indicates normal operation of rubber discs: Yes, normal level  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Head  | Same level as water level at when close to water level: Yes, difference 2 cm.  | JERK/13.8. |
|   |   | Water level stabile during measurement: No, water level decreased first and then rose. biggest difference 0.45 m which is not too large. | JERK/13.8. |
|   |   | Increasing as function of depth: Yes   | JERK/13.8. |
|   |   | Indications of flow resistance in flow sensor: No  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | EC/Temp   | Comparison of down and upwards runs: Similar   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Start, stop depths: 987.65 m - 59.39 m (measurement run is completed)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113001847006600.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |  |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m:<br>Water level and drawdown after 5 hours of pumping:  |  |            |

|   |   |   |  |
|---|---|---|--|
|   |   |   |  |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping   | <b>"Between loggings" check</b>   |   |  |
|   | EC/Temp<br>downwards  | Start, stop depths                                      |  |
|   |   | Pressure data indicates correct depth correction:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Flow rate   | The highest measured flow:                              |  |
|   |   | Lower limit:  |  |
|   |   | Flow sum:   |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | SPR   | Clear anomalies visible:                                |  |
|   |   | Level indicates normal operation of rubber discs:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Head  | Same level as water level at when close to water level: |  |
|   |   | Increasing as function of depth:                        |  |
|   |   | Indications of flow resistance in flow sensor:          |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | EC/Temp   | Comparison of down and upwards runs:                    |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Comparison with run 1:<br>Start, stop depths:<br>Reparations, fixes:<br>Filenames (.dat and .csv):<br>Additional comments and observations:<br>Pumping rate and drawdown stabile: |   |  |
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping | <b>"Between loggings" check</b>   |   |  |
|   | EC/Temp<br>downwards  | Start, stop depths:                                     |  |
|   |   | Pressure data indicates correct depth correction:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Flow rate   | The highest measured flow:                              |  |
|   |   | Lower limit:  |  |
|   |   | Flow sum:   |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | SPR   | Clear anomalies visible:                                |  |
|   |   | Level indicates normal operation of rubber discs:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Head  | Same level as water level at when close to water level: |  |

|                                      |   |  |  |
|--------------------------------------|---|--|--|
|                                      |   | Increasing as function of depth:                   |  |
|                                      |   | Indications of flow resistance in flow sensor:     |  |
|                                      |   | Data intact and entire measurement length covered: |  |
|                                      | EC/Temp   | Comparison of down and upwards runs:               |  |
|                                      |   | Data intact and entire measurement length covered: |  |
|                                      | Comparison with run 1 and 2:<br>Start, stop depths:<br>Reparations, fixes:<br>Filenames (.dat and .csv):<br><br>Additional comments and observations: |  |  |
| During data processing and reporting |   |  |  |
| Transmissivity                       | Highest and lowest detected T:  |  |  |
|                                      | Largest error limits:   |  |  |
|                                      | Fracture and section specific results consistent:   |  |  |
| Hydraulic head                       | Highest and lowest value:   |  |  |
|                                      | Largest error limits:   |  |  |



# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description   | Initials and date |
|----------------------------------|---|---|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05  | PEHE/11.8.        |
|                                  |   | Inclination: 70.1   | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm  | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl   | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63  | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xlsm</i> received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13   | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal  | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4   | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal  | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal  | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz  | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m   | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm   | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m  | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m   | PEHE/11.8.        |
|                                  |   | check the rubber disks  | PEHE/11.8.        |
|                                  |   | no coating on EC electrode  | PEHE/11.8.        |
|                                  |   | flow sensor clean   | PEHE/11.8.        |
|                                  |   | tubing clean  | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"  | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |   |                   |
|                                  |   | correct equipment setup   | -                 |
|                                  |   | check the rubber disks  | -                 |
|                                  |   | no coating on EC electrode  | -                 |
|                                  |   | flow sensor clean   | -                 |
|                                  |   | tubing clean  | -                 |
| <b>During loggings</b>           |   |   |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |   | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |   | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |   | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |   | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |   | PEHE/11.8.        |

|   |  |   |            |
|---|--|---|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.                                       |   |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m   |   | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming  |   | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.   |   | PEHE/11.8. |
| Additional comments and observations:       |  |   |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check   |   | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)  | Start, stop depths: 38.24 m - 988.69  | JERK/12.8. |
|   |  | Pressure data indicates correct depth correction: Yes   | JERK/12.8. |
|   |  | Data intact and entire measurement length covered: Entire length covered.   | JERK/12.8. |
|   | Flow rate  | The highest measured flow: -534 ml/h flow at depth of c. 790 m  | JERK/13.8. |
|   |  | Lower limit: 30 mL/h  | JERK/13.8. |
|   |  | Flow sum: +26 ml/h (+560 ml/h and -534 ml/h)  | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   | SPR  | Clear anomalies visible: Yes  | JERK/13.8. |
|   |  | Level indicates normal operation of rubber discs: Yes, normal level   | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   | Head   | Same level as water level at when close to water level: Yes, difference 2 cm.   | JERK/13.8. |
|   |  | Water level stabile during measurement: No, water level decreased first and then rose. biggest difference 0.45 m which is not too large.  | JERK/13.8. |
|   |  | Increasing as function of depth: Yes  | JERK/13.8. |
|   |  | Indications of flow resistance in flow sensor: No   | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   | EC/Temp  | Comparison of down and upwards runs: Similar  | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   |  | Start, stop depths: 987.65 m - 59.39 m (measurement run is completed)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113001847006600.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m: drawdown of 15 m was selected as total yield is so small. |   |            |

|   |  |   |            |
|---|--|---|------------|
|   | Water level and drawdown after 5 hours of pumping: Drawdown 15m and yield 0.24l/min  |   |            |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping   | <b>"Between loggings" check</b>  |   |            |
|   | EC/Temp<br>downwards   | Start, stop depths  | -          |
|   |  | Pressure data indicates correct depth correction:                                   | -          |
|   |  | Data intact and entire measurement length covered:                                  | -          |
|   | Flow rate  | The highest measured flow: 230 ml/h   | JERK/14.8. |
|   |  | Lower limit:30 ml/h   | JERK/14.8. |
|   |  | Flow sum: - (measurement run uncompleted)   | JERK/14.8. |
|   |  | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/14.8. |
|   | SPR  | Clear anomalies visible: Yes, so far  | JERK/14.8. |
|   |  | Level indicates normal operation of rubber discs: Yes                               | JERK/14.8. |
|   |  | Data intact and entire measurement length covered: Yes, run uncompleted             | JERK/14.8. |
|   | Head   | Same level as water level at when close to water level: Measurement run uncompleted | JERK/14.8. |
|   |  | Increasing as function of depth: Yes  | JERK/14.8. |
|   |  | Indications of flow resistance in flow sensor: No                                   | JERK/14.8. |
|   |  | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/14.8. |
|   | EC/Temp  | Comparison of down and upwards runs: -  | JERK/14.8. |
|   |  | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/14.8. |
|   | Comparison with run 1: Single point similar,<br>Start, stop depths: 987.67 - 523.41 m<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC43E050R113.DAT<br>IGBH05SP43E050R113.DAT<br>IGBH05FL43E050R113000001098900.DAT<br>IGBH05FL43E050R113000923052800.DAT<br>IGBH05GW43E050R113.DAT<br>IGBH05EC43E050D113.CSV<br>IGBH05SP43E050D113.CSV<br>IGBH05FL43E050S113.CSV<br>IGBH05GW43E050D113.CSV<br><br>Additional comments and observations: No<br>Pumping rate and drawdown stabile: 15m drawdown, 0.24 l/min pumping |   |            |
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping | <b>"Between loggings" check</b>  |   |            |
|   | EC/Temp<br>downwards   | Start, stop depths:   |            |
|   |  | Pressure data indicates correct depth correction:                                   |            |
|   |  | Data intact and entire measurement length covered:                                  |            |
|   | Flow rate  | The highest measured flow:  |            |
|   |  | Lower limit:  |            |
|   |  | Flow sum:   |            |

|   |   |   |  |
|---|---|---|--|
|   |   | Data intact and entire measurement length covered:      |  |
|   | SPR   | Clear anomalies visible:                                |  |
|   |   | Level indicates normal operation of rubber discs:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Head  | Same level as water level at when close to water level: |  |
|   |   | Increasing as function of depth:                        |  |
|   |   | Indications of flow resistance in flow sensor:          |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | EC/Temp   | Comparison of down and upwards runs:                    |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Comparison with run 1 and 2:<br>Start, stop depths:<br>Reparations, fixes:<br>Filenames (.dat and .csv):<br><br>Additional comments and observations: |   |  |
| <b>During data processing and reporting</b> |   |   |  |
| Transmissivity                              | Highest and lowest detected T:  |   |  |
|   | Largest error limits:   |   |  |
|   | Fracture and section specific results consistent:   |   |  |
| Hydraulic head                              | Highest and lowest value:   |   |  |
|   | Largest error limits:   |   |  |

# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description  | Initials and date |
|----------------------------------|---|--|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05   | PEHE/11.8.        |
|                                  |   | Inclination: 70.1  | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm   | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl  | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63   | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xls</i> m received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13  | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal   | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4  | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal   | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal   | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz   | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m  | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm  | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m   | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m  | PEHE/11.8.        |
|                                  |   | check the rubber disks   | PEHE/11.8.        |
|                                  |   | no coating on EC electrode   | PEHE/11.8.        |
|                                  |   | flow sensor clean  | PEHE/11.8.        |
|                                  |   | tubing clean   | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"   | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |  |                   |
|                                  |   | correct equipment setup  | -                 |
|                                  |   | check the rubber disks   | -                 |
|                                  |   | no coating on EC electrode   | -                 |
|                                  |   | flow sensor clean  | -                 |
|                                  |   | tubing clean   | -                 |
| <b>During loggings</b>           |   |  |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |  | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |  | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |  | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |  | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |  | PEHE/11.8.        |

|   |   |  |            |
|---|---|--|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.  |  |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m  |  | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming   |  | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.  |  | PEHE/11.8. |
| Additional comments and observations:       |   |  |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check  |  | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)   | Start, stop depths: 38.24 m - 988.69   | JERK/12.8. |
|   |   | Pressure data indicates correct depth correction: Yes  | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Entire length covered.  | JERK/12.8. |
|   |   |  |            |
|   | Flow rate   | The highest measured flow: -534 ml/h flow at depth of c. 790 m   | JERK/13.8. |
|   |   | Lower limit: 30 mL/h   | JERK/13.8. |
|   |   | Flow sum: +26 ml/h (+560 ml/h and -534 ml/h)   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | SPR   | Clear anomalies visible: Yes   | JERK/13.8. |
|   |   | Level indicates normal operation of rubber discs: Yes, normal level  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Head  | Same level as water level at when close to water level: Yes, difference 2 cm.  | JERK/13.8. |
|   |   | Water level stabile during measurement: No, water level decreased first and then rose. biggest difference 0.45 m which is not too large. | JERK/13.8. |
|   |   | Increasing as function of depth: Yes   | JERK/13.8. |
|   |   | Indications of flow resistance in flow sensor: No  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | EC/Temp   | Comparison of down and upwards runs: Similar   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Start, stop depths: 987.65 m - 59.39 m (measurement run is completed)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113001847006600.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |  |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m: drawdown of 15 m was selected as total yield is so small.  |  |            |

|   |   |   |            |
|---|---|---|------------|
|   | Water level and drawdown after 5 hours of pumping: Drawdown 15m and yield 0.24l/min |   |            |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping   | <b>"Between loggings" check</b>   |   |            |
|   | EC/Temp<br>downwards  | Start, stop depths  | -          |
|   |   | Pressure data indicates correct depth correction:                                   | -          |
|   |   | Data intact and entire measurement length covered:                                  | -          |
|   | Flow rate   | The highest measured flow: 336 ml/h   | JERK/15.8. |
|   |   | Lower limit:30 ml/h   | JERK/15.8. |
|   |   | Flow sum: 1297 ml/h   | JERK/15.8. |
|   |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|   | SPR   | Clear anomalies visible: Yes  | JERK/15.8. |
|   |   | Level indicates normal operation of rubber discs: Yes                               | JERK/15.8. |
|   |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|   | Head  | Same level as water level at when close to water level: Yes                         | JERK/15.8. |
|   |   | Increasing as function of depth: Yes  | JERK/15.8. |
|   |   | Indications of flow resistance in flow sensor: No                                   | JERK/15.8. |
|   |   | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/15.8. |
|   | EC/Temp   | Comparison of down and upwards runs: -  | JERK/15.8. |
|   |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
| <p>Comparison with run 1: Single point similar,<br/>Start, stop depths: 987.67 - 59.4 m<br/>Reparations, fixes: No<br/>Filenames (.dat and .csv):<br/>IGBH05EC43E050R113.DAT<br/>IGBH05SP43E050R113.DAT<br/>IGBH05FL43E050R113000001098900.DAT<br/>IGBH05FL43E050R113001847006600.DAT<br/>IGBH05GW43E050R113.DAT<br/>IGBH05EC43E050D113.CSV<br/>IGBH05SP43E050D113.CSV<br/>IGBH05FL43E050S113.CSV<br/>IGBH05GW43E050D113.CSV</p> <p>Additional comments and observations: Sum of detected fracture flows was 1297 ml/h and pumping rate 14400 ml/h. The most obvious reasons for difference could be, all flowing fractures were not found or flow rates of found fractures were not measured correctly. The borehole probe was dirty when lifted up from borehole. For not detecting a flowing fracture above base level is not likely as flow channel would have to be plugged entirely. Small flows that can be detected with PFL probe would flow through very small opening in the flow channel. Getting incorrect flow rate values due to dirt in flow sensor in more likely as flow measurement technique is very sensitive for impurities at measurement thermistors. Therefore we believe all flowing fracture locations have been detected based on measurement runs #1 and #2 and run#3 can be started. If the quality of measurement results are still doubted after the run#3 additional measurements to find more flowing fractures can be done.</p> <p>Pumping rate and drawdown stabile: 15m drawdown, 0.24 l/min pumping</p> |   |   |            |

|   |   |   |  |
|---|---|---|--|
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping     | <b>"Between loggings" check</b>   |   |  |
|   | EC/Temp<br>downwards  | Start, stop depths:                                     |  |
|   |   | Pressure data indicates correct depth correction:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Flow rate   | The highest measured flow:                              |  |
|   |   | Lower limit:  |  |
|   |   | Flow sum:   |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | SPR   | Clear anomalies visible:                                |  |
|   |   | Level indicates normal operation of rubber discs:       |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Head  | Same level as water level at when close to water level: |  |
|   |   | Increasing as function of depth:                        |  |
|   |   | Indications of flow resistance in flow sensor:          |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | EC/Temp   | Comparison of down and upwards runs:                    |  |
|   |   | Data intact and entire measurement length covered:      |  |
|   | Comparison with run 1 and 2:<br>Start, stop depths:<br>Reparations, fixes:<br>Filenames (.dat and .csv):<br><br>Additional comments and observations: |   |  |
| <b>During data processing and reporting</b> |   |   |  |
| Transmissivity                              | Highest and lowest detected T:  |   |  |
|   | Largest error limits:   |   |  |
|   | Fracture and section specific results consistent:   |   |  |
| Hydraulic head                              | Highest and lowest value:   |   |  |
|   | Largest error limits:   |   |  |



# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description   | Initials and date |
|----------------------------------|---|---|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05  | PEHE/11.8.        |
|                                  |   | Inclination: 70.1   | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm  | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl   | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63  | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xlsm</i> received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13   | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal  | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4   | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal  | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal  | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz  | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m   | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm   | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m  | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m   | PEHE/11.8.        |
|                                  |   | check the rubber disks  | PEHE/11.8.        |
|                                  |   | no coating on EC electrode  | PEHE/11.8.        |
|                                  |   | flow sensor clean   | PEHE/11.8.        |
|                                  |   | tubing clean  | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"  | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |   |                   |
|                                  |   | correct equipment setup   | -                 |
|                                  |   | check the rubber disks  | -                 |
|                                  |   | no coating on EC electrode  | -                 |
|                                  |   | flow sensor clean   | -                 |
|                                  |   | tubing clean  | -                 |
| <b>During loggings</b>           |   |   |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |   | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |   | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |   | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |   | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |   | PEHE/11.8.        |

|   |   |  |            |
|---|---|--|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.  |  |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m  |  | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming   |  | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.  |  | PEHE/11.8. |
| Additional comments and observations:       |   |  |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check  |  | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)   | Start, stop depths: 38.24 m - 988.69   | JERK/12.8. |
|   |   | Pressure data indicates correct depth correction: Yes  | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Entire length covered.  | JERK/12.8. |
|   | Flow rate   | The highest measured flow: -534 ml/h flow at depth of c. 790 m   | JERK/13.8. |
|   |   | Lower limit: 30 mL/h   | JERK/13.8. |
|   |   | Flow sum: +26 ml/h (+560 ml/h and -534 ml/h)   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | SPR   | Clear anomalies visible: Yes   | JERK/13.8. |
|   |   | Level indicates normal operation of rubber discs: Yes, normal level  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Head  | Same level as water level at when close to water level: Yes, difference 2 cm.  | JERK/13.8. |
|   |   | Water level stabile during measurement: No, water level decreased first and then rose. biggest difference 0.45 m which is not too large. | JERK/13.8. |
|   |   | Increasing as function of depth: Yes   | JERK/13.8. |
|   |   | Indications of flow resistance in flow sensor: No  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | EC/Temp   | Comparison of down and upwards runs: Similar   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Start, stop depths: 987.65 m - 59.39 m (measurement run is completed)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113001847006600.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |  |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m: drawdown of 15 m was selected as total yield is so small.  |  |            |

|  |   |   |            |
|--|---|---|------------|
|  | Water level and drawdown after 5 hours of pumping: Drawdown 15m and yield 0.24l/min |   |            |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping  | <b>"Between loggings" check</b>   |   |            |
|  | EC/Temp<br>downwards  | Start, stop depths  | -          |
|  |   | Pressure data indicates correct depth correction:                                   | -          |
|  |   | Data intact and entire measurement length covered:                                  | -          |
|  | Flow rate   | The highest measured flow: 336 ml/h   | JERK/15.8. |
|  |   | Lower limit:30 ml/h   | JERK/15.8. |
|  |   | Flow sum: 1297 ml/h   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | SPR   | Clear anomalies visible: Yes  | JERK/15.8. |
|  |   | Level indicates normal operation of rubber discs: Yes                               | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | Head  | Same level as water level at when close to water level: Yes                         | JERK/15.8. |
|  |   | Increasing as function of depth: Yes  | JERK/15.8. |
|  |   | Indications of flow resistance in flow sensor: No                                   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/15.8. |
|  | EC/Temp   | Comparison of down and upwards runs: -  | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
| <p>Comparison with run 1: Single point similar,<br/>Start, stop depths: 987.67 - 59.4 m<br/>Reparations, fixes: No<br/>Filenames (.dat and .csv):<br/>IGBH05EC43E050R113.DAT<br/>IGBH05SP43E050R113.DAT<br/>IGBH05FL43E050R113000001098900.DAT<br/>IGBH05FL43E050R113001847006600.DAT<br/>IGBH05GW43E050R113.DAT<br/>IGBH05EC43E050D113.CSV<br/>IGBH05SP43E050D113.CSV<br/>IGBH05FL43E050S113.CSV<br/>IGBH05GW43E050D113.CSV</p> <p>Additional comments and observations: Sum of detected fracture flows was 1297 ml/h and pumping rate 14400 ml/h. The most obvious reasons for difference could be, all flowing fractures were not found or flow rates of found fractures were not measured correctly. The borehole probe was dirty when lifted up from borehole. For not detecting a flowing fracture above base level is not likely as flow channel would have to be plugged entirely. Small flows that can be detected with PFL probe would flow through very small opening in the flow channel. Getting incorrect flow rate values due to dirt in flow sensor in more likely as flow measurement technique is very sensitive for impurities at measurement thermistors. Therefore we believe all flowing fracture locations have been detected based on measurement runs #1 and #2 and run#3 can be started. If the quality of measurement results are still doubted after the run#3 additional measurements to find more flowing fractures can be done.</p> <p>Pumping rate and drawdown stabile: 15m drawdown, 0.24 l/min pumping</p> <p>Additions after NWMO-Golder-Posiva Teams meeting August 15<sup>th</sup> 2021 09:15-10:00 (Toronto</p> |   |   |            |

|   |  |  |            |
|---|--|--|------------|
|   | time): Quality of measurement run 2 results was discussed and options for continuing the measurements were evaluated. Posiva's opinion was that the dirt in borehole that had attached to probe is causing incorrect measurement results but most probably it has not affected finding flowing fractures in borehole. Flowing fractures had been found in borehole but the flow rate results were unreasonable as at one fracture flow was the same in pumped and in unpumped conditions (flow should be larger in pumped conditions) and sum of flows did not match with pumping rate. Two options were discussed; Conducting run2 again in sequences starting from top of the borehole. This way dirtier (presumably) lower part of the borehole would be measured last. Another option was to continue with run 3 (also starting at top part of the borehole) and measured depth zones where fractures had been detected during runs 1 and 2. If sum of flows obtained during run 3 matches with pumping rate with accuracy of $\pm 10\%$ it is assumed that all flowing fractures have been found. |  |            |
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping | <b>"Between loggings" check</b>  |  |            |
|   | EC/Temp downwards  | Start, stop depths: not conducted as probe was not lowered to bottom.  | JERK/13.8. |
|   |  | Pressure data indicates correct depth correction: -                    | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: -                   | JERK/13.8. |
|   | Flow rate  | The highest measured flow: 3810 ml/h                                   | JERK/13.8. |
|   |  | Lower limit: 30 ml/h   | JERK/13.8. |
|   |  | Flow sum: 10069 ml/h so far  | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes                 | JERK/13.8. |
|   | SPR  | Clear anomalies visible: Yes   | JERK/13.8. |
|   |  | Level indicates normal operation of rubber discs: Yes                  | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes                 | JERK/13.8. |
|   | Head   | Same level as water level at when close to water level:                | JERK/13.8. |
|   |  | Increasing as function of depth: Yes                                   | JERK/13.8. |
|   |  | Indications of flow resistance in flow sensor: No                      | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes                 | JERK/13.8. |
|   | EC/Temp  | Comparison of down and upwards runs: Measuring downwards was not done. | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: -                   | JERK/13.8. |
|   | Comparison with run 1 and 2: Clearly larger flows that during run 2 and heat pulse is now cleaner (no signs of dirt in thermistors).<br>Start, stop depths: Several intervals.<br>230.92 - 228.39m<br>170.17 - 157.1 m<br>94.76 - 92.25 m<br>321.2 - 310.66 m<br>394.54 - 385.54 m<br>581.47 - 564.96 m<br>631.21 - 626.4 m<br>Reparations, fixes: the probe was thoroughly cleaned before starting the measurement<br>Filenames (.dat and .csv):<br>IGBH05EC43E005R113.DAT<br>IGBH05SP43E005R113.DAT<br>IGBH05FL43E005R113000001023250.DAT -  |  |            |

|                                      |   |  |
|--------------------------------------|---|--|
|                                      | IGBH05FL43E005R113000595062620.DAT<br>IGBH05GW43E005R113.DAT<br>IGBH05EC43E005D113.CSV<br>IGBH05SP43E005D113.CSV<br>IGBH05FL43E005S113.CSV<br>IGBH05GW43E005D113.CSV<br><br>Additional comments and observations:<br>So far sum of flows is 10069 ml/h and pumpig rate in August 14 <sup>th</sup> 13:00 was 11100 ml/h (0.185 l/min). The pumping rate decreases by the time so average of pumping rate during the run 3 need to be calculated when run 3 is ready. |  |
| During data processing and reporting |   |  |
| Transmissivity                       | Highest and lowest detected T:  |  |
|                                      | Largest error limits:   |  |
|                                      | Fracture and section specific results consistent:   |  |
| Hydraulic head                       | Highest and lowest value:   |  |
|                                      | Largest error limits:   |  |

# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description   | Initials and date |
|----------------------------------|---|---|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05  | PEHE/11.8.        |
|                                  |   | Inclination: 70.1   | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm  | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl   | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63  | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xlsm</i> received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13   | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal  | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4   | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal  | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal  | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz  | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m   | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm   | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m  | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m   | PEHE/11.8.        |
|                                  |   | check the rubber disks  | PEHE/11.8.        |
|                                  |   | no coating on EC electrode  | PEHE/11.8.        |
|                                  |   | flow sensor clean   | PEHE/11.8.        |
|                                  |   | tubing clean  | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"  | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |   |                   |
|                                  |   | correct equipment setup   | -                 |
|                                  |   | check the rubber disks  | -                 |
|                                  |   | no coating on EC electrode  | -                 |
|                                  |   | flow sensor clean   | -                 |
|                                  |   | tubing clean  | -                 |
| <b>During loggings</b>           |   |   |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |   | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |   | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |   | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |   | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |   | PEHE/11.8.        |

|   |  |   |            |
|---|--|---|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.                                       |   |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m   |   | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming  |   | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.   |   | PEHE/11.8. |
| Additional comments and observations:       |  |   |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check   |   | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)  | Start, stop depths: 38.24 m - 988.69  | JERK/12.8. |
|   |  | Pressure data indicates correct depth correction: Yes   | JERK/12.8. |
|   |  | Data intact and entire measurement length covered: Entire length covered.   | JERK/12.8. |
|   | Flow rate  | The highest measured flow: -534 ml/h flow at depth of c. 790 m  | JERK/13.8. |
|   |  | Lower limit: 30 mL/h  | JERK/13.8. |
|   |  | Flow sum: +26 ml/h (+560 ml/h and -534 ml/h)  | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   | SPR  | Clear anomalies visible: Yes  | JERK/13.8. |
|   |  | Level indicates normal operation of rubber discs: Yes, normal level   | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   | Head   | Same level as water level at when close to water level: Yes, difference 2 cm.   | JERK/13.8. |
|   |  | Water level stabile during measurement: No, water level decreased first and then rose. biggest difference 0.45 m which is not too large.  | JERK/13.8. |
|   |  | Increasing as function of depth: Yes  | JERK/13.8. |
|   |  | Indications of flow resistance in flow sensor: No   | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   | EC/Temp  | Comparison of down and upwards runs: Similar  | JERK/13.8. |
|   |  | Data intact and entire measurement length covered: Yes  | JERK/13.8. |
|   |  | Start, stop depths: 987.65 m - 59.39 m (measurement run is completed)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113001847006600.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m: drawdown of 15 m was selected as total yield is so small. |   |            |

|  |   |   |            |
|--|---|---|------------|
|  | Water level and drawdown after 5 hours of pumping: Drawdown 15m and yield 0.24l/min |   |            |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping  | <b>"Between loggings" check</b>   |   |            |
|  | EC/Temp<br>downwards  | Start, stop depths  | -          |
|  |   | Pressure data indicates correct depth correction:                                   | -          |
|  |   | Data intact and entire measurement length covered:                                  | -          |
|  | Flow rate   | The highest measured flow: 336 ml/h   | JERK/15.8. |
|  |   | Lower limit:30 ml/h   | JERK/15.8. |
|  |   | Flow sum: 1297 ml/h   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | SPR   | Clear anomalies visible: Yes  | JERK/15.8. |
|  |   | Level indicates normal operation of rubber discs: Yes                               | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | Head  | Same level as water level at when close to water level: Yes                         | JERK/15.8. |
|  |   | Increasing as function of depth: Yes  | JERK/15.8. |
|  |   | Indications of flow resistance in flow sensor: No                                   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/15.8. |
|  | EC/Temp   | Comparison of down and upwards runs: -  | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
| <p>Comparison with run 1: Single point similar,<br/>Start, stop depths: 987.67 - 59.4 m<br/>Reparations, fixes: No<br/>Filenames (.dat and .csv):<br/>IGBH05EC43E050R113.DAT<br/>IGBH05SP43E050R113.DAT<br/>IGBH05FL43E050R113000001098900.DAT<br/>IGBH05FL43E050R113001847006600.DAT<br/>IGBH05GW43E050R113.DAT<br/>IGBH05EC43E050D113.CSV<br/>IGBH05SP43E050D113.CSV<br/>IGBH05FL43E050S113.CSV<br/>IGBH05GW43E050D113.CSV</p> <p>Additional comments and observations: Sum of detected fracture flows was 1297 ml/h and pumping rate 14400 ml/h. The most obvious reasons for difference could be, all flowing fractures were not found or flow rates of found fractures were not measured correctly. The borehole probe was dirty when lifted up from borehole. For not detecting a flowing fracture above base level is not likely as flow channel would have to be plugged entirely. Small flows that can be detected with PFL probe would flow through very small opening in the flow channel. Getting incorrect flow rate values due to dirt in flow sensor in more likely as flow measurement technique is very sensitive for impurities at measurement thermistors. Therefore we believe all flowing fracture locations have been detected based on measurement runs #1 and #2 and run#3 can be started. If the quality of measurement results are still doubted after the run#3 additional measurements to find more flowing fractures can be done.</p> <p>Pumping rate and drawdown stabile: 15m drawdown, 0.24 l/min pumping</p> <p>Additions after NWMO-Golder-Posiva Teams meeting August 15<sup>th</sup> 2021 09:15-10:00 (Toronto</p> |   |   |            |



|   |  |  |            |
|---|--|--|------------|
|   | time): Quality of measurement run 2 results was discussed and options for continuing the measurements were evaluated. Posiva's opinion was that the dirt in borehole that had attached to probe is causing incorrect measurement results but most probably it has not affected finding flowing fractures in borehole. Flowing fractures had been found in borehole but the flow rate results were unreasonable as at one fracture flow was the same in pumped and in unpumped conditions (flow should be larger in pumped conditions) and sum of flows did not match with pumping rate. Two options were discussed; Conducting run2 again in sequences starting from top of the borehole. This way dirtier (presumably) lower part of the borehole would be measured last. Another option was to continue with run 3 (also starting at top part of the borehole) and measured depth zones where fractures had been detected during runs 1 and 2. If sum of flows obtained during run 3 matches with pumping rate with accuracy of $\pm 10\%$ it is assumed that all flowing fractures have been found. |  |            |
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping | <b>"Between loggings" check</b>  |  |            |
|   | EC/Temp downwards  | Start, stop depths: not conducted as probe was not lowered to bottom.                      | JERK/17.8. |
|   |  | Pressure data indicates correct depth correction: -  | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: -                                       | JERK/17.8. |
|   | Flow rate  | The highest measured flow: 3810 ml/h   | JERK/17.8. |
|   |  | Lower limit: 30 ml/h   | JERK/17.8. |
|   |  | Flow sum: 10465 ml/h   | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | SPR  | Clear anomalies visible: Yes   | JERK/17.8. |
|   |  | Level indicates normal operation of rubber discs: Yes                                      | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | Head   | Same level as water level at when close to water level: 0.5 m difference (will be checked) | JERK/17.8. |
|   |  | Increasing as function of depth: Yes   | JERK/17.8. |
|   |  | Indications of flow resistance in flow sensor: No  | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | EC/Temp  | Comparison of down and upwards runs: Measuring downwards was not done.                     | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: -                                       | JERK/17.8. |
|   | Comparison with run 1 and 2: Clearly larger flows that during run 2 and heat pulse is now cleaner (no signs of dirt in thermistors).<br>Start, stop depths: Several intervals.<br>230.92 - 228.39m<br>170.17 - 157.1 m<br>94.76 - 92.25 m<br>321.2 - 310.66 m<br>394.54 - 385.54 m<br>581.47 - 564.96 m<br>631.21 - 626.4 m<br>707.17 - 701.47 m<br>792.97 - 786.87 m<br>859.66 - 853.10 m<br>985.60 - 980,69 m<br>Reparations, fixes: the probe was thoroughly cleaned before starting the measurement  |  |            |

|   |  |  |
|---|--|--|
|   | <p>Filenames (.dat and .csv):<br/>IGBH05EC43E005R113.DAT<br/>IGBH05SP43E005R113.DAT<br/>IGBH05FL43E005R113000001023250.DAT -<br/>IGBH05FL43E005R113000841097910.DAT<br/>IGBH05GW43E005R113.DAT<br/>IGBH05EC43E005D113.CSV<br/>IGBH05SP43E005D113.CSV<br/>IGBH05FL43E005S113.CSV<br/>IGBH05GW43E005D113.CSV</p> <p>Additional comments and observations:<br/>Sum of flows is 10465 ml/h and average pumpig rate was 11700 ml/h (0.195 l/min). Difference between pumping rate and sum of flows is 1235 ml/h (12% of sum of flow). This is slightly over accuracy limit (10%) and additional measurements will be conducted in order to find if some fracture zones were not detected during run 2. 12% difference can be caused by varying conditions in borehole and it is possible that matching results will not be obtained even after additional measurement. Additional measurement will be measuring flow along the borehole in order to find if flow along the borehole changes in depth zones where fractures were not detected.</p> |  |
| <b>During data processing and reporting</b> |  |  |
| Transmissivity                              | Highest and lowest detected T:   |  |
|   | Largest error limits:  |  |
|   | Fracture and section specific results consistent:  |  |
| Hydraulic head                              | Highest and lowest value:  |  |
|   | Largest error limits:  |  |

# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description  | Initials and date |
|----------------------------------|---|--|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05   | PEHE/11.8.        |
|                                  |   | Inclination: 70.1  | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm   | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl  | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63   | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xls</i> m received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13  | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal   | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4  | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal   | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal   | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz   | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m  | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm  | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m   | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m  | PEHE/11.8.        |
|                                  |   | check the rubber disks   | PEHE/11.8.        |
|                                  |   | no coating on EC electrode   | PEHE/11.8.        |
|                                  |   | flow sensor clean  | PEHE/11.8.        |
|                                  |   | tubing clean   | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"   | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |  |                   |
|                                  |   | correct equipment setup  | -                 |
|                                  |   | check the rubber disks   | -                 |
|                                  |   | no coating on EC electrode   | -                 |
|                                  |   | flow sensor clean  | -                 |
|                                  |   | tubing clean   | -                 |
| <b>During loggings</b>           |   |  |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |  | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |  | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |  | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |  | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |  | PEHE/11.8.        |

|   |   |  |            |
|---|---|--|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.  |  |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m  |  | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming   |  | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.  |  | PEHE/11.8. |
| Additional comments and observations:       |   |  |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check  |  | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)   | Start, stop depths: 38.24 m - 988.69   | JERK/12.8. |
|   |   | Pressure data indicates correct depth correction: Yes  | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Entire length covered.  | JERK/12.8. |
|   | Flow rate   | The highest measured flow: -534 ml/h flow at depth of c. 790 m   | JERK/13.8. |
|   |   | Lower limit: 30 mL/h   | JERK/13.8. |
|   |   | Flow sum: +26 ml/h (+560 ml/h and -534 ml/h)   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | SPR   | Clear anomalies visible: Yes   | JERK/13.8. |
|   |   | Level indicates normal operation of rubber discs: Yes, normal level  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Head  | Same level as water level at when close to water level: Yes, difference 2 cm.  | JERK/13.8. |
|   |   | Water level stabile during measurement: No, water level decreased first and then rose. biggest difference 0.45 m which is not too large. | JERK/13.8. |
|   |   | Increasing as function of depth: Yes   | JERK/13.8. |
|   |   | Indications of flow resistance in flow sensor: No  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | EC/Temp   | Comparison of down and upwards runs: Similar   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Start, stop depths: 987.65 m - 59.39 m (measurement run is completed)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113001847006600.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |  |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m: drawdown of 15 m was selected as total yield is so small.  |  |            |

|  |   |   |            |
|--|---|---|------------|
|  | Water level and drawdown after 5 hours of pumping: Drawdown 15m and yield 0.24l/min |   |            |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping  | <b>"Between loggings" check</b>   |   |            |
|  | EC/Temp<br>downwards  | Start, stop depths  | -          |
|  |   | Pressure data indicates correct depth correction:                                   | -          |
|  |   | Data intact and entire measurement length covered:                                  | -          |
|  | Flow rate   | The highest measured flow: 336 ml/h   | JERK/15.8. |
|  |   | Lower limit:30 ml/h   | JERK/15.8. |
|  |   | Flow sum: 1297 ml/h   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | SPR   | Clear anomalies visible: Yes  | JERK/15.8. |
|  |   | Level indicates normal operation of rubber discs: Yes                               | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | Head  | Same level as water level at when close to water level: Yes                         | JERK/15.8. |
|  |   | Increasing as function of depth: Yes  | JERK/15.8. |
|  |   | Indications of flow resistance in flow sensor: No                                   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/15.8. |
|  | EC/Temp   | Comparison of down and upwards runs: -  | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
| <p>Comparison with run 1: Single point similar,<br/>Start, stop depths: 987.67 - 59.4 m<br/>Reparations, fixes: No<br/>Filenames (.dat and .csv):<br/>IGBH05EC43E050R113.DAT<br/>IGBH05SP43E050R113.DAT<br/>IGBH05FL43E050R113000001098900.DAT<br/>IGBH05FL43E050R113001847006600.DAT<br/>IGBH05GW43E050R113.DAT<br/>IGBH05EC43E050D113.CSV<br/>IGBH05SP43E050D113.CSV<br/>IGBH05FL43E050S113.CSV<br/>IGBH05GW43E050D113.CSV</p> <p>Additional comments and observations: Sum of detected fracture flows was 1297 ml/h and pumping rate 14400 ml/h. The most obvious reasons for difference could be, all flowing fractures were not found or flow rates of found fractures were not measured correctly. The borehole probe was dirty when lifted up from borehole. For not detecting a flowing fracture above base level is not likely as flow channel would have to be plugged entirely. Small flows that can be detected with PFL probe would flow through very small opening in the flow channel. Getting incorrect flow rate values due to dirt in flow sensor in more likely as flow measurement technique is very sensitive for impurities at measurement thermistors. Therefore we believe all flowing fracture locations have been detected based on measurement runs #1 and #2 and run#3 can be started. If the quality of measurement results are still doubted after the run#3 additional measurements to find more flowing fractures can be done.</p> <p>Pumping rate and drawdown stabile: 15m drawdown, 0.24 l/min pumping</p> <p>Additions after NWMO-Golder-Posiva Teams meeting August 15<sup>th</sup> 2021 09:15-10:00 (Toronto</p> |   |   |            |

|   |  |  |            |
|---|--|--|------------|
|   | time): Quality of measurement run 2 results was discussed and options for continuing the measurements were evaluated. Posiva's opinion was that the dirt in borehole that had attached to probe is causing incorrect measurement results but most probably it has not affected finding flowing fractures in borehole. Flowing fractures had been found in borehole but the flow rate results were unreasonable as at one fracture flow was the same in pumped and in unpumped conditions (flow should be larger in pumped conditions) and sum of flows did not match with pumping rate. Two options were discussed; Conducting run2 again in sequences starting from top of the borehole. This way dirtier (presumably) lower part of the borehole would be measured last. Another option was to continue with run 3 (also starting at top part of the borehole) and measured depth zones where fractures had been detected during runs 1 and 2. If sum of flows obtained during run 3 matches with pumping rate with accuracy of $\pm 10\%$ it is assumed that all flowing fractures have been found. |  |            |
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping | <b>"Between loggings" check</b>  |  |            |
|   | EC/Temp downwards  | Start, stop depths: not conducted as probe was not lowered to bottom.                      | JERK/17.8. |
|   |  | Pressure data indicates correct depth correction: -  | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: -                                       | JERK/17.8. |
|   | Flow rate  | The highest measured flow: 3810 ml/h   | JERK/17.8. |
|   |  | Lower limit: 30 ml/h   | JERK/17.8. |
|   |  | Flow sum: 10465 ml/h   | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | SPR  | Clear anomalies visible: Yes   | JERK/17.8. |
|   |  | Level indicates normal operation of rubber discs: Yes                                      | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | Head   | Same level as water level at when close to water level: 0.5 m difference (will be checked) | JERK/17.8. |
|   |  | Increasing as function of depth: Yes   | JERK/17.8. |
|   |  | Indications of flow resistance in flow sensor: No  | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | EC/Temp  | Comparison of down and upwards runs: Measuring downwards was not done.                     | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: -                                       | JERK/17.8. |
|   | Comparison with run 1 and 2: Clearly larger flows that during run 2 and heat pulse is now cleaner (no signs of dirt in thermistors).<br>Start, stop depths: Several intervals.<br>230.92 - 228.39m<br>170.17 - 157.1 m<br>94.76 - 92.25 m<br>321.2 - 310.66 m<br>394.54 - 385.54 m<br>581.47 - 564.96 m<br>631.21 - 626.4 m<br>707.17 - 701.47 m<br>792.97 - 786.87 m<br>859.66 - 853.10 m<br>985.60 - 980,69 m<br>Reparations, fixes: the probe was thoroughly cleaned before starting the measurement  |  |            |

|  |  |
|--|--|
|  | <p>Filenames (.dat and .csv):<br/>           IGBH05EC43E005R113.DAT<br/>           IGBH05SP43E005R113.DAT<br/>           IGBH05FL43E005R113000001023250.DAT -<br/>           IGBH05FL43E005R113000841097910.DAT<br/>           IGBH05GW43E005R113.DAT<br/>           IGBH05EC43E005D113.CSV<br/>           IGBH05SP43E005D113.CSV<br/>           IGBH05FL43E005S113.CSV<br/>           IGBH05GW43E005D113.CSV</p> <p>Additional comments and observations:<br/>           Sum of flows is 10465 ml/h and average pumpig rate was 11700 ml/h (0.195 l/min). Difference between pumping rate and sum of flows is 1235 ml/h (12% of sum of flow). This is slightly over accuracy limit (10%) and additional measurements will be conducted in order to find if some fracture zones were not detected during run 2. 12% difference can be caused by varying conditions in borehole and it is possible that matching results will not be obtained even after additional measurement. Additional measurement will be measuring flow along the borehole in order to find if flow along the borehole changes in depth zones where fractures were not detected.</p>   |
| <p><b>4. run<br/>Flow along<br/>borehole<br/>with<br/>pumping.</b></p> | <p>Flow along the borehole measurement at certain depths was conducted as an additional measurement run to investigate if flowing fracture have been undetected during measurement run 2. Run 3 was conducted at depths where fractures were detected but sum of flows measured and pumping rate did not match. Difference was 12% of sum of flow rates which is slightly larger than accuracy of flow sensor (10%).</p> <p>Overall view of the results is that there was large noise/variation in flow measurement results which question the reliability of the results. Average of flow at every measurement point was calculated but as mentioned variation in result values was large.</p> <p>Note! Single point resistance result has bad interference but depth matching could be done during positioning the probe. Data will be filtered later.</p> <p>The following presents the flow along the borehole at upper and lower end of depth zones where fractures were not detected in run2.</p> <p>top of borehole - 91.23 m: Casing pipe is larger than borehole so it was not possible to measure flow along casing pipe. For some reason flow at depth of 72.22 m was smaller (6037 ml/h) than at depth of 91.23 m (8499 ml/h). Not possible to say anything about fracture flows within this section.</p> <p>95.23 - 156.51 m: Flow at 95.23 m was 5600 ml/h and at depth of 156.51 5612 ml/h so there should not be flows in this depth interval.</p> <p>175.53 - 114.7 m: Flow 175.53m, 1984 ml/h and 224.7 m, 1868 ml/h. Difference in flow 116 ml/h. There is change but smaller than measurement accuracy. Not possible to interpret anything certain.</p> <p>233.71 - 307.13 m: Flow 233.71m, 1244 ml/h and 307.13m, 1286 ml/h. Difference 42 ml/h, clearly below accuracy.</p> <p>320.13 - 388m: Flow 320.13m, 802 ml/h and 388m, 689 ml/h. Difference 113 ml/h. Above flow sensor accuracy but variability so large that it is difficult to say if the change is real.</p> <p>394 - 848.8m: Flow 394m, 764 ml/h and 848.8m, 550 ml/h. Difference 214 ml/h. Above slow sensor accuracy but smaller than variability of results.</p> <p>865.8 - bottom of borehole: Flow 865.8 m 90 ml/h. Flow was measured but due to variability is it difficult to say whether it is real.</p> <p>In total flow changed 533 ml/h in depth intervals where flowing fractures were not detected</p> |

|                  |  |  |
|------------------|--|--|
|                  | during run2. But flow result variation was so large that it cannot be considered as certain indication of flowing fractures. |  |
|                  | 18.8.2021 Jere Komulainen  |  |
|                  |  |  |
| During reporting |  |  |
| Transmissivity   | Highest and lowest detected T:   |  |
|                  | Largest error limits:  |  |
|                  | Fracture and section specific results consistent:  |  |
| Hydraulic head   | Highest and lowest value:  |  |
|                  | Largest error limits:  |  |



# PFL DIFF flow logging, Quality Control Form, Posiva Solutions Oy

Borehole: IG\_BH05

Starting Date (day/month/year) : 11/08/2021

Operators: Petri Heikkinen, Jere Komulainen (monitoring by remote connection)

|                                  |   | Check description  | Initials and date |
|----------------------------------|---|--|-------------------|
| <b>Borehole data from Client</b> |   | Borehole name: IG_BH05   | PEHE/11.8.        |
|                                  |   | Inclination: 70.1  | PEHE/11.8.        |
|                                  |   | Borehole diameter: 96 mm   | PEHE/11.8.        |
|                                  |   | Reference depth (Z ground): 431.90 masl  | PEHE/11.8.        |
|                                  |   | Borehole length: 1000.63   | PEHE/11.8.        |
|                                  |   | Borehole deviation data received and in use (file name: <i>DQC Drilling IG_BH05 WP02 Gyro - While Drilling - Minimum Curvature Method.xls</i> received from Chris Phillips on 9 <sup>th</sup> of August 2021. Data down to 972 depth | PEHE/11.8.        |
| <b>Equipment data</b>            |   | Probe number: PFL DIFF 13  | PEHE/11.8.        |
|                                  |   | Probe calibration file: 19051413.cal   | PEHE/11.8.        |
|                                  |   | Trailer number: PFL Trailer 4  | PEHE/11.8.        |
|                                  |   | Trailer calibration file: 191204TR04.cal   | PEHE/11.8.        |
|                                  |   | Cable calibration file: 190927CC04.cal   | PEHE/11.8.        |
| <b>Check before loggings</b>     |   | Electricity: 230 V / 60 Hz   | PEHE/11.8.        |
|                                  |   | Casing length above ground: 0.81m  | PEHE/11.8.        |
|                                  |   | Casing diameter: 96mm  | PEHE/11.8.        |
|                                  |   | Distance to water level from top of casing: 28.04m   | PEHE/11.8.        |
|                                  |   | Trailer distance to casing (cable): 4.38m  | PEHE/11.8.        |
|                                  |   | check the rubber disks   | PEHE/11.8.        |
|                                  |   | no coating on EC electrode   | PEHE/11.8.        |
|                                  |   | flow sensor clean  | PEHE/11.8.        |
|                                  |   | tubing clean   | PEHE/11.8.        |
|                                  |   | check data with software's "test mode"   | PEHE/11.8.        |
| <b>Check between loggings</b>    |   |  |                   |
|                                  |   | correct equipment setup  | -                 |
|                                  |   | check the rubber disks   | -                 |
|                                  |   | no coating on EC electrode   | -                 |
|                                  |   | flow sensor clean  | -                 |
|                                  |   | tubing clean   | -                 |
| <b>During loggings</b>           |   |  |                   |
| Dummy, Run #1                    | Evaluate collected material: Large amount of pure-vis and small pieces of rock. not considered to cause risk to get jammed into borehole with measurement probe but pure-vis might get into flow sensor |  | PEHE/11.8.        |
|                                  | The lowest position of dummy: Bottom of borehole 1000.63 m  |  | PEHE/11.8.        |
|                                  | Possible jamming of the dummy, depths: At some depths dummy went down quite slowly, most likely due to pure-vis in borehole.  |  | PEHE/11.8.        |
|                                  | Cable tension up and down: down 40 - 100 kg (occasionally very small), up 140 - 180kg.  |  | PEHE/11.8.        |
| Dummy,                           | Evaluate collected material: Clearly smaller amount of pure-vis than  |  | PEHE/11.8.        |

|   |   |  |            |
|---|---|--|------------|
| Run #2                                      | at previous run. Borehole is considered safe for flow logging.  |  |            |
|   | The lowest position of dummy: bottom of borehole 1000.63 m  |  | PEHE/11.8. |
|   | Possible jamming of the dummy, depths: No jamming   |  | PEHE/11.8. |
|   | Cable tension up and down: down 60 - 100 kg, up 140 - 180kg.  |  | PEHE/11.8. |
| Additional comments and observations:       |   |  |            |
| 1. run<br>L=5 m<br>dL=0.5m<br>No<br>pumping | "Between loggings" check  |  | PEHE/11.8. |
|   | EC/Temp<br>downwards<br>(control)   | Start, stop depths: 38.24 m - 988.69   | JERK/12.8. |
|   |   | Pressure data indicates correct depth correction: Yes  | JERK/12.8. |
|   |   | Data intact and entire measurement length covered: Entire length covered.  | JERK/12.8. |
|   | Flow rate   | The highest measured flow: -534 ml/h flow at depth of c. 790 m   | JERK/13.8. |
|   |   | Lower limit: 30 mL/h   | JERK/13.8. |
|   |   | Flow sum: +26 ml/h (+560 ml/h and -534 ml/h)   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | SPR   | Clear anomalies visible: Yes   | JERK/13.8. |
|   |   | Level indicates normal operation of rubber discs: Yes, normal level  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Head  | Same level as water level at when close to water level: Yes, difference 2 cm.  | JERK/13.8. |
|   |   | Water level stabile during measurement: No, water level decreased first and then rose. biggest difference 0.45 m which is not too large. | JERK/13.8. |
|   |   | Increasing as function of depth: Yes   | JERK/13.8. |
|   |   | Indications of flow resistance in flow sensor: No  | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | EC/Temp   | Comparison of down and upwards runs: Similar   | JERK/13.8. |
|   |   | Data intact and entire measurement length covered: Yes   | JERK/13.8. |
|   | Start, stop depths: 987.65 m - 59.39 m (measurement run is completed)<br>Reparations, fixes: No<br>Filenames (.dat and .csv):<br>IGBH05EC31B050R113.DAT<br>IGBH05SP31B050R113.DAT<br>IGBH05FL31B050R113000001098900.DAT -<br>IGBH05FL31B050R113001847006600.DAT<br>IGBH05GW31B050R113.DAT<br><br>IGBH05EC31B050D113.CSV<br>IGBH05SP31B050D113.CSV<br>IGBH05FL31B050S113.CSV<br>IGBH05GW31B050D113.CSV<br>Additional comments and observations: Data quality good. |  |            |
| Pumping                                     | Starting pumping. Target drawdown is 10 m: drawdown of 15 m was selected as total yield is so small.  |  |            |

|  |   |   |            |
|--|---|---|------------|
|  | Water level and drawdown after 5 hours of pumping: Drawdown 15m and yield 0.24l/min |   |            |
| 2. run<br>L=5 m<br>dL=0.5m<br>Pumping  | <b>"Between loggings" check</b>   |   |            |
|  | EC/Temp<br>downwards  | Start, stop depths  | -          |
|  |   | Pressure data indicates correct depth correction:                                   | -          |
|  |   | Data intact and entire measurement length covered:                                  | -          |
|  | Flow rate   | The highest measured flow: 336 ml/h   | JERK/15.8. |
|  |   | Lower limit:30 ml/h   | JERK/15.8. |
|  |   | Flow sum: 1297 ml/h   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | SPR   | Clear anomalies visible: Yes  | JERK/15.8. |
|  |   | Level indicates normal operation of rubber discs: Yes                               | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
|  | Head  | Same level as water level at when close to water level: Yes                         | JERK/15.8. |
|  |   | Increasing as function of depth: Yes  | JERK/15.8. |
|  |   | Indications of flow resistance in flow sensor: No                                   | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes, measurement run uncompleted | JERK/15.8. |
|  | EC/Temp   | Comparison of down and upwards runs: -  | JERK/15.8. |
|  |   | Data intact and entire measurement length covered: Yes                              | JERK/15.8. |
| <p>Comparison with run 1: Single point similar,<br/>Start, stop depths: 987.67 - 59.4 m<br/>Reparations, fixes: No<br/>Filenames (.dat and .csv):<br/>IGBH05EC43E050R113.DAT<br/>IGBH05SP43E050R113.DAT<br/>IGBH05FL43E050R113000001098900.DAT<br/>IGBH05FL43E050R113001847006600.DAT<br/>IGBH05GW43E050R113.DAT<br/>IGBH05EC43E050D113.CSV<br/>IGBH05SP43E050D113.CSV<br/>IGBH05FL43E050S113.CSV<br/>IGBH05GW43E050D113.CSV</p> <p>Additional comments and observations: Sum of detected fracture flows was 1297 ml/h and pumping rate 14400 ml/h. The most obvious reasons for difference could be, all flowing fractures were not found or flow rates of found fractures were not measured correctly. The borehole probe was dirty when lifted up from borehole. For not detecting a flowing fracture above base level is not likely as flow channel would have to be plugged entirely. Small flows that can be detected with PFL probe would flow through very small opening in the flow channel. Getting incorrect flow rate values due to dirt in flow sensor in more likely as flow measurement technique is very sensitive for impurities at measurement thermistors. Therefore we believe all flowing fracture locations have been detected based on measurement runs #1 and #2 and run#3 can be started. If the quality of measurement results are still doubted after the run#3 additional measurements to find more flowing fractures can be done.</p> <p>Pumping rate and drawdown stabile: 15m drawdown, 0.24 l/min pumping</p> <p>Additions after NWMO-Golder-Posiva Teams meeting August 15<sup>th</sup> 2021 09:15-10:00 (Toronto</p> |   |   |            |

|   |  |  |            |
|---|--|--|------------|
|   | time): Quality of measurement run 2 results was discussed and options for continuing the measurements were evaluated. Posiva's opinion was that the dirt in borehole that had attached to probe is causing incorrect measurement results but most probably it has not affected finding flowing fractures in borehole. Flowing fractures had been found in borehole but the flow rate results were unreasonable as at one fracture flow was the same in pumped and in unpumped conditions (flow should be larger in pumped conditions) and sum of flows did not match with pumping rate. Two options were discussed; Conducting run2 again in sequences starting from top of the borehole. This way dirtier (presumably) lower part of the borehole would be measured last. Another option was to continue with run 3 (also starting at top part of the borehole) and measured depth zones where fractures had been detected during runs 1 and 2. If sum of flows obtained during run 3 matches with pumping rate with accuracy of $\pm 10\%$ it is assumed that all flowing fractures have been found. |  |            |
| 3. run<br>L=0.5 m<br>dL=0.1m<br>Pumping | <b>"Between loggings" check</b>  |  |            |
|   | EC/Temp downwards  | Start, stop depths: not conducted as probe was not lowered to bottom.                      | JERK/17.8. |
|   |  | Pressure data indicates correct depth correction: -  | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: -                                       | JERK/17.8. |
|   | Flow rate  | The highest measured flow: 3810 ml/h   | JERK/17.8. |
|   |  | Lower limit: 30 ml/h   | JERK/17.8. |
|   |  | Flow sum: 10465 ml/h   | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | SPR  | Clear anomalies visible: Yes   | JERK/17.8. |
|   |  | Level indicates normal operation of rubber discs: Yes                                      | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | Head   | Same level as water level at when close to water level: 0.5 m difference (will be checked) | JERK/17.8. |
|   |  | Increasing as function of depth: Yes   | JERK/17.8. |
|   |  | Indications of flow resistance in flow sensor: No  | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: Yes                                     | JERK/17.8. |
|   | EC/Temp  | Comparison of down and upwards runs: Measuring downwards was not done.                     | JERK/17.8. |
|   |  | Data intact and entire measurement length covered: -                                       | JERK/17.8. |
|   | Comparison with run 1 and 2: Clearly larger flows that during run 2 and heat pulse is now cleaner (no signs of dirt in thermistors).<br>Start, stop depths: Several intervals.<br>230.92 - 228.39m<br>170.17 - 157.1 m<br>94.76 - 92.25 m<br>321.2 - 310.66 m<br>394.54 - 385.54 m<br>581.47 - 564.96 m<br>631.21 - 626.4 m<br>707.17 - 701.47 m<br>792.97 - 786.87 m<br>859.66 - 853.10 m<br>985.60 - 980,69 m<br>Reparations, fixes: the probe was thoroughly cleaned before starting the measurement  |  |            |

|  |  |
|--|--|
|  | <p>Filenames (.dat and .csv):<br/>           IGBH05EC43E005R113.DAT<br/>           IGBH05SP43E005R113.DAT<br/>           IGBH05FL43E005R113000001023250.DAT -<br/>           IGBH05FL43E005R113000841097910.DAT<br/>           IGBH05GW43E005R113.DAT<br/>           IGBH05EC43E005D113.CSV<br/>           IGBH05SP43E005D113.CSV<br/>           IGBH05FL43E005S113.CSV<br/>           IGBH05GW43E005D113.CSV</p> <p>Additional comments and observations:<br/>           Sum of flows is 10465 ml/h and average pumpig rate was 11700 ml/h (0.195 l/min). Difference between pumping rate and sum of flows is 1235 ml/h (12% of sum of flow). This is slightly over accuracy limit (10%) and additional measurements will be conducted in order to find if some fracture zones were not detected during run 2. 12% difference can be caused by varying conditions in borehole and it is possible that matching results will not be obtained even after additional measurement. Additional measurement will be measuring flow along the borehole in order to find if flow along the borehole changes in depth zones where fractures were not detected.</p>   |
| <p><b>4. run<br/>Flow along<br/>borehole<br/>with<br/>pumping.</b></p> | <p>Flow along the borehole measurement at certain depths was conducted as an additional measurement run to investigate if flowing fracture have been undetected during measurement run 2. Run 3 was conducted at depths where fractures were detected but sum of flows measured and pumping rate did not match. Difference was 12% of sum of flow rates which is slightly larger than accuracy of flow sensor (10%).</p> <p>Overall view of the results is that there was large noise/variation in flow measurement results which question the reliability of the results. Average of flow at every measurement point was calculated but as mentioned variation in result values was large.</p> <p>Note! Single point resistance result has bad interference but depth matching could be done during positioning the probe. Data will be filtered later.</p> <p>The following presents the flow along the borehole at upper and lower end of depth zones where fractures were not detected in run2.</p> <p>top of borehole - 91.23 m: Casing pipe is larger than borehole so it was not possible to measure flow along casing pipe. For some reason flow at depth of 72.22 m was smaller (6037 ml/h) than at depth of 91.23 m (8499 ml/h). Not possible to say anything about fracture flows within this section.</p> <p>95.23 - 156.51 m: Flow at 95.23 m was 5600 ml/h and at depth of 156.51 5612 ml/h so there should not be flows in this depth interval.</p> <p>175.53 - 114.7 m: Flow 175.53m, 1984 ml/h and 224.7 m, 1868 ml/h. Difference in flow 116 ml/h. There is change but smaller than measurement accuracy. Not possible to interpret anything certain.</p> <p>233.71 - 307.13 m: Flow 233.71m, 1244 ml/h and 307.13m, 1286 ml/h. Difference 42 ml/h, clearly below accuracy.</p> <p>320.13 - 388m: Flow 320.13m, 802 ml/h and 388m, 689 ml/h. Difference 113 ml/h. Above flow sensor accuracy but variability so large that it is difficult to say if the change is real.</p> <p>394 - 848.8m: Flow 394m, 764 ml/h and 848.8m, 550 ml/h. Difference 214 ml/h. Above slow sensor accuracy but smaller than variability of results.</p> <p>865.8 - bottom of borehole: Flow 865.8 m 90 ml/h. Flow was measured but due to variability is it difficult to say whether it is real.</p> <p>In total flow changed 533 ml/h in depth intervals where flowing fractures were not detected</p> |

|                |  |  |
|----------------|--|--|
|                | during run2. But flow result variation was so large that it cannot be considered as certain indication of flowing fractures.   |  |
|                | 18.8.2021 Jere Komulainen  |  |
|                | <p>As run4 was unseccesfull and it was still unclear why sum of flows detected with PFL probe did not match pumping rate it was decided that Golder will conduct heat pulse flowmeter test in the borehole. Total flow of borehole under pumped conditions is within range of heat pulse flowmeter so it should provide data for comparing it with PFL results. Sum of flows detected with PFL probe was 10465 ml/h and flow along the borehole at depth of 85 m measured with heat pulse flowmeter was 10459 ml/h. These match very well and confirm that all water flowing fractures below 85 m were measured with PFL probe. Above 85 m no fractures were found on the basis of heat pulse flow meter nor with the PFL probe. The reason for difference between pumping rate and flow in borehole still remain unclear but based on all these measurements all flowing fractures in borehole were detected.</p> <p>All necessary measurements for identifying flowing fractures in borehole and calculating their transmissivities have been done. Tests at IG_BH05 have been completed by Posiva.</p> <p>19.8.2021 Jere Komulainen</p> |  |
|                | <b>During reporting</b>  |  |
| Transmissivity | Highest and lowest detected T:   |  |
|                | Largest error limits:  |  |
|                | Fracture and section specific results consistent:  |  |
| Hydraulic head | Highest and lowest value:  |  |
|                | Largest error limits:  |  |

-----  
**CALIBRATION REPORT : MSI1-GR5602-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**

---



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

**Name : Caliper**  
**Source : MChProc**  
**Alias : Caliper**  
**Units : cm**  
**Calibration Date : 17/08/21 19:44**  
**Calibration Type : Linear - 2 pts**  
**CalA : 0.00867732**  
**CalB : -26.3889**  
**Reference1 : 10.2**  
**Reference2 : 15.2**  
**Value1 : 4216.61**  
**Value2 : 4792.83**  
-----

-----  
**CALIBRATION REPORT : 2PIA + 2PGA 0-1000ms, Gamma for Matrix**  
-----

**Name** : Cond  
**Source** : MCHProc  
**Alias** : Cond  
**Units** : mS  
**Calibration Date** : 20/08/21 19:01  
**Calibration Type** : Linear - 2 pts  
**CalA** : 0.21913  
**CalB** : -2676.02  
**Reference1** : 0  
**Reference2** : 463  
**Value1** : 12212  
**Value2** : 14324.9

-----

**Name** : Gamma  
**Source** : MCHProc  
**Alias** : Gamma  
**Units** : cps  
**Calibration Date** :  
**Calibration Type** : Linear - 2 pts  
**CalA** : 1  
**CalB** : 0  
**Reference1** : 0  
**Reference2** : 100  
**Value1** : 0  
**Value2** : 100

-----

-----  
**CALIBRATION REPORT : 2PIA + 2PGA 0-1000ms, Gamma for Matrix**  
-----

**Name** : Cond  
**Source** : MCHProc  
**Alias** : Cond  
**Units** : mS  
**Calibration Date** : 21/08/21 19:37  
**Calibration Type** : Linear - 2 pts  
**CalA** : 0.230613  
**CalB** : -2830.07  
**Reference1** : 0  
**Reference2** : 102  
**Value1** : 12272  
**Value2** : 12714.3  
-----

**Name** : Gamma  
**Source** : MCHProc  
**Alias** : Gamma  
**Units** : cps  
**Calibration Date** :  
**Calibration Type** : Linear - 2 pts  
**CalA** : 1  
**CalB** : 0  
**Reference1** : 0  
**Reference2** : 100  
**Value1** : 0  
**Value2** : 100  
-----

-----  
**CALIBRATION REPORT : 2PCA-F Fres, Temp for Matrix (Combo) S/N: 5032 \*\*\***  
**After Power On, wait 90 seconds for data to be valid! \*\*\***  
-----

**Name : Temperature**  
**Source : MChProc**  
**Alias : Temperature**  
**Units : deg C**  
**Calibration Date : 17/08/21 20:34**  
**Calibration Type : Linear - 2 pts**  
**CalA : 0.0159022**  
**CalB : -14.8825**  
**Reference1 : 8**  
**Reference2 : 40**  
**Value1 : 1438.95**  
**Value2 : 3451.25**  
-----

**Name : FRes**  
**Source : MChProc**  
**Alias : FRes**  
**Units : Ohm-m**  
**Calibration Date : 17/08/21 20:08**  
**Calibration Type : Linear - 2 pts**  
**CalA : -0.00543219**  
**CalB : 172.62**  
**Reference1 : 4.06**  
**Reference2 : 100**  
**Value1 : 31029.8**  
**Value2 : 13368.5**  
-----

-----  
**CALIBRATION REPORT : 2PCA-F Fres, Temp for Matrix (Combo) S/N: 5032 \*\*\***  
**After Power On, wait 90 seconds for data to be valid! \*\*\***  
-----

**Name : Temperature**  
**Source : MChProc**  
**Alias : Temperature**  
**Units : deg C**  
**Calibration Date : 17/08/21 20:34**  
**Calibration Type : Linear - 2 pts**  
**CalA : 0.0159022**  
**CalB : -14.8825**  
**Reference1 : 8**  
**Reference2 : 40**  
**Value1 : 1438.95**  
**Value2 : 3451.25**  
-----

**Name : FRes**  
**Source : MChProc**  
**Alias : FRes**  
**Units : Ohm-m**  
**Calibration Date : 17/08/21 20:08**  
**Calibration Type : Linear - 2 pts**  
**CalA : -0.00543219**  
**CalB : 172.62**  
**Reference1 : 4.06**  
**Reference2 : 100**  
**Value1 : 31029.8**  
**Value2 : 13368.5**  
-----

-----  
**CALIBRATION REPORT : BH05\_MSI\_BRIDLE\_GAM5602\_IP5579**  
-----

**Name : EHT**  
**Source : GRA**  
**Alias : EHT**  
**Units : Volts**  
**Calibration Date : 24/08/21 13:53**  
**Calibration Type : Linear - 2 pts**  
**CalA : -4.14414**  
**CalB : 0**  
**Reference1 : 0**  
**Reference2 : -1127**  
**Value1 : -0**  
**Value2 : 271.95**  
-----

**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 : 24/08/21 13:53**  
**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 : 24/08/21 13:53  
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 : 24/08/21 13:53  
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 : 24/08/21 13:53  
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 : 24/08/21 13:53  
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 : 24/08/21 13:53  
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 : 24/08/21 13:53  
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** : 24/08/21 13:53  
**Calibration Type** : *Linear - 2 pts*  
**CalA** : 1.07801  
**CalB** : 0.0929151  
**Reference1** : 1  
**Reference2** : 10000  
**Value1** : 0.841444  
**Value2** : 9276.27

---

**Name** : N64  
**Source** : MChProc  
**Alias** : N64  
**Units** : Ohm.m  
**Calibration Date** : 24/08/21 13:53  
**Calibration Type** : *Linear - 2 pts*  
**CalA** : 1.1129  
**CalB** : 1.7231  
**Reference1** : 1  
**Reference2** : 10000  
**Value1** : -0.649744  
**Value2** : 8983.98

---

**Name** : N8  
**Source** : MChProc  
**Alias** : N8  
**Units** : Ohm.m  
**Calibration Date** : 24/08/21 13:53  
**Calibration Type** : *Linear - 2 pts*  
**CalA** : 1.0939  
**CalB** : 0.0920681

Reference1 : 1  
Reference2 : 10000  
Value1 : 0.829995  
Value2 : 9141.52

---

Name : N32  
Source : MChProc  
Alias : N32  
Units : Ohm.m  
Calibration Date : 24/08/21 13:53  
Calibration Type : Linear - 2 pts  
CalA : 1.09099  
CalB : 0.506086  
Reference1 : 1  
Reference2 : 10000  
Value1 : 0.452721  
Value2 : 9165.52

---

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | MECHANICAL CALIPER |
| <b>Serial Number</b>   | 5032               |
| <b>Date</b>            | MARCH 22, 2021     |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | NWMO BH05 site     |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| cm                | 15.2              | 15.2           | 0          |
| cm                | 10.2              | 10.21          | 0.01       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:     ☒ Check Passed  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked using calibration jig.<br>IG_BH05_WP05_2PCA_PreUseCheck_01Shift.tfd<br>Caliper cal file: Caliper 5032_Calibration_01ShiftBH05.txt |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 22, 2021<br>Date |
|--------------------------------------|--|------------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                            |
|------------------------|----------------------------|
| <b>Equipment Model</b> | ABI 2G ACOUSTIC TELEVIEWER |
| <b>Serial Number</b>   | 190404                     |
| <b>Date</b>            | May 22, 2021               |
| <b>Operator</b>        | OLGA FOMENKO               |
| <b>Location</b>        | NWMO_IG_BH05 site          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.0            | 0          |
| DEG ROLL / DEG    | 90                | 90.2           | 0.2        |
| DEG ROLL / DEG    | 180               | 180.4          | 0.4        |
| DEG ROLL / DEG    | 270               | 270.1          | 0.1        |
| TILT / DEG        | 90                | 90.8           | 0.8        |
| TILT / DEG        | 0                 | 0              | 0          |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
    ☐ Needs Recalibration

| Testing Notes   |
|---|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH05_WP05_ABI_PreRollCeck_01Shift.tfd<br>IG_BH05_WP05_ABI_PreTiltCeck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                   |
|------------------------|-------------------|
| <b>Equipment Model</b> | QL NATURAL GAMMA  |
| <b>Serial Number</b>   | 6752              |
| <b>Date</b>            | May 22, 2021      |
| <b>Operator</b>        | OLGA FOMENKO      |
| <b>Location</b>        | NWMO_IG_BH05 site |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| BACKGROUND        | 8-10              | NA             | NA         |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench. No radioactive source on site to check. Files saved for each of the tests for reference.<br>IG_BH05_WP05_GAM_PreUseCheck_01Shift |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                  |
|------------------------|----------------------------------|
| <b>Equipment Model</b> | <i>OBI 2G OPTICAL TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>160304</i>                    |
| <b>Date</b>            | <i>May 22, 2021</i>              |
| <b>Operator</b>        | <i>OLGA FOMENKO</i>              |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>         |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.4            | 0.4        |
| DEG ROLL / DEG    | 90                | 90.4           | 0.4        |
| DEG ROLL / DEG    | 180               |                |            |
| DEG ROLL / DEG    | 270               | 270.7          | 0.7        |
| TILT / DEG        | 90                | 90.2           | 0.2        |
| TILT / DEG        | 0                 | 0              | 0          |
| COLOUR WHEEL      | NA                | NA             | NA         |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH05_WP05_OBI_PreRollCeck_01Shift.tfd<br>IG_BH05_WP05_OBI_PreTiltCeck_01Shift.tfd<br>IG_BH05_WP05_OBI_PreColourCheck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

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## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                    |
|------------------------|--------------------|
| <b>Equipment Model</b> | MECHANICAL CALIPER |
| <b>Serial Number</b>   | 5032               |
| <b>Date</b>            | MARCH 22, 2021     |
| <b>Operator</b>        | OLGA FOMENKO       |
| <b>Location</b>        | NWMO BH05 site     |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| cm                | 15.2              | 14.94          | 0.26       |
| cm                | 10.2              | 10.01          | 0.19       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Check Results:    ☒ Check Passed  
    ☐ Needs Recalibration

|  |
|--|
| <b>Testing Notes</b>   |
| Probe checked using calibration jig.<br>IG_BH05_WP05_2PCA_PostUseCheck_01Shift.tfd<br>Caliper cal file: Caliper 5032_Calibration_01ShiftBH05.txt |

|                                      |  |                        |
|--------------------------------------|--|------------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | March 22, 2021<br>Date |
|--------------------------------------|--|------------------------|



## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                            |
|------------------------|----------------------------|
| <b>Equipment Model</b> | ABI 2G ACOUSTIC TELEVIEWER |
| <b>Serial Number</b>   | 190404                     |
| <b>Date</b>            | May 22, 2021               |
| <b>Operator</b>        | OLGA FOMENKO               |
| <b>Location</b>        | NWMO_IG_BH05 site          |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.8            | 0.8        |
| DEG ROLL / DEG    | 90                | 90.4           | 0.4        |
| DEG ROLL / DEG    | 180               | 179.9          | -0.1       |
| DEG ROLL / DEG    | 270               | 269.6          | -0.4       |
|                   |                   |                |            |
|                   |                   |                |            |
|                   |                   |                |            |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

| Testing Notes  |
|--|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH04_WP05_ABI_PostRollCeck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

## EQUIPMENT CALIBRATION CHECK SHEET

|                        |                                  |
|------------------------|----------------------------------|
| <b>Equipment Model</b> | <i>OBI 2G OPTICAL TELEVIEWER</i> |
| <b>Serial Number</b>   | <i>160304</i>                    |
| <b>Date</b>            | <i>May 22, 2021</i>              |
| <b>Operator</b>        | <i>OLGA FOMENKO</i>              |
| <b>Location</b>        | <i>NWMO_IG_BH05 site</i>         |

| Calibration Units | Calibration Value | Measured Value | Difference |
|-------------------|-------------------|----------------|------------|
| DEG ROLL / DEG    | 0                 | 0.3            | 0.3        |
| DEG ROLL / DEG    | 90                | 90.2           | 0.2        |
| DEG ROLL / DEG    | 180               |                |            |
| DEG ROLL / DEG    | 270               | 270.3          | 0.3        |
| TILT / DEG        | 90                | 90.3           | 0.3        |
| TILT / DEG        | 0                 | 0.1            | 0.1        |
| COLOUR WHEEL      | NA                | NA             | NA         |

Calibration Results:      ☒ Passed Check  
                                      ☐ Needs Recalibration

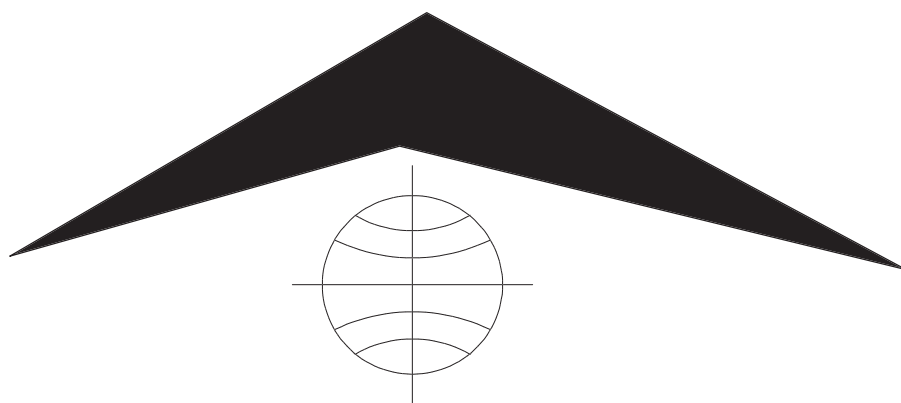
| Testing Notes   |
|---|
| Probe checked on bench, rolling by hand. Files saved for each of the tests for reference.<br>IG_BH05_WP05_OBI_PostColourCheck_01Shift.tfd |

|                                      |  |                      |
|--------------------------------------|--|----------------------|
| Olga Fomenko<br>Calibration Operator | <br>Signature | May 22, 2021<br>Date |
|--------------------------------------|--|----------------------|

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

## General Information

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### 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)                           |       |

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

### **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.

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

### 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.



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

### 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.

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

**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.

**Calibration Settings**

Temp. | F-Res.

**First Point**

Reference: 0 Deg C

Value: 1114.0 cps

Use Current

**Second Point**

Reference: 0 Deg C

Value: 1114.0 cps

Use Current

**Channel Calibration Factors**

Temp.(Deg C) = 0.0195 x Temp.(cps) + -21.81

Store Unit

- 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.

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

**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:

**PolyLog Acquisition Program**  
**Calibration Entry Screen**

**Calibration Entry Screen**

**Channel 1 of 3**

**Channel Name: Temp**  
**Cal Type: 1**

**Units: DegC**

**Low Input 2513.5**  
**Low Reference 23.2**

**High Input 3547**  
**High Reference 40.3**

**Instructions:**  
Press TAB or Shift-TAB to move between fields, F5 or F6  
to Pick Previous or Next Channel, Control-ENTER when done.  
Press F3 to place current input value into Low Input field.  
Press F4 to place current input value into High Input field.

|             |              |              |
|-------------|--------------|--------------|
| <b>Temp</b> | <b>FRes</b>  | <b>FCond</b> |
| <b>DegC</b> | <b>Ohm-m</b> | <b>uS/cm</b> |

\*\*\*\*\* Initializing logger...Please Wait \*\*\*\*\*

**Vertical Scale: 0.00**

**Mode: Depth Drive**

**Output File Name: C:\TEST\TEST.W06 (OFF)**

**Graph Printer (OFF)**

**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)

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

### 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:

```

ACQSBC 1.34 Depth: 1.87 -- Speed: 0.00 D:0.10 T: 5 DpS: 10
  ▾
Depth  Speed  Pulse1  Temp  Pulse2  F_Res  F_Cond
Feet   ft/min  cps    DegC  cps    OhmM   uS/cm
1.87   0.0    0.00   -25.07 0.00   132.39 75.52

Chan LeftInp InValue RgtInp LftOut RgtOut TK FL DepShf LfPlot RgPlot PlotPerCt
DD00 195      0       570    0     1000 0 0 0 0 0 0
DS00 0        0.0     100    0     100 0 0 0 0 -10 0.0%
CS32 0        0     1000    0     1000 0 0 0 0 0 0
CS32 1333     0     4923 2.3000 76 4 0 0 12 16 -926.6%
CS33 0        0     1000    0     1000 0 0 0 0 0 0
CS33 30070    0     10480 9.9000 89.700 7 0 0.1650 0 50 264.8%
IV06 0        132.39 1       0     10000 10 0 0.1650 0 10000 0.8%

COMMENT: *
OUT:Not Yet Assigned (OFF) Recs:0 Bytes:0 Free:83344K
PB:MKW2WE.PB2 P: 0 L: 1
Q: 0

```

Err: 102 \*50 Scans: No serial data received

### MGX Example

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

|   | LftInp     | RgtInp   | LftOut      | RgtOut     |
|---|------------|----------|-------------|------------|
| Temperature (2 <sup>nd</sup> line CS32)       | 1333 cps   | 4923 cps | 2.30 deg. C | 76 deg. C. |
| Fluid Resistivity (2 <sup>nd</sup> 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.

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

### **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.

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

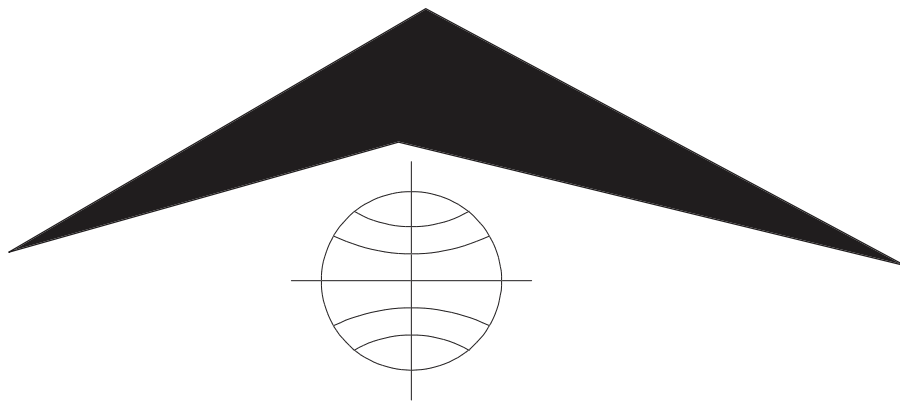
## Schematics

---

|                |                |       |                               |
|----------------|----------------|-------|-------------------------------|
| 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      |

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



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

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## General Information

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### 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**

|           | <b>2CAA-1000</b> |        | <b>2PCA-1000 w/2ADP adapter (no Gamma)</b> |        |
|-----------|------------------|--------|--|--------|
| 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

**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

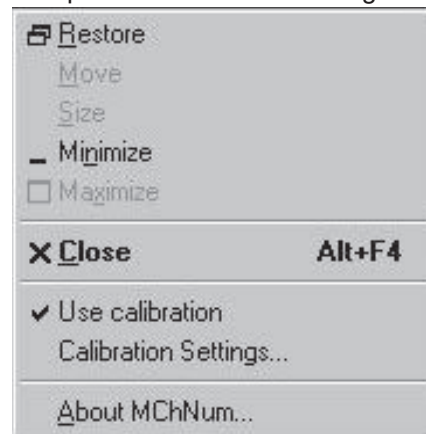
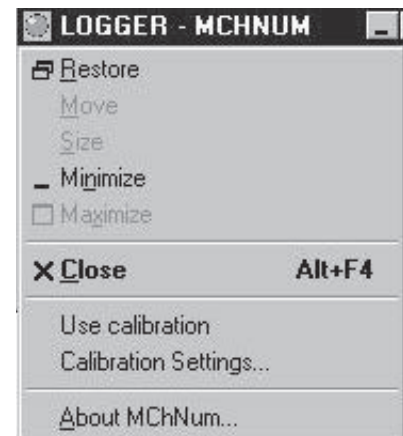
The 2PCA-1000 will need to be calibrated through the LOGSHELL or MSLog software before logging. Follow the procedure above for opening the caliper, and see the sections in either the LOGSHELL or MSLog manuals for calibrations. The normal operating mode of the MGX II system updates data each time the 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

The screenshot shows a 'Calibration Settings' window with two tabs: 'Cond.' and 'Mag. Sus.'. The 'Cond.' tab is active. It contains two sections: 'First Point' and 'Second Point'. Each section has a 'Reference' field with a checkmark icon, a 'Value' field, and a 'Use Current' button. Below these is a 'Channel Calibration Factors' section with a formula:  $\text{Cond. (mS/m)} = 0.2210 \times \text{Cond. (cps)} + -2808$ . There are 'Store' and 'Unit' buttons at the bottom of this section.

| Point        | Reference                           | Value | Unit |
|--------------|-------------------------------------|-------|------|
| First Point  | <input checked="" type="checkbox"/> | 12703 | cps  |
| Second Point | <input type="checkbox"/>            | 14774 | cps  |

Channel Calibration Factors:

$$\text{Cond. (mS/m)} = 0.2210 \times \text{Cond. (cps)} + -2808$$

**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 (nitrobenzene, 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.

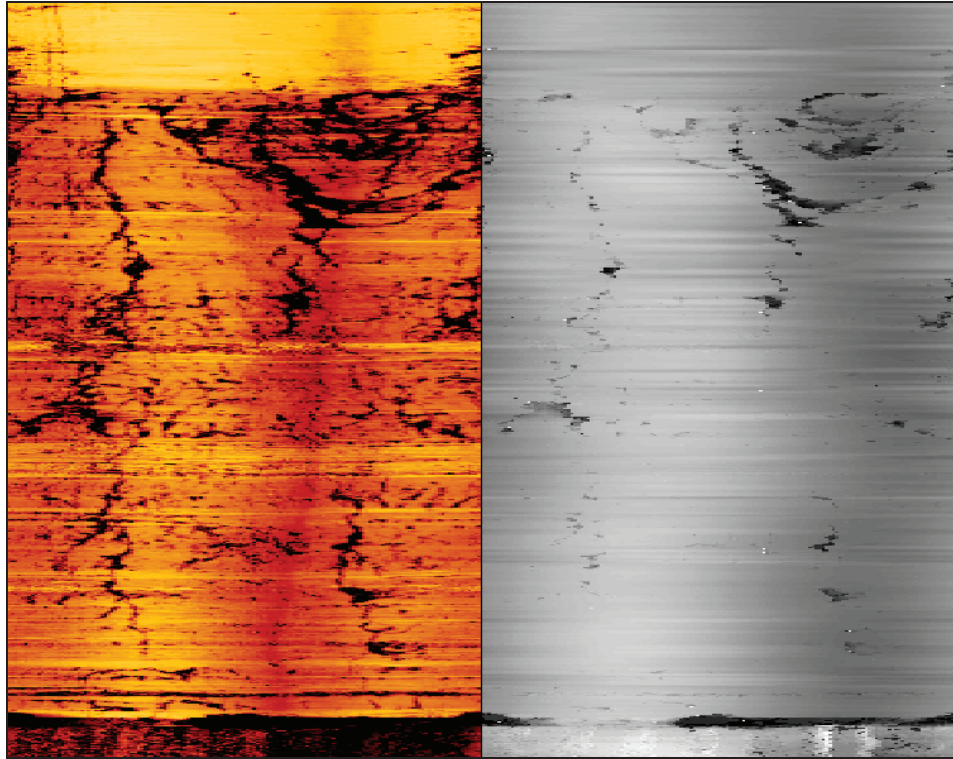
General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

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.

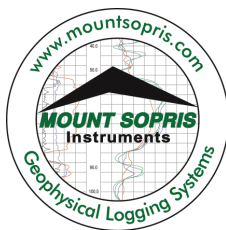
A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated 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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# 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

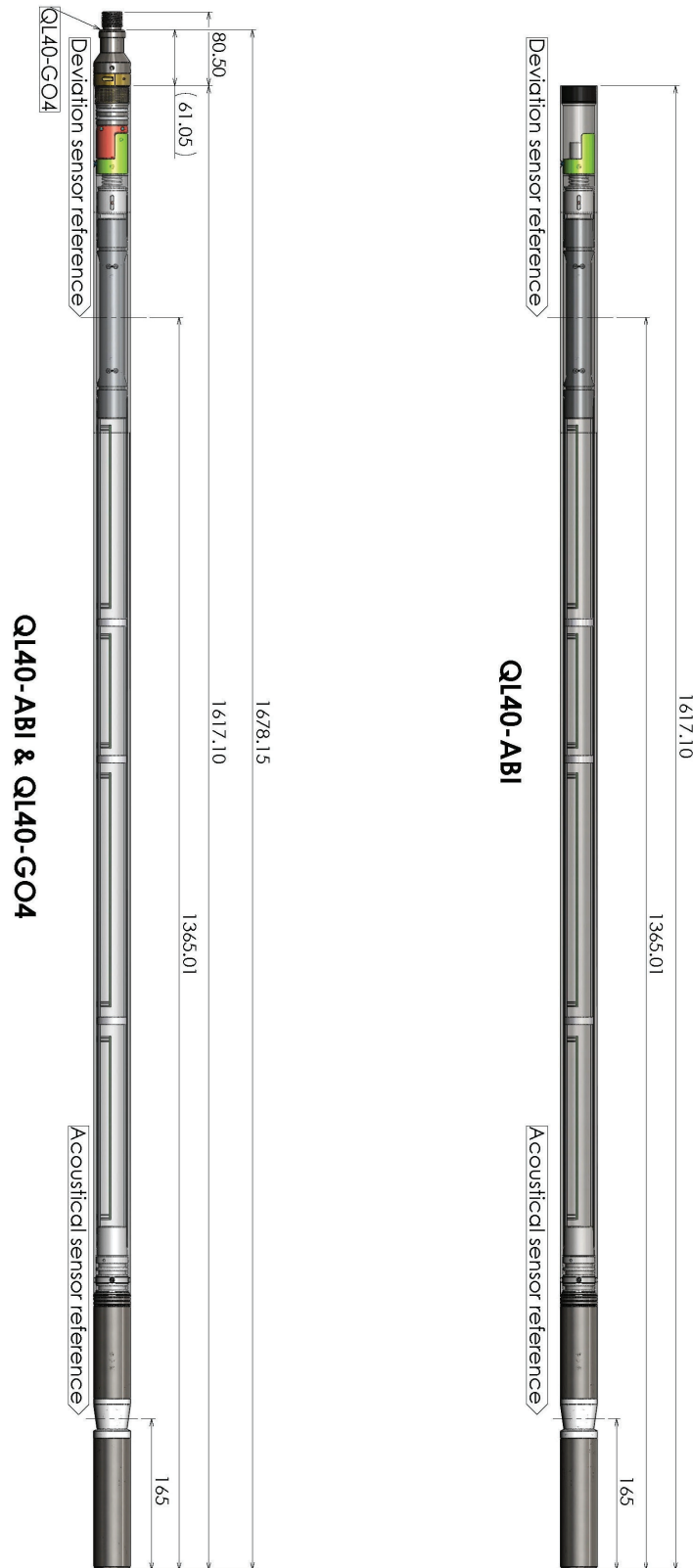


Figure 1-1 QL40-ABI-2G dimensions

### 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 <sup>1</sup> : | 2.5" – 20" (64mm-500mm)                       |
| Focusing diameter <sup>2</sup> : | 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   |

<sup>1</sup> Diameter range of the hole in which the measurement is possible (depends on borehole conditions).

<sup>2</sup> 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 |

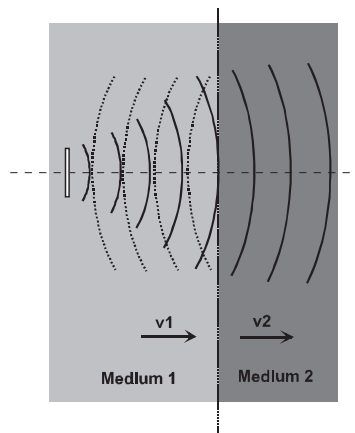
**Logger Firmware requirements:**

|             |                 |
|-------------|-----------------|
| 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:

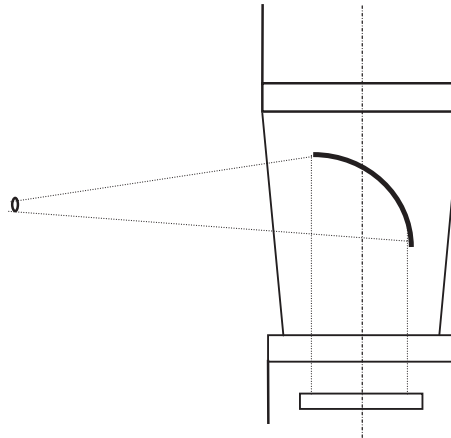
$$r = (\rho_b v_b - \rho_m v_m) / (\rho_b v_b + \rho_m v_m)$$

where  $\rho_b$  = density of formation  
 $\rho_m$  = density of borehole fluid  
 $v_b$  = velocity of sound of formation  
 $v_m$  = velocity of sound of borehole fluid

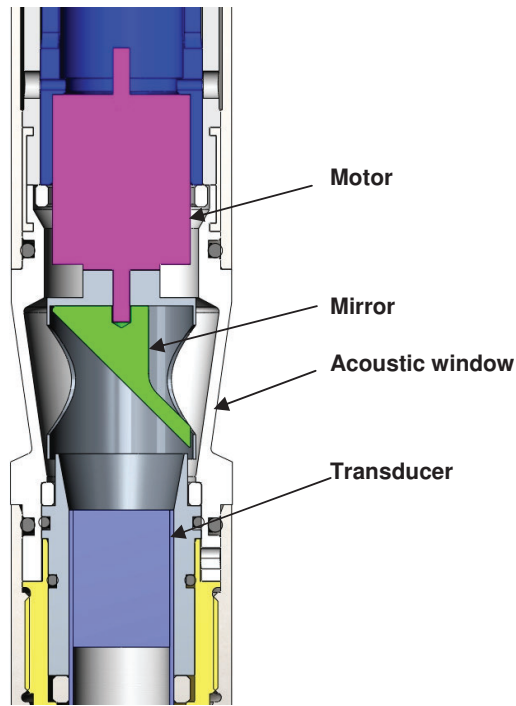
The larger the reflection coefficient is the greater is the signal reflection and thus the ability to detect the signal. From the equation above it may be seen that when the properties of the borehole fluid and borehole wall are similar, i.e.  $\rho_b v_b \approx \rho_m v_m$ , the reflection coefficient  $r$  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  $\pm 1.5$  mm diameter. The radial distance of the focal point from the axis of the tool is determined by the focal length of the mirror,  $\pm 75$ mm (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  $360^\circ$ . 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 **Quick Link** 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.

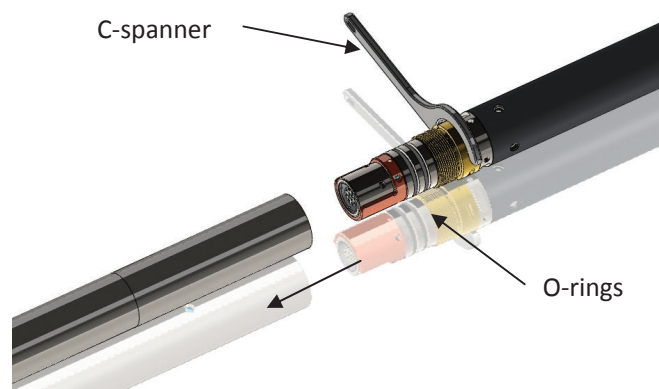
### Mid Sub

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

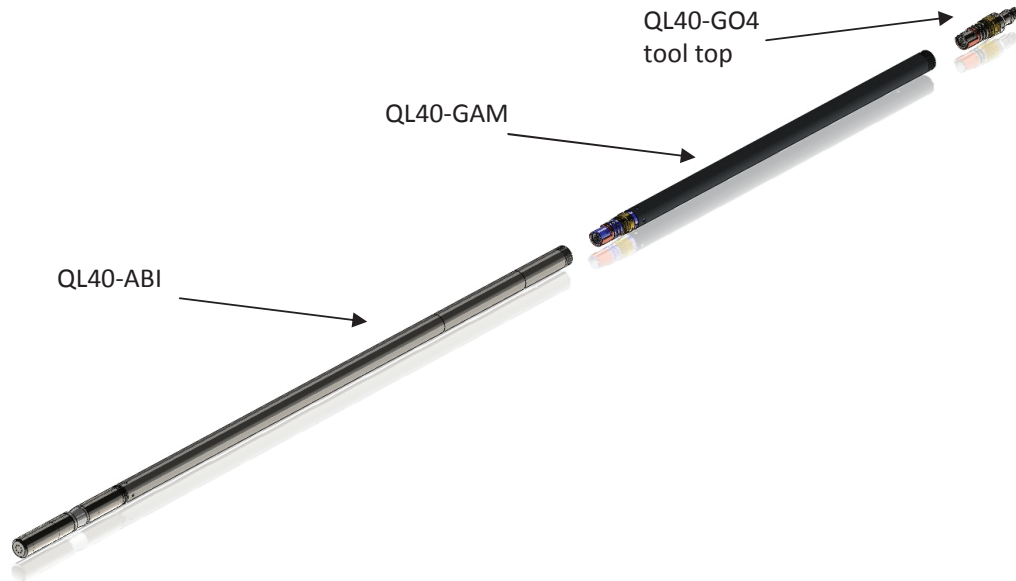
QL40 tool stacks are terminated by either a QL40 bottom sub or a QL40 bottom plug. At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available, special ones can be made on request.

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.



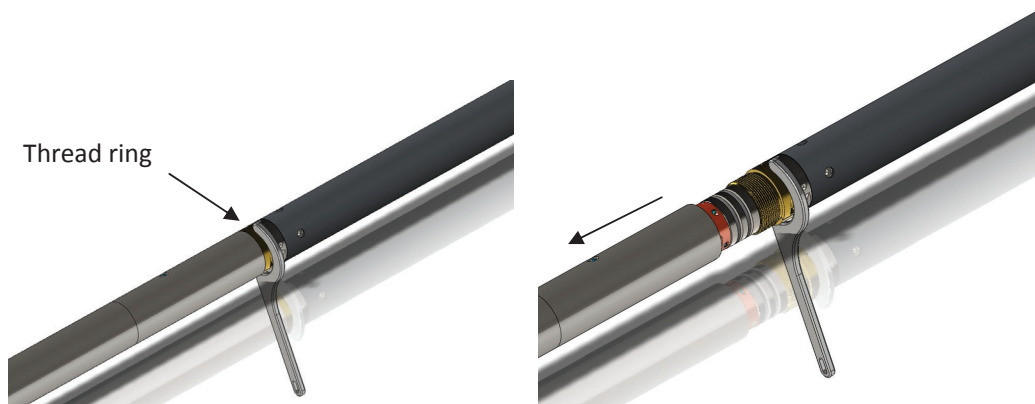
**Figure 3-1** C-spanner and O-rings of QL connection

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:

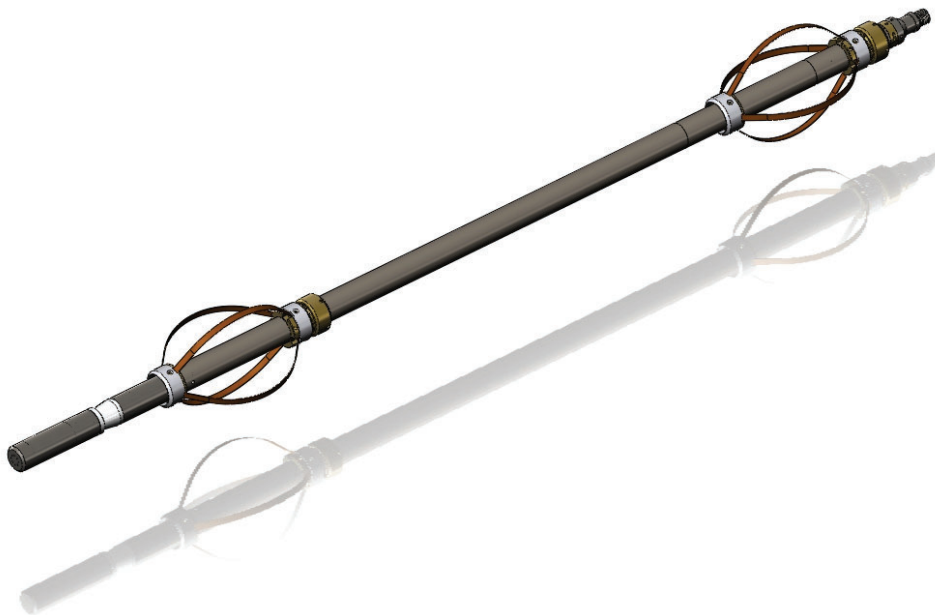
The centralisers should be fitted before mating the tool with the wireline cable head and should always be fitted from the cable head end to avoid damaging the acoustic window.

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.



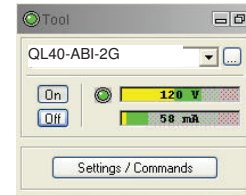
*Figure 4-1 QL40 ABI with mounted centralizers.*

## 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).

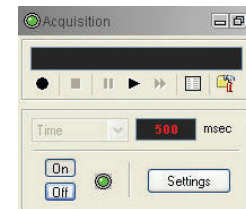


**Figure 4-2** Tool panel

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).

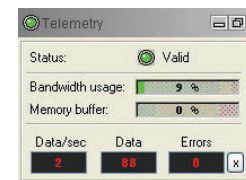


**Figure 4-3** Acquisition panel

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.

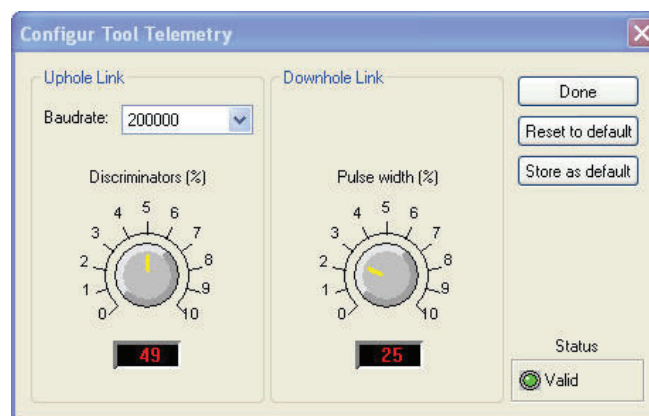


Figure 4-5 Tool communication settings

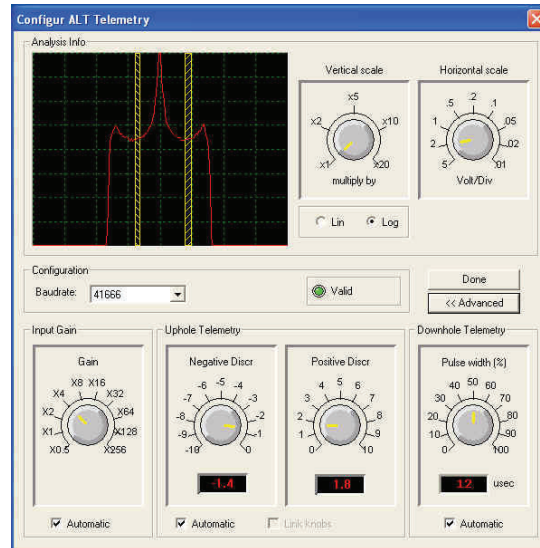
### 4.4 Tool Communication with MATRIX

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 **linear / logarithmic** 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.

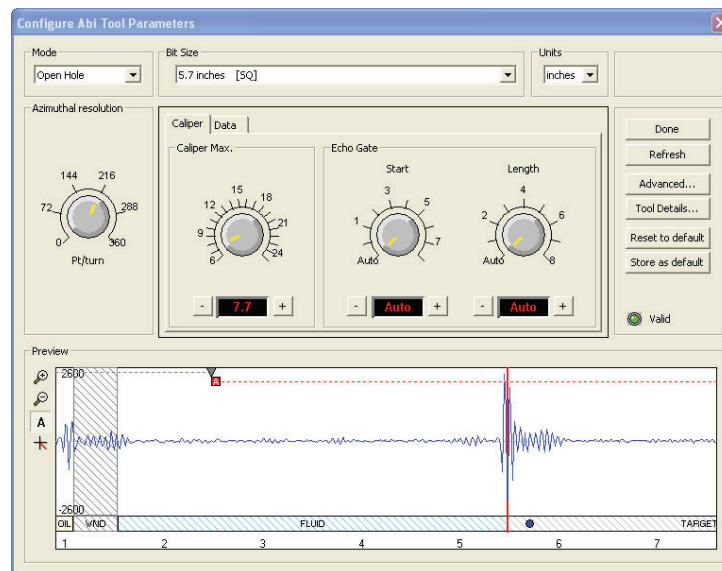
### 4.5.1 Operating Modes

**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.



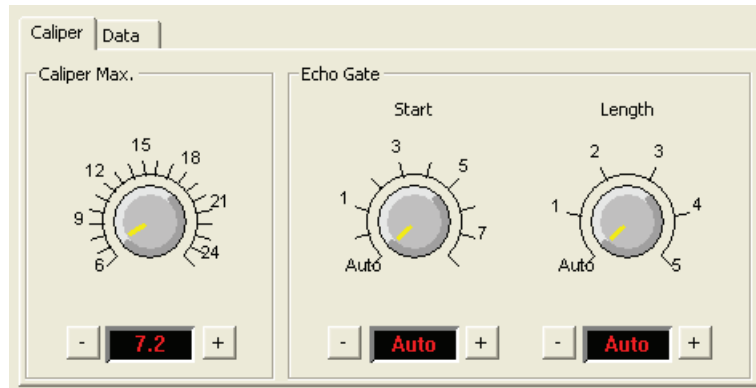
**Figure 4-7** Example of tool settings – Open hole mode

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:**

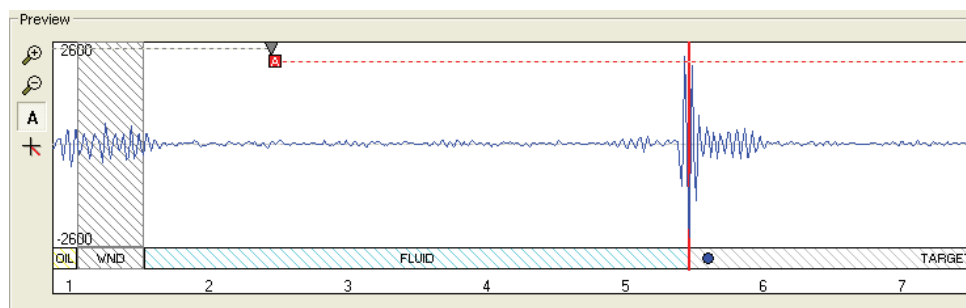


**Figure 4-8** Caliper and Echo Gate settings

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 travel time of the borehole echo.



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



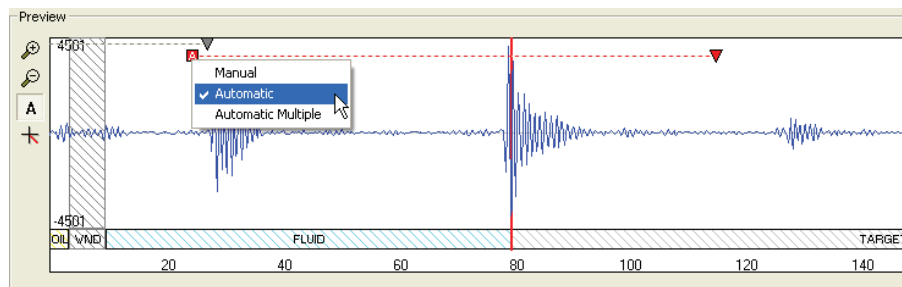
**Figure 4-9** Waveform preview - Echo gate Automatic setting

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**. The Acoustic Window is represented by a grey dashed line while the Echo Gate is shown as red dashed line.

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

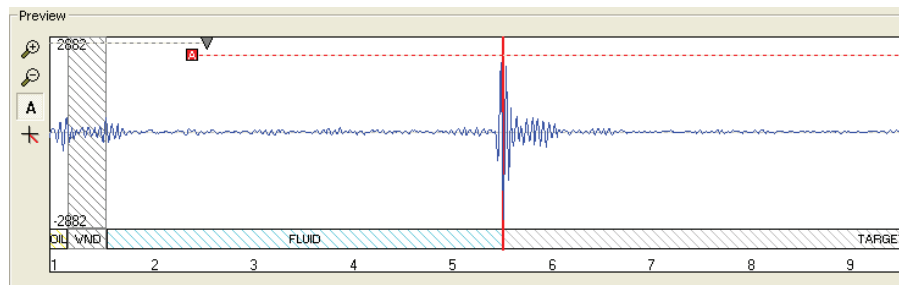
The **Echo Gate “Start”** limit can be determined automatically or adjusted interactively in the preview. Square and triangle symbols indicate whether the limit of the “**Start**” gate is automatically set (square symbol - ) or if the user can adjust the limit with the mouse cursor (triangle - )

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.



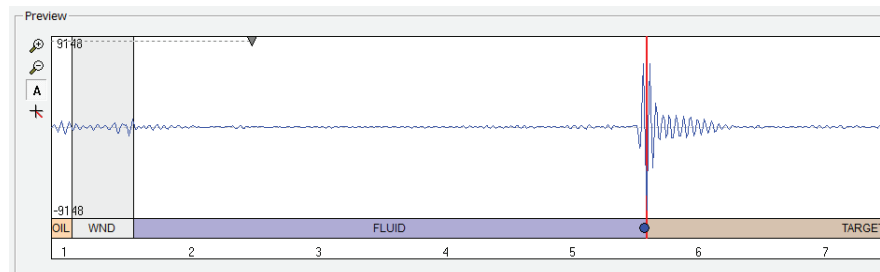
**Figure 4-10** Toggling between Echo Gate detection modes

- **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.



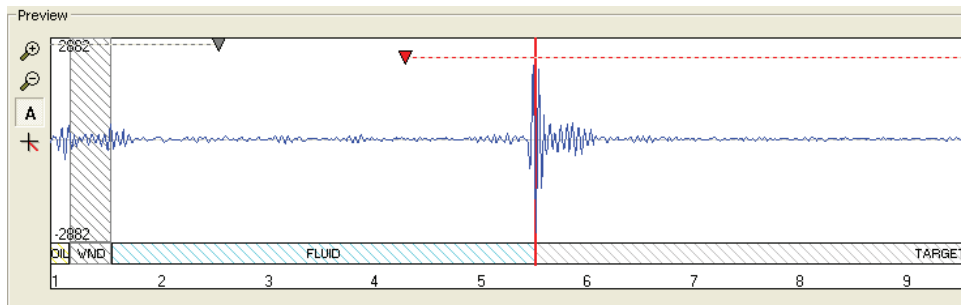
**Figure 4-11** Start gate set in automatic mode

- **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

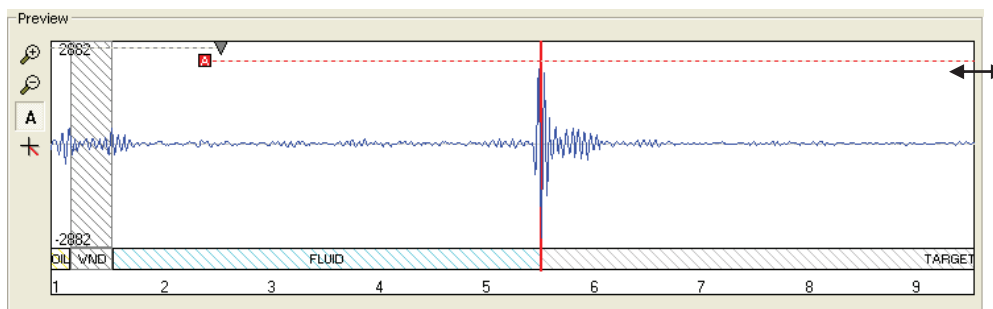
- **Manual:** Manual adjustment of the Echo Gate start time is useful to exclude noise with amplitudes higher than the formation signal (e.g. exclude the reflection from the inside of a PVC casing) – (Figure 4-13).



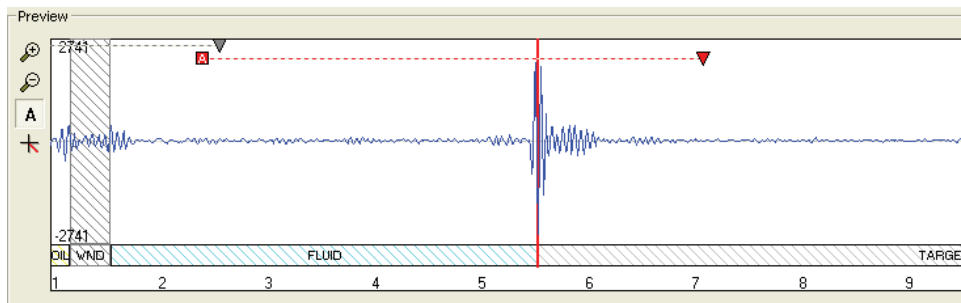
**Figure 4-13** Start gate set in manual mode

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.

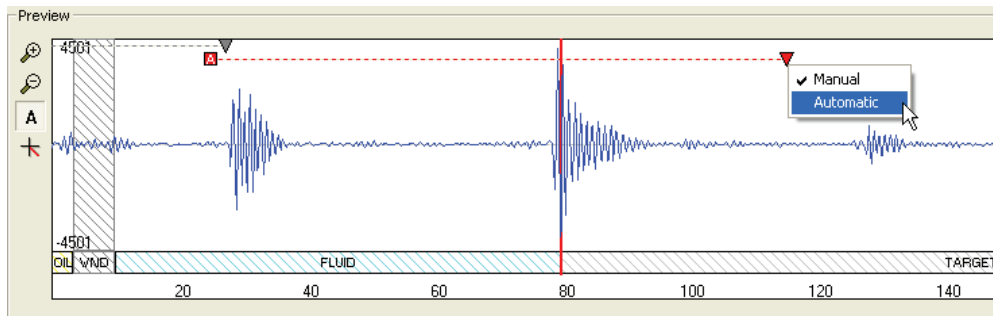


**Figure 4-14** Toggling the Echo Gate Length between automatic and manual mode



**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.



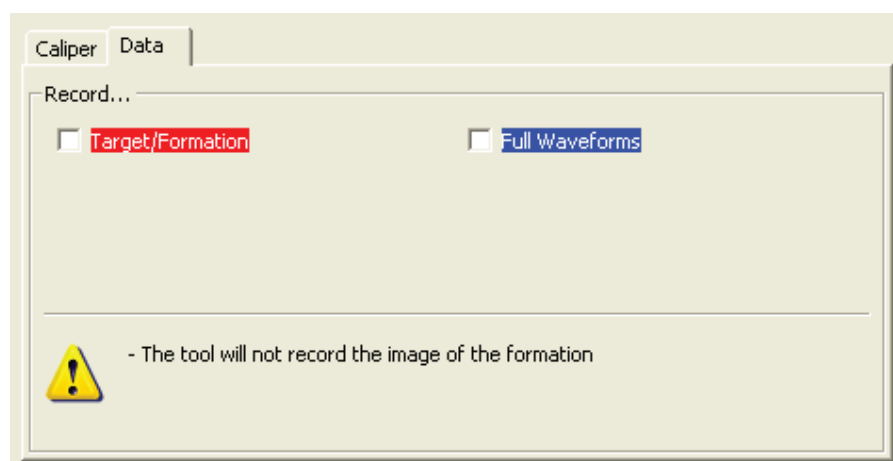
**Figure 4-16** Toggling the Echo Length setting from manual to automatic

#### Data tab:



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

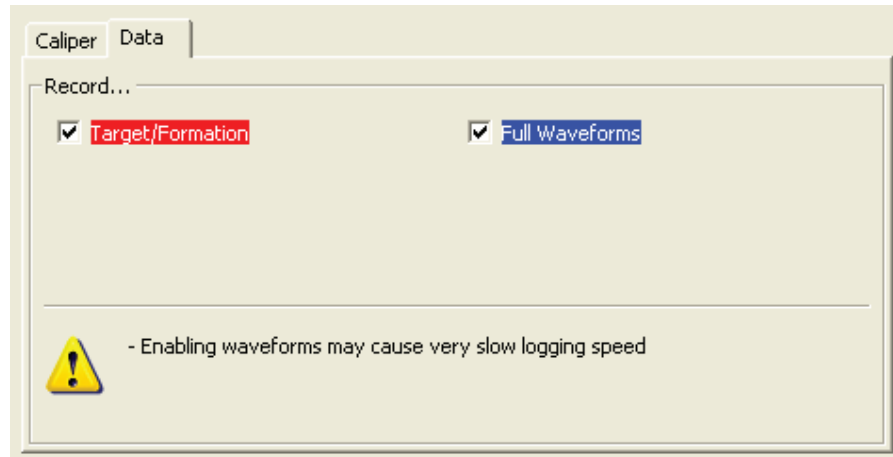
The **“Target/Formation”** record option must always be checked. If unchecked, no acoustic image will be recorded and the warning message below will be displayed.



**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.



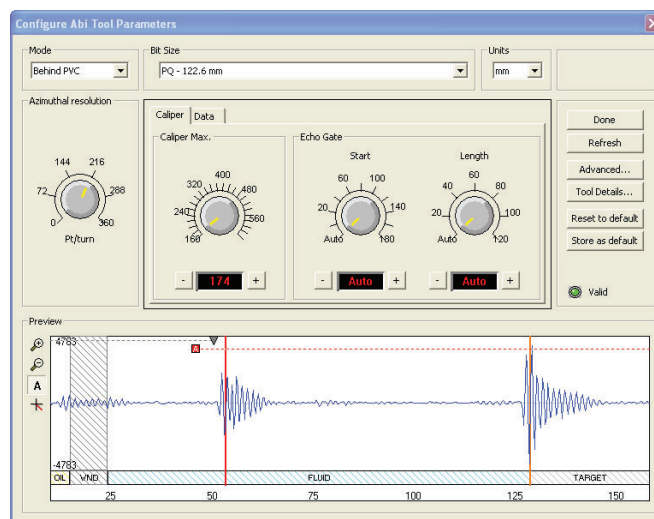
**Figure 4-19** Full Waveforms record option selected

#### 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.

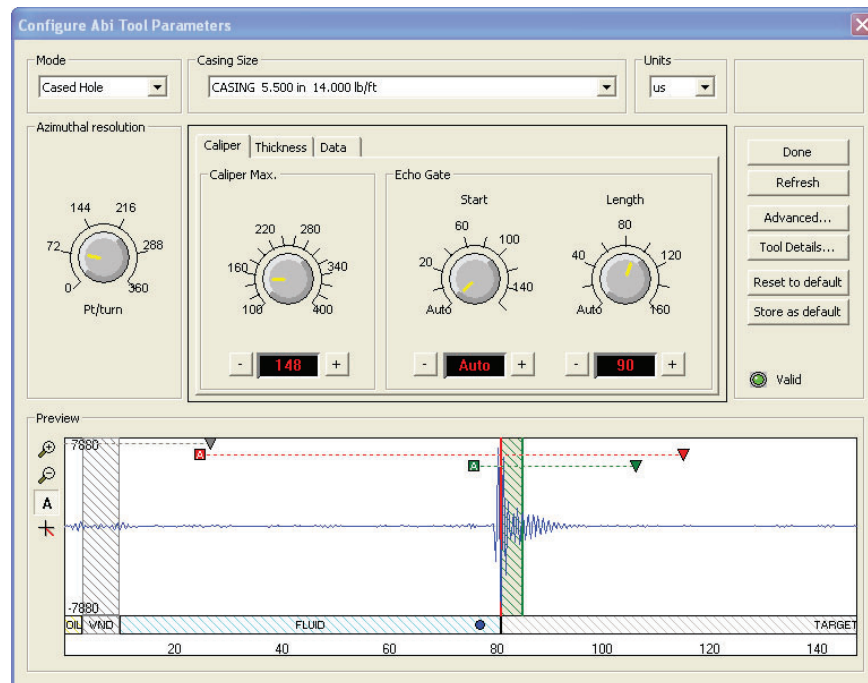


Figure 4-22 Example of Cased hole settings

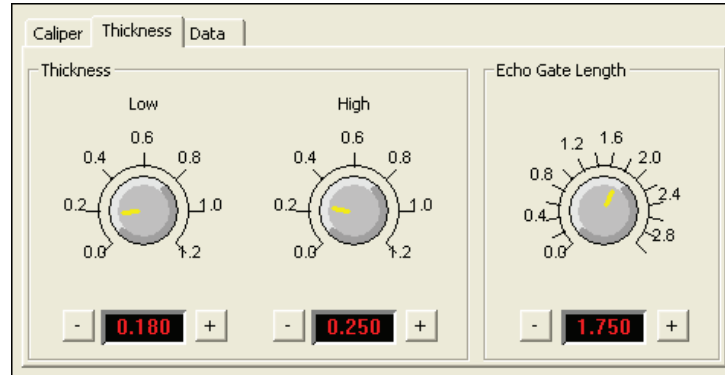
#### Caliper tab:

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.

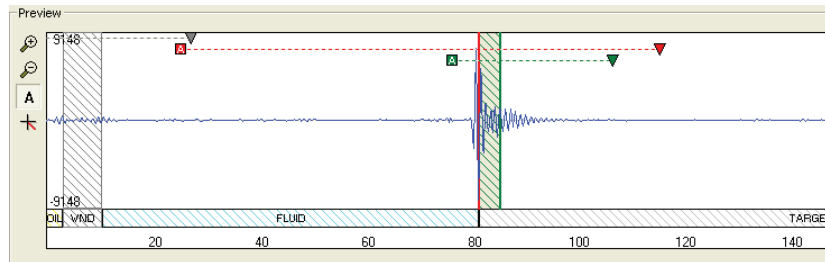
**Thickness tab:**

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.



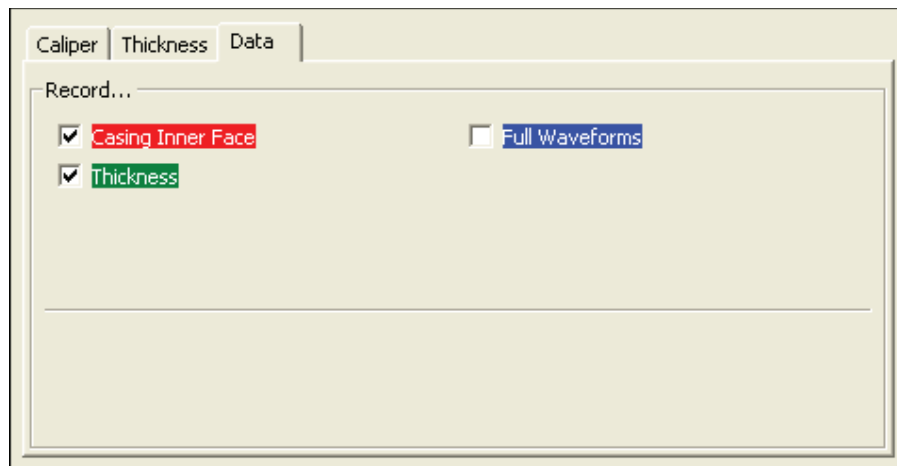
**Figure 4-23** Thickness and Echo Gate Length settings



**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

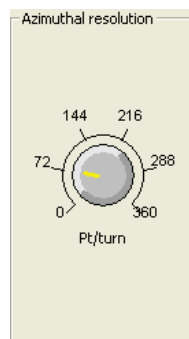
Option is given to the user to record or not the image of the inner face of the steel casing. Recording the casing inner face image is required for further internal caliper processing and for casing thickness/corrosion evaluation.

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.








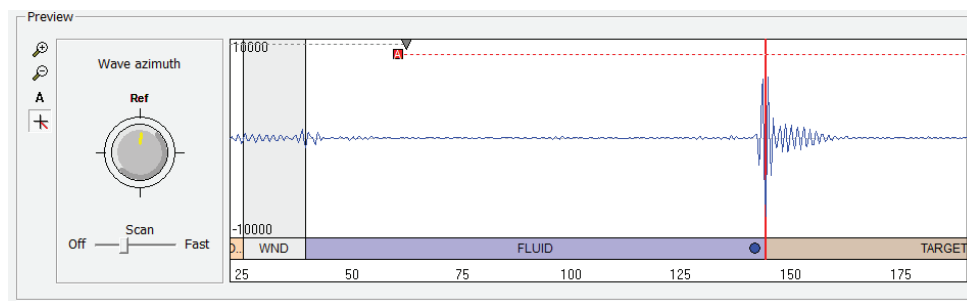
**Figure 4-26** choice of azimuthal resolutions

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  $\mu\text{sec}$  to metric or imperial units. The default values are 1480 m/s for the fluid velocity and 5850 m/s for the steel velocity.

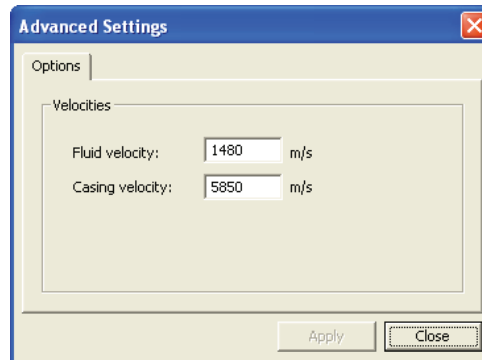


Figure 4-28 Advanced settings

#### 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.

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

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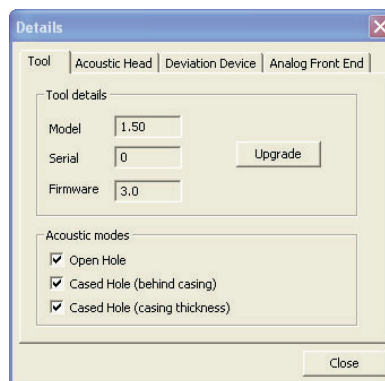
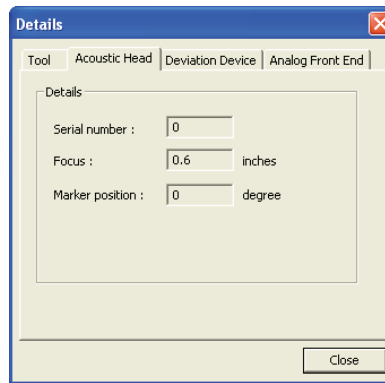
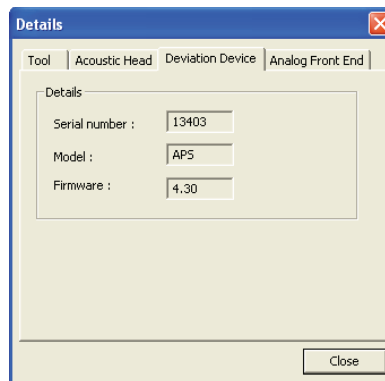


Figure 4-29 Tool details



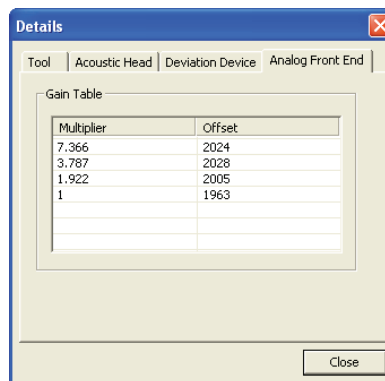
The 'Details' dialog box has four tabs: 'Tool', 'Acoustic Head', 'Deviation Device', and 'Analog Front End'. The 'Acoustic Head' tab is selected. The 'Details' section contains three input fields: 'Serial number' with value '0', 'Focus' with value '0.6' and unit 'inches', and 'Marker position' with value '0' and unit 'degree'. A 'Close' button is at the bottom right.

**Figure 4-30** Acoustic head details



The 'Details' dialog box has four tabs: 'Tool', 'Acoustic Head', 'Deviation Device', and 'Analog Front End'. The 'Deviation Device' tab is selected. The 'Details' section contains three input fields: 'Serial number' with value '13403', 'Model' with value 'AP5', and 'Firmware' with value '4.30'. A 'Close' button is at the bottom right.

**Figure 4-31** Deviation sensor details



The 'Details' dialog box has four tabs: 'Tool', 'Acoustic Head', 'Deviation Device', and 'Analog Front End'. The 'Analog Front End' tab is selected. The 'Gain Table' section contains a table with two columns: 'Multiplier' and 'Offset'.

| Multiplier | Offset |
|------------|--------|
| 7.366      | 2024   |
| 3.787      | 2028   |
| 1.922      | 2005   |
| 1          | 1963   |
|            |        |
|            |        |

A 'Close' button is at the bottom right.

**Figure 4-32** Analog Front End

## 4.6 Recorded Parameters and Browsers

### 4.6.1 Recorded parameters

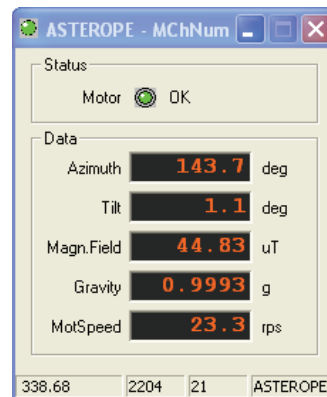
The following data channels are recorded by the tool:

|                                     |  |
|-------------------------------------|--|
| TravelTime (1 <sup>st</sup> echo):  | Two Way Traveltime 1 <sup>st</sup> echo - $\mu$ sec                  |
| Amplitude (1 <sup>st</sup> echo):   | Amplitude 1 <sup>st</sup> echo (NM = North Magnetic, HS = High Side) |
| TravelTime2 (2 <sup>nd</sup> echo): | Two Way Traveltime 2 <sup>nd</sup> echo - $\mu$ sec                  |
| Amplitude2 (2 <sup>nd</sup> echo):  | Amplitude 2 <sup>nd</sup> echo (NM = North Magnetic, HS = High Side) |
| ThicknessTTime:                     | Two Way Traveltime within casing - $\mu$ sec                         |
| 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 - $\mu$ T                    |
| Gravity:                            | Absolute value of the Earth gravity – g                              |
| Orientation:                        | Orientation diagnostic code  |
|                                     |  |
| WndTime:                            | Two way traveltime of acoustic window reflection – $\mu$ sec         |
| 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

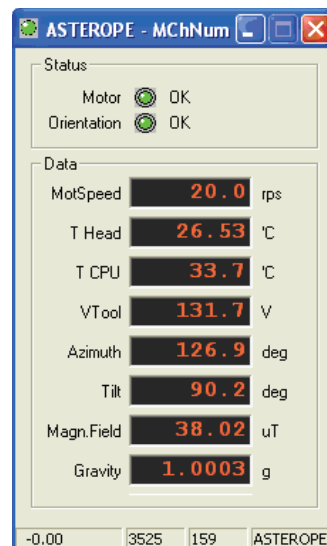
Figure 4-33 and 4-34 show typical examples of the numerical values displayed in the MChNum browser window during logging.



**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 - $\mu$ T |
| 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.

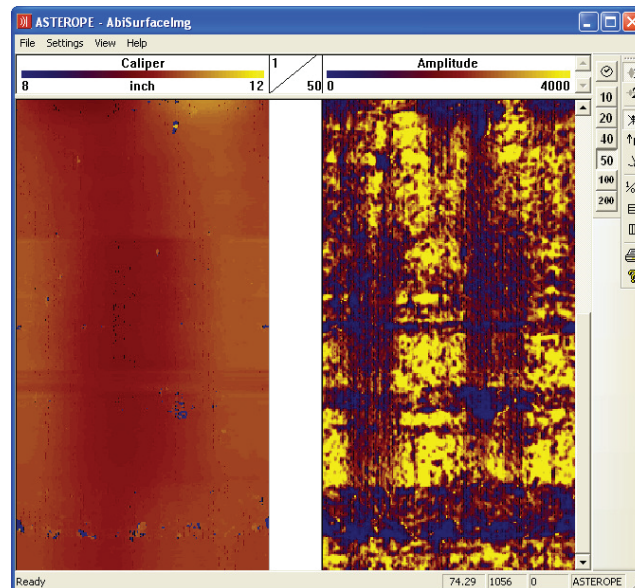


**Figure 4-34** Multi Channel Browser for Numerical Data (MChNum) displaying additional channels

### 4.6.3 Surface Image Browser Window (AbiSurfacelmg)

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.

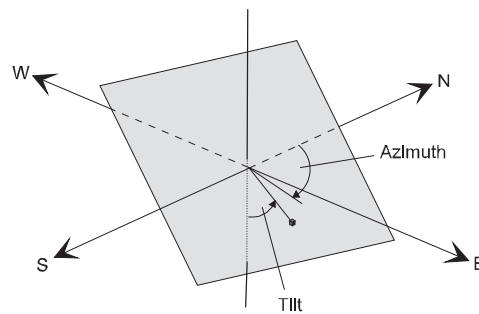
#### Echo selection :

-  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).



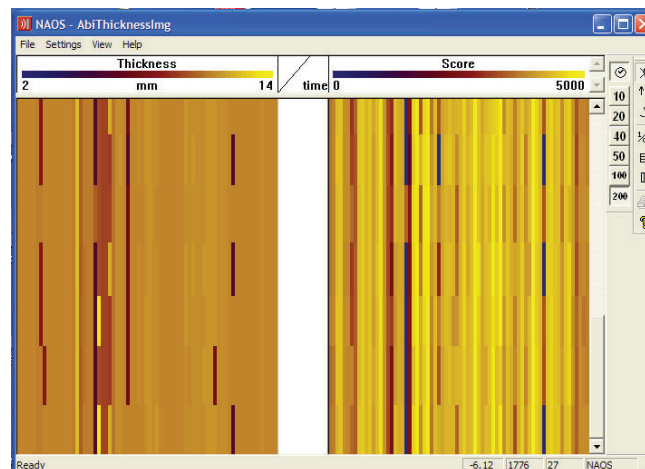
**Figure 4-36** Orientation to Magnetic North

#### 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.*

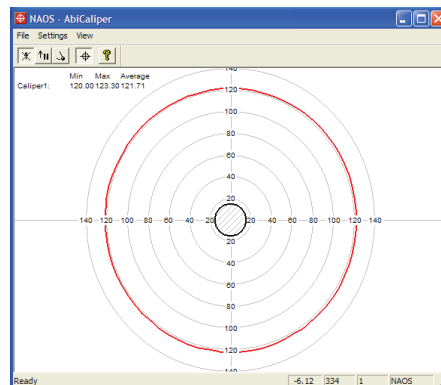
*The red circle is the cross section of the acoustic caliper corresponding to the main reflector detected by the system (borehole wall or inner surface of a casing).*

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**

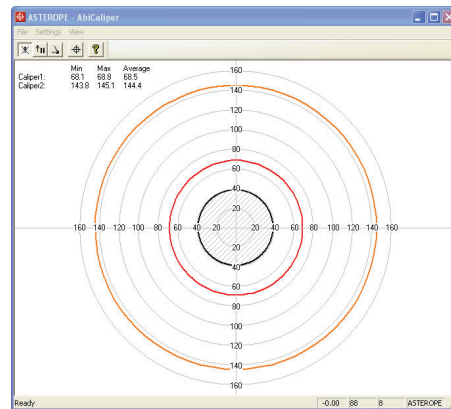
#### Caliper browser – Behind PVC mode

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.

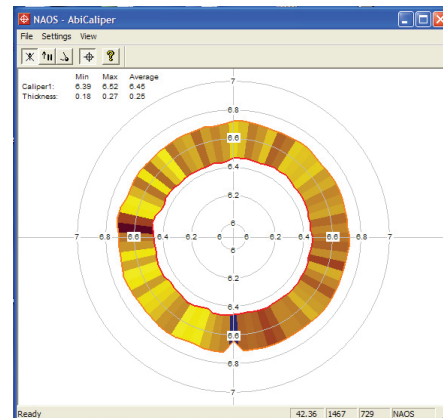


**Figure 4-39** ABI Caliper – Behind PVC Mode

### 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.



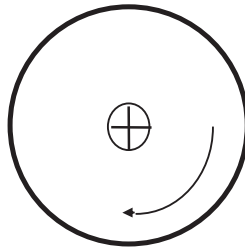
**Figure 4-40** ABI Caliper – Cased Hole Mode

## 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<sup>3</sup> on the acoustic window may check mirror rotation. In time mode, record the 2 finger traces shown<sup>4</sup> 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  $0^\circ \pm 1^\circ$ . 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  $\pm 1.5^\circ$  and a deviation of the tilt less than the limit  $\pm 0.5^\circ$ .

<sup>3</sup> Wet your fingers first for a better coupling

<sup>4</sup> Adjust the amplitude scale to enhance the finger traces

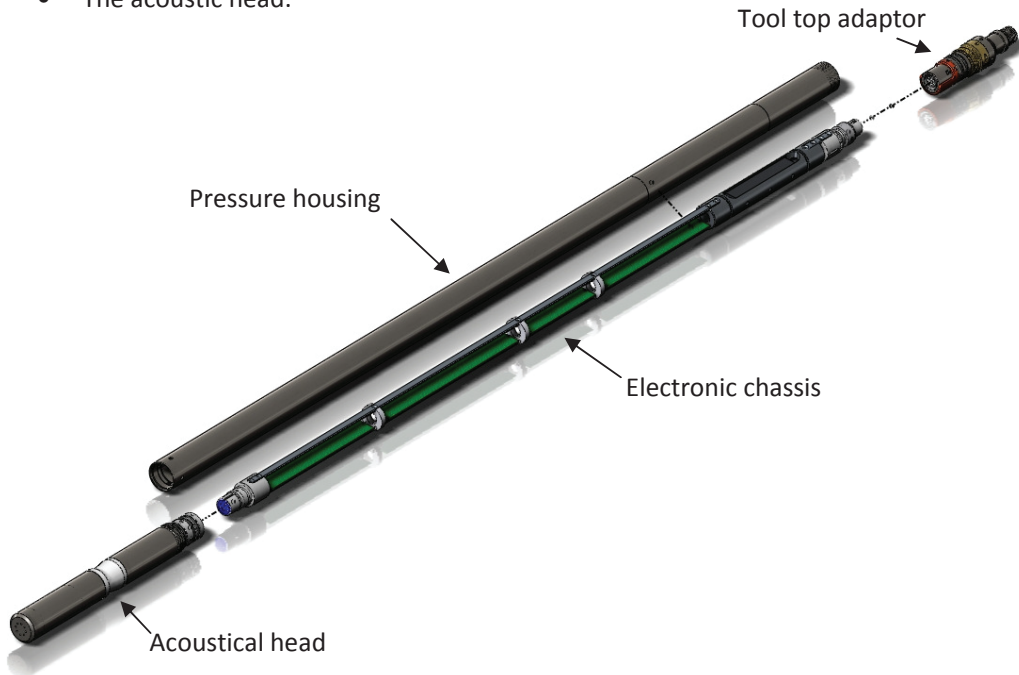
## 6 Maintenance

**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

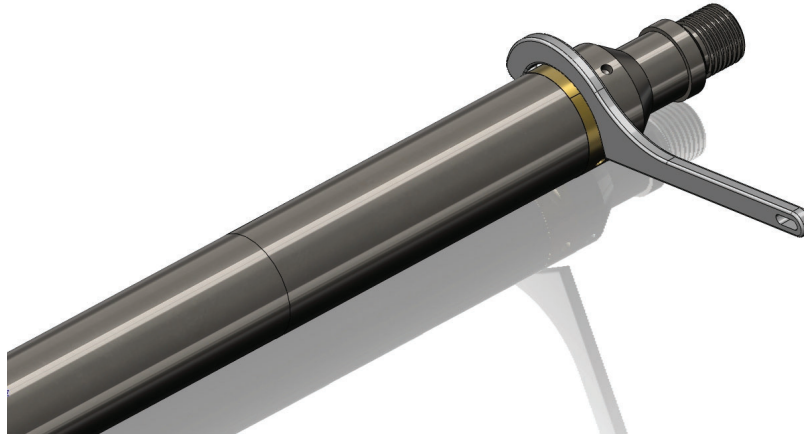
Should it become necessary to open the tool, the tool parts must be separated in the following sequence:

1. Remove the tool top adaptor
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)*

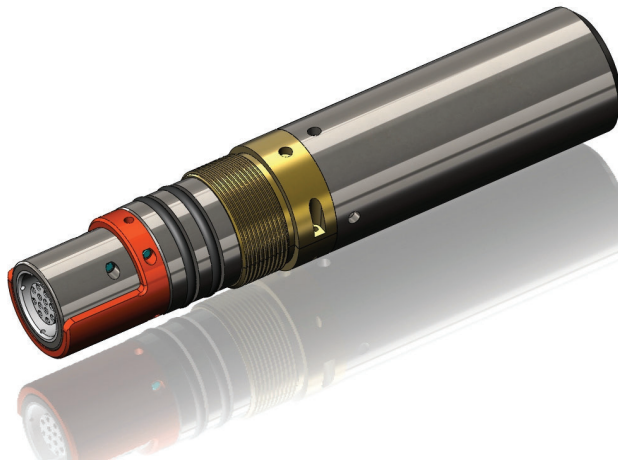


**Figure 6-3** QL40-GO4 Tool top adaptor





**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.

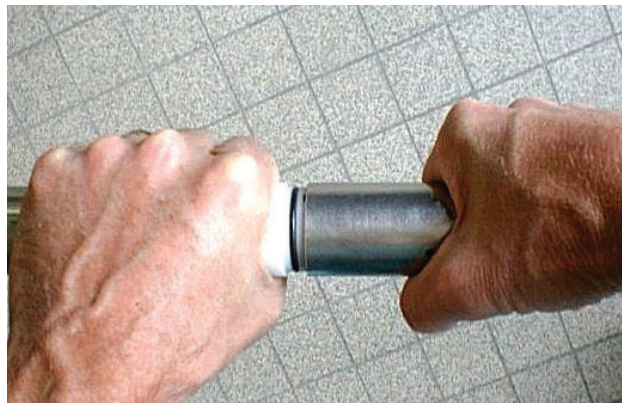
When removing the cover, it is important to **hold the nylon mirror section only**, which is locked integrally with the main tool, while unscrewing the cover. Wrenches must **NOT** be used (Figure 6-7 and Figure 6-8).

---

**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).

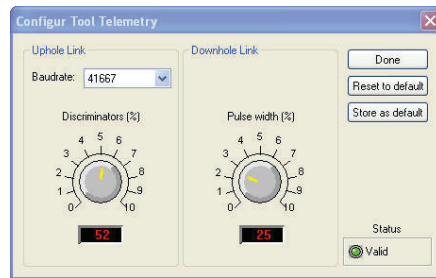


Figure 6-9 Tool communication settings - ALTLog

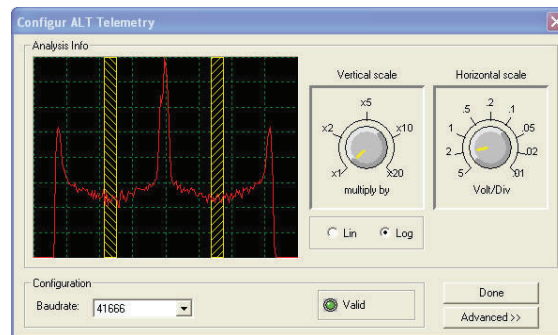


Figure 6-10 Tool communication settings - Matrix

**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).

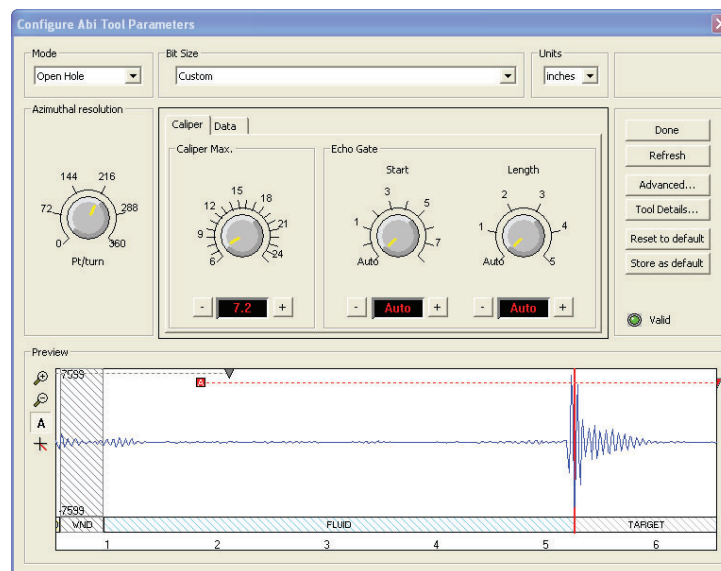
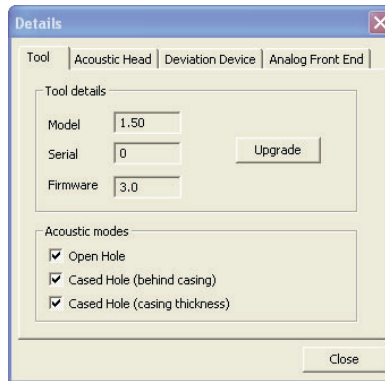


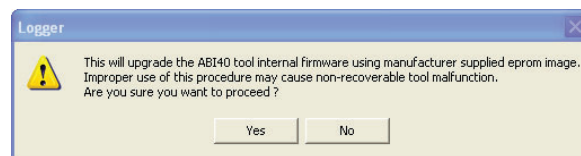
Figure 6-11 Tool settings dialog box

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).



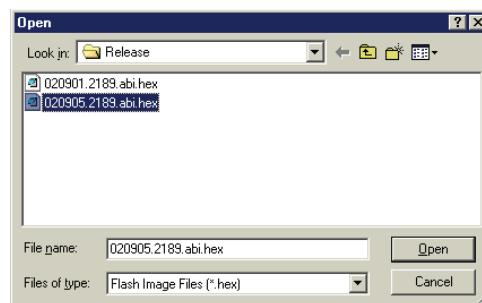
**Figure 6-12** Tool Details dialog box

2. The following message will appear (Figure 6-13). Click **Yes** to validate your choice.



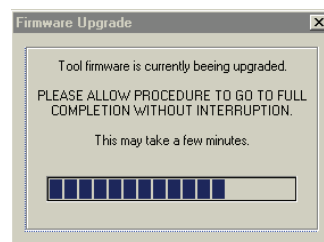
**Figure 6-13** Warning Message during firmware upload

3. Select and open the appropriate **.hex** file provided (Figure 6-14). The upgrade will start.



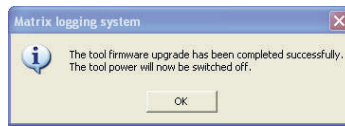
**Figure 6-14** Select firmware upgrade

4. During the upgrade procedure, the following message is displayed:



**Figure 6-15** Firmware upgrade progress window

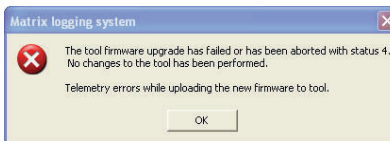
5. Once the upgrade has been successfully completed (Figure 6-16), click on **OK** to turn off the tool.



**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   |
|---|---|
| <i>Tool not listed in Tool panel drop down list.</i>                              | <ul style="list-style-type: none"> <li>- Do you have a configuration file?</li> <li>- Has the configuration file been copied into the .../Tools folder (refer to MATRIX or ALTLog manual about details of the directory structure)?</li> </ul>  |
| <i>Tool configuration error message when powering on the tool.</i>                | <ul style="list-style-type: none"> <li>- Check all connections.</li> <li>- 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).</li> </ul>   |
| <i>Tool panel - No current.</i>   | <ul style="list-style-type: none"> <li>- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system.</li> <li>- Verify cable head integrity.</li> <li>- Verify voltage output at the cable head (it should be 120V).</li> </ul>  |
| <i>Tool panel - Too much current (red area).</i>                                  | <p><b>! Immediately switch off the tool !</b></p> <ul style="list-style-type: none"> <li>- Possible short-circuit (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity.</li> <li>- 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.</li> <li>- If the above shows no issues, use test cable provided by ALT to verify tool functionality.</li> <li>- If the problem still occurs, please contact service centre.</li> </ul> |
| <i>Telemetry panel - status shows red.</i>  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4).</li> <li>- If problem cannot be resolved contact support@alt.lu .</li> </ul>   |
| <i>Telemetry panel - memory buffer shows 100%.</i>                                | <ul style="list-style-type: none"> <li>- 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.</li> </ul>   |
| <i>Telemetry panel – bandwidth usage shows 100%.<br/>(Overrun error message.)</i> | <ul style="list-style-type: none"> <li>- Set the baudrate to highest value allowed by your wireline configuration.</li> <li>- Reduce logging speed, decrease azimuthal resolution and/or increase vertical sample step.</li> </ul>  |
| <i>Telemetry panel - large number of errors.</i>                                  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4).</li> <li>- Check bandwidth usage and telemetry error status.</li> </ul>  |



| Observation   | To Do  |
|---|--|
| <i>Permanent No Sync message and red led status in MChNum browser.</i><br><br><i>Motor stalled and increase of current drawn by the tool.</i> | <b>! Immediately switch off the tool !</b><br><br>- Stepper motor and mirror synchronization issue. Contact ALT for Acoustic Head service. |
| <i>WellCADimport : acoustic images not imported</i>   | - Check your WellCAD version (please refer to 1.3 Technical Specifications chapter).   |
| <i>WellCAD import : Magnetic North and High Side orientation options not available</i>  | - 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.

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).

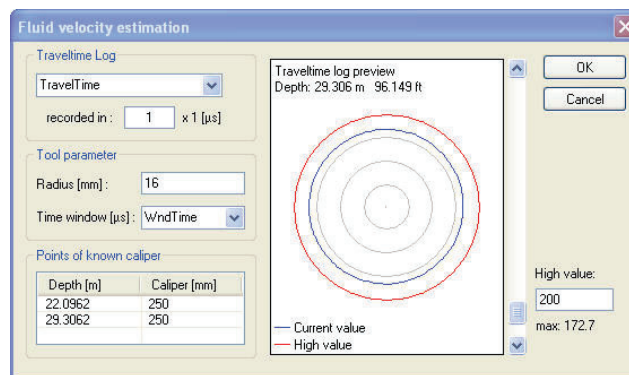


Figure 8-1 Fluid velocity estimation dialog box

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  $\mu\text{s}$ . (Older tools measured in 0.1  $\mu\text{s}$ . You can find out by double left clicking on the log title of the TravelTime log. The unit should show  $\mu\text{s}$ . If no unit is shown the measurement was made on 0.1  $\mu\text{s}$ .)
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).

- 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].

| Depth [m] | Caliper [mm] |
|-----------|--------------|
| 22.0962   | 250          |
| 29.3062   | 250          |

- Try to set at 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:

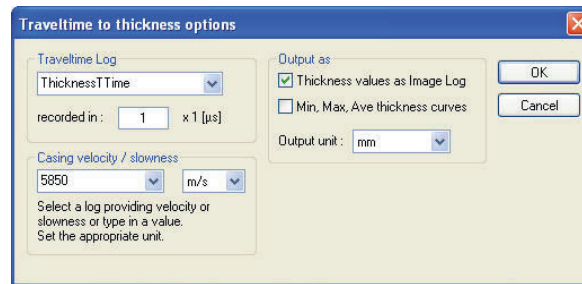
- Select the **Calculate Caliper** process from the **Process > Image Module > Image Logs** menu. The options dialog box (Figure 8-2) will open.

Figure 8-2 Travelttime to caliper conversion dialog box

- Select the TravelTime log from the corresponding drop down list in the dialog box.
- 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  $\mu\text{s}$ . (Older tools measured in 0.1  $\mu\text{s}$ . You can find out by double left clicking on the log title of the TravelTime log. The unit should show  $\mu\text{s}$ . If no unit is shown the measurement was made on 0.1  $\mu\text{s}$ .)
- 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.
- 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).
- 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.
- 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.
- Click on **OK** to close the dialog box and 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  $\mu\text{s}$ . (Older tools measured in 0.01  $\mu\text{s}$ . You can find out by double left clicking on the log title of the ThicknessTTime log. The unit should show  $\mu\text{s}$ . If no unit is shown the measurement was made on 0.01  $\mu\text{s}$ .)
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](mailto:support@alt.lu) for further details.

### **9.2 Technical drawings**

The following technical drawings are available on request:

- 19" Rack connection diagram.
- Wiring Diagram.

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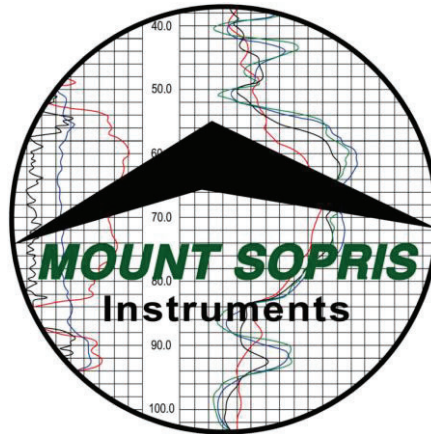
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# QL40-GAM QL40 - GAMMA PROBE

(Preliminary)



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May 6, 2010



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## General Information

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### 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   | Aarmor           |
| Center pin in probe top | Tool power positive | Center conductor |

GOI-4 conductor

|                   |                     |               |
|-------------------|---------------------|---------------|
| Pin               | Signal              | Origin        |
| Probe top housing | Tool power ground   | Aarmor        |
| 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

Nal (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**

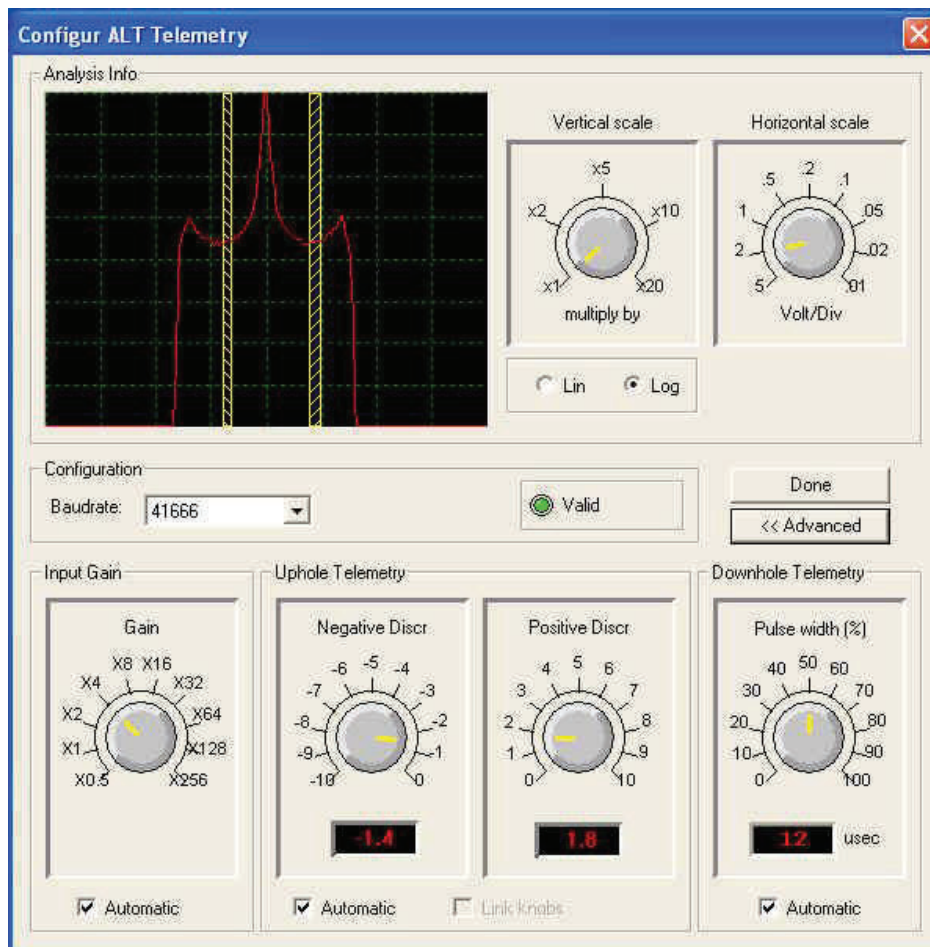
In order to operate the sub as a stand-alone probe, a top and bottom sub must be connected to the sub. Remove the probe-top thread protector from the top sub then thread the top sub onto the cablehead of the winch assembly. Inspect the o-ring on the cablehead for cuts or abrasions before each use to 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:

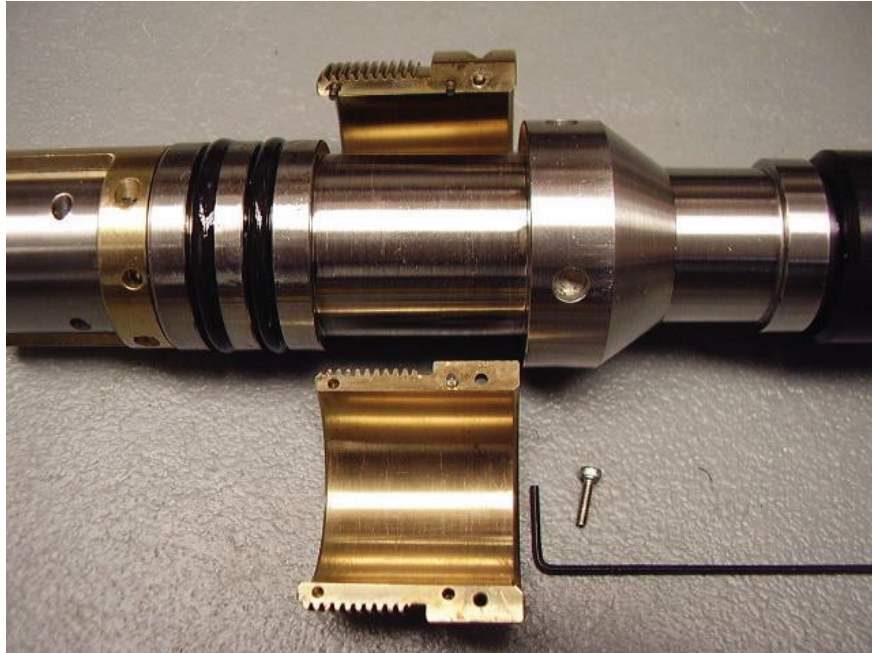
Unscrew and remove the two M2x8 socket head cap screws and separate the two halves. Four guide pins align the two ring halves and tend to hold them together after the screws are removed. To pry the halves apart you can use a pair of spanner wrenches inserted into the wrench holes on opposite sides of 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.

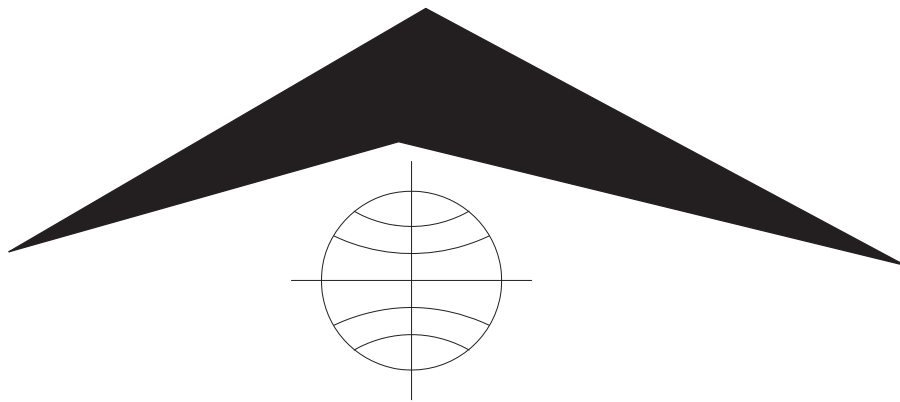
The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter 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

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### 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.

$$\text{Ohms law: } r = E / I$$

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**

Nal (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.

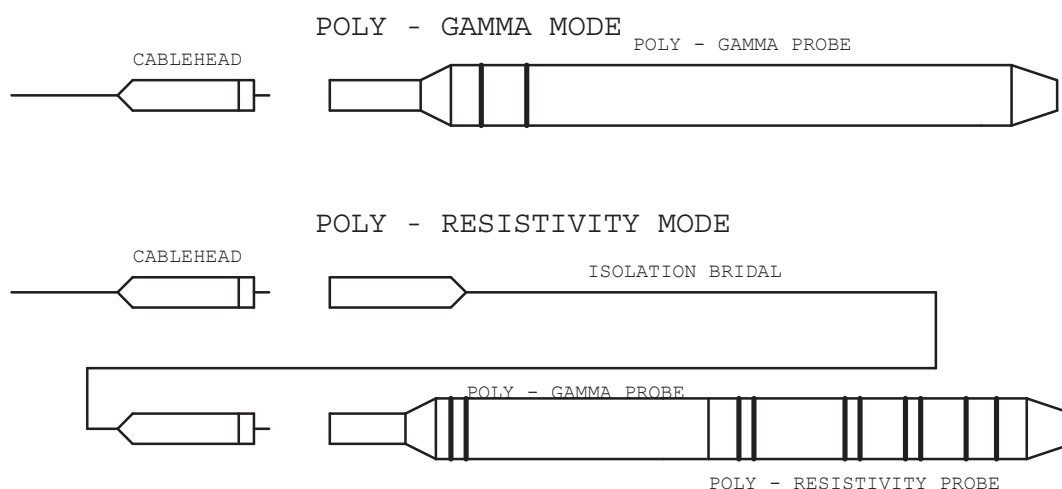
#### Poly - Gamma stand alone mode

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.

#### CONNECTIONS FOR POLY - GAMMA



## 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

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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

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### 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.

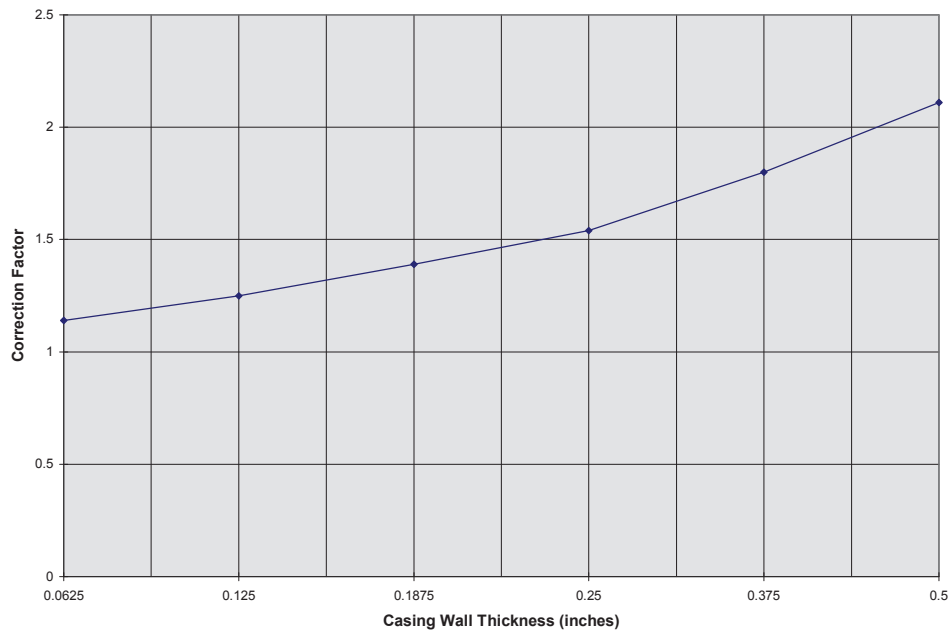
The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter 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.

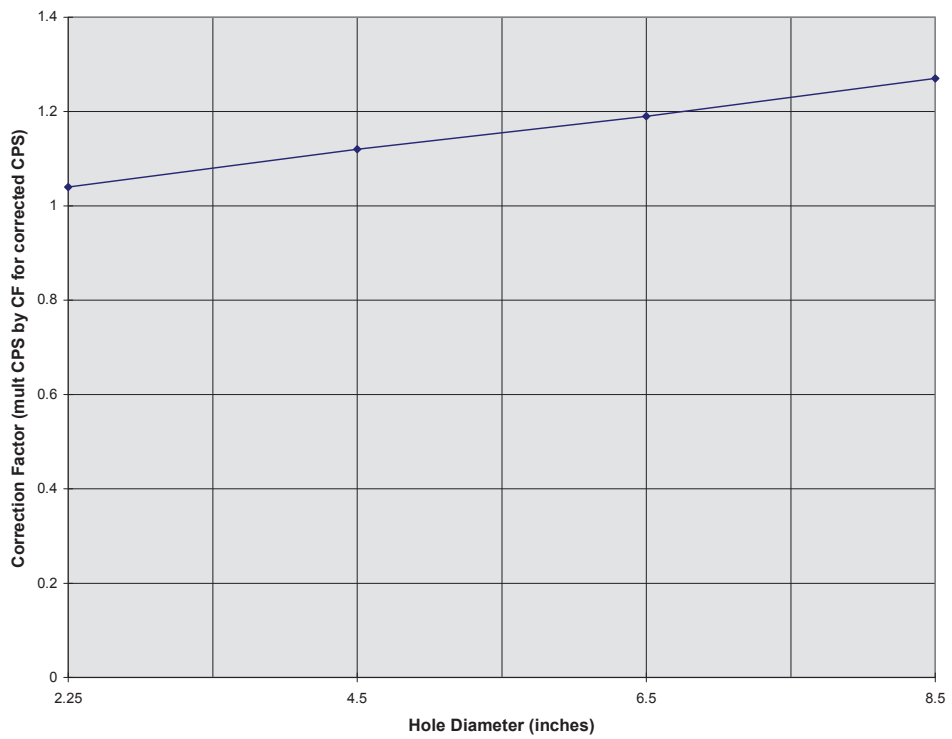


## Casing and Water Factors for 2PGA-1000

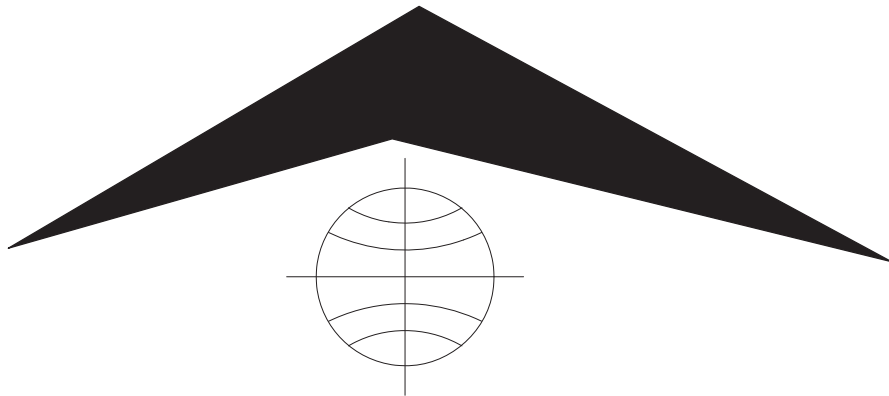
Casing Factors (4.5 inch hole) for 2PGA-1000 Polygamma s/n 2416



Water Factors for 2PGA-1000 PolyGamma s/n 2416



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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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, Mississauga, Ontario, Canada.

## General Information

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### 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

| <u>Ring</u> | <u>Signal</u>          | <u>Origin</u>         |
|-------------|------------------------|-----------------------|
| 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                  | Aarmor                |
| 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

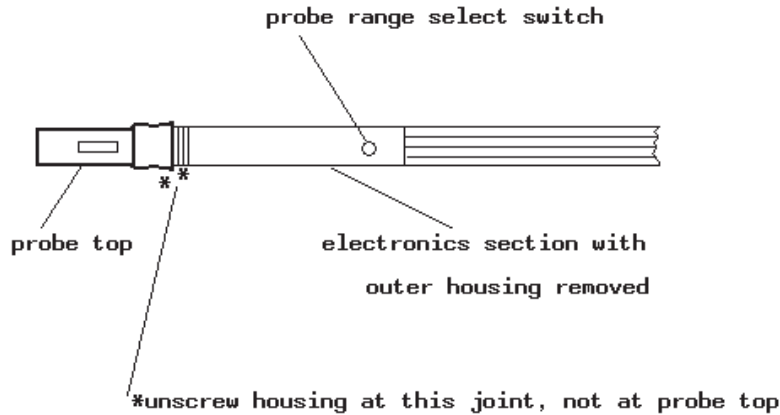


Figure 1 Probe Range Select Switch

## 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

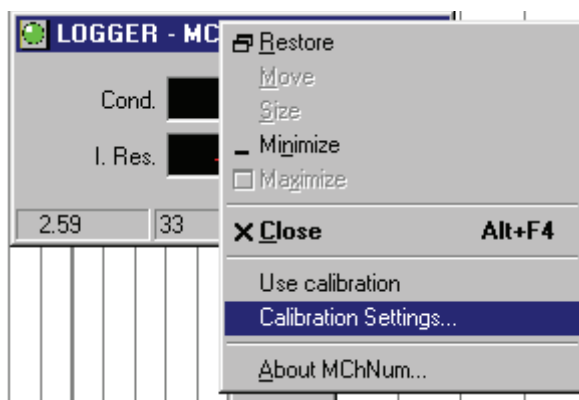
Although the instrument is set to read correctly at the factory, it is necessary to check the instrument calibration before logging the tool. For highest accuracy, it is recommended to perform these calibrations prior to logging. Allow the probe to operate under power for at least 10 minutes, in borehole 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. 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.

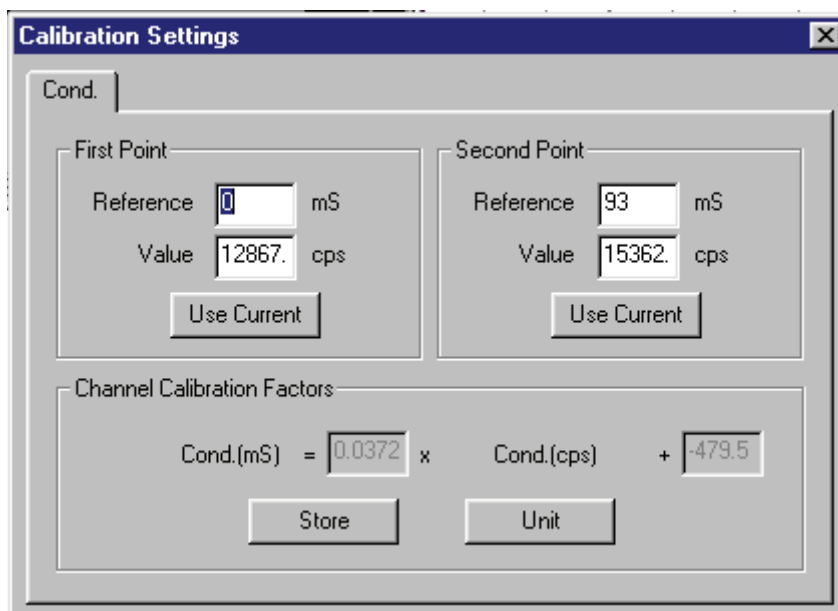
### MSLog calibration

- 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.

The screenshot shows the Logshell calibration screen. At the top, it displays 'ACQSBC 1.32', 'Depth: 0.00', 'Speed: 0.00', 'D:0.10', 'T: 5', and 'DpS: 10'. Below this is a table with columns: Depth (Feet), Speed (Ft/Min), Conduct (mS/m), Mag\_Sus (Pcnt), and Resist (Ohm-m). The values are: Depth 0.0, Speed 0.0, Conduct -2721.06, Mag\_Sus 400.62, Resist -0.37. Below the table is another table with columns: Chan, LeftInp, InValue, RgtInp, LftOut, RgtOut, TK, FL, DepShf, LfPlot, RgPlot, and PlotPerCt. The rows are: DD00 (195, 0, 570, 0, 1000, 0, 0, 0, 0, 100, 0.0%), DS00 (0, 0.0, 1000, 0, 1000, 0, 0, 0, 0, 100, 0.0%), CS32 (11869, 0, 12785, 0, 210, 21, 22, 0, 0, 500, -544.2%), CS33 (12299, 0, 11992, 0, 10, 27, 22, 0, 0, 500, 80.1%), and IU03 (1, -2721, 1000, 1000, 1, 22, 22, 0, 0, 500, -0.1%). At the bottom, it shows 'COMMENT: \*\*', 'OUT:Not Yet Assigned', '(OFF) Recs:0', 'Bytes:0', 'Free:55784K', 'Q: 0', 'L: 1', and '0903: Left Cal Input Uall195'.

| Chan | LeftInp | InValue | RgtInp | LftOut | RgtOut | TK | FL | DepShf | LfPlot | RgPlot | PlotPerCt |
|------|---------|---------|--------|--------|--------|----|----|--------|--------|--------|-----------|
| DD00 | 195     | 0       | 570    | 0      | 1000   | 0  | 0  | 0      | 0      | 100    | 0.0%      |
| DS00 | 0       | 0.0     | 1000   | 0      | 1000   | 0  | 0  | 0      | 0      | 100    | 0.0%      |
| CS32 | 11869   | 0       | 12785  | 0      | 210    | 21 | 22 | 0      | 0      | 500    | -544.2%   |
| CS33 | 12299   | 0       | 11992  | 0      | 10     | 27 | 22 | 0      | 0      | 500    | 80.1%     |
| IU03 | 1       | -2721   | 1000   | 1000   | 1      | 22 | 22 | 0      | 0      | 500    | -0.1%     |

- 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 into 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!

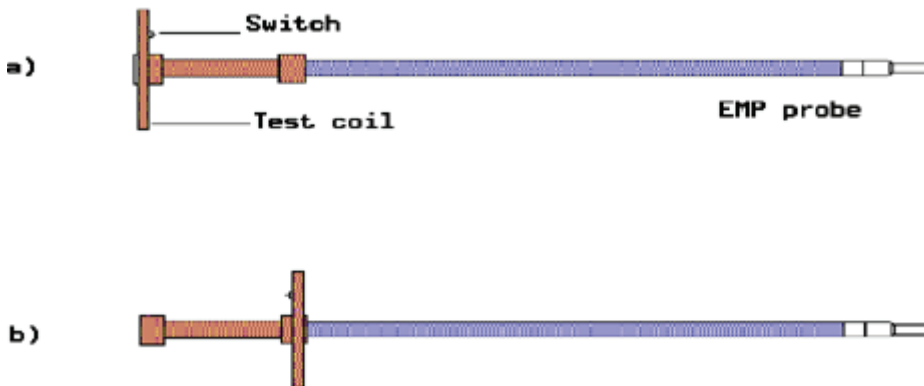


Figure 2 Calibration Set-up with Geonics Test Coil

## Preventive Maintenance

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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.

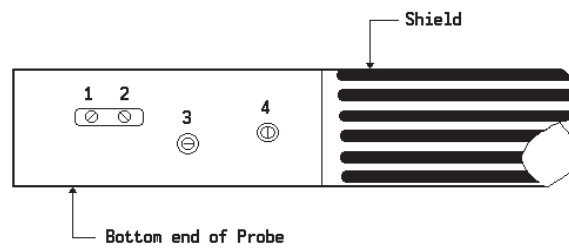


Figure 3 Linearity and Null Adjustment

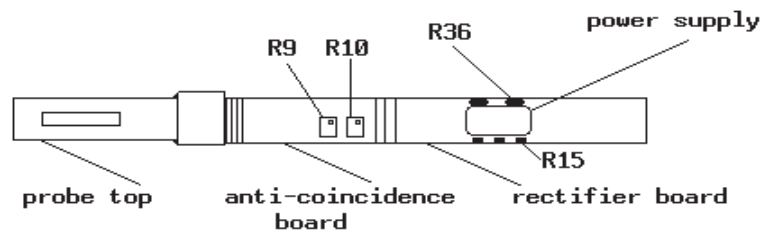


Figure 4 Location of Discrete Components

## 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)

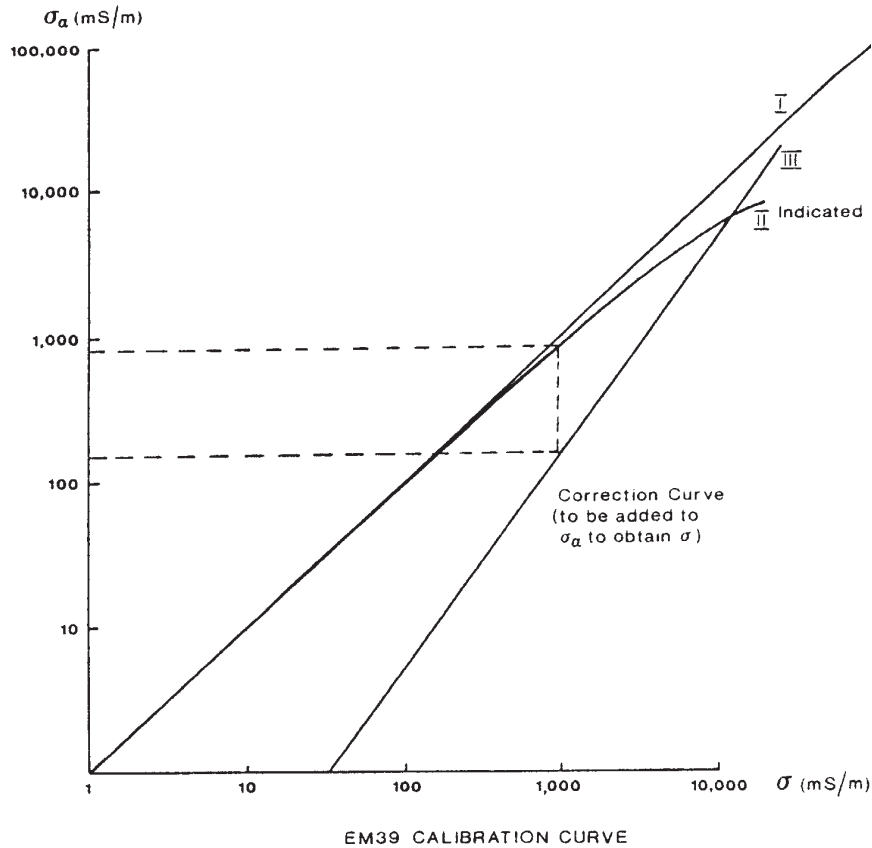


Figure 5 EMP/EM39 Calibration Curve

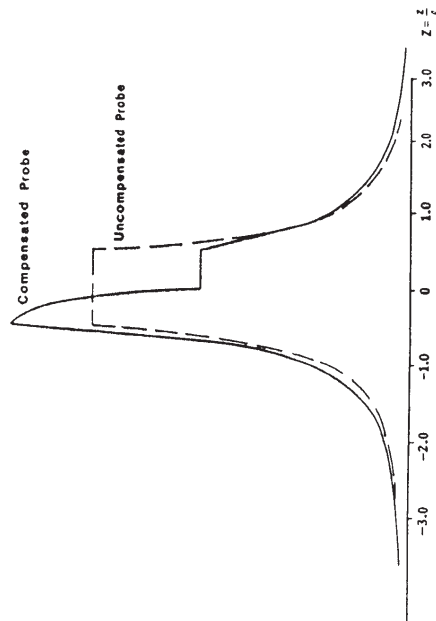
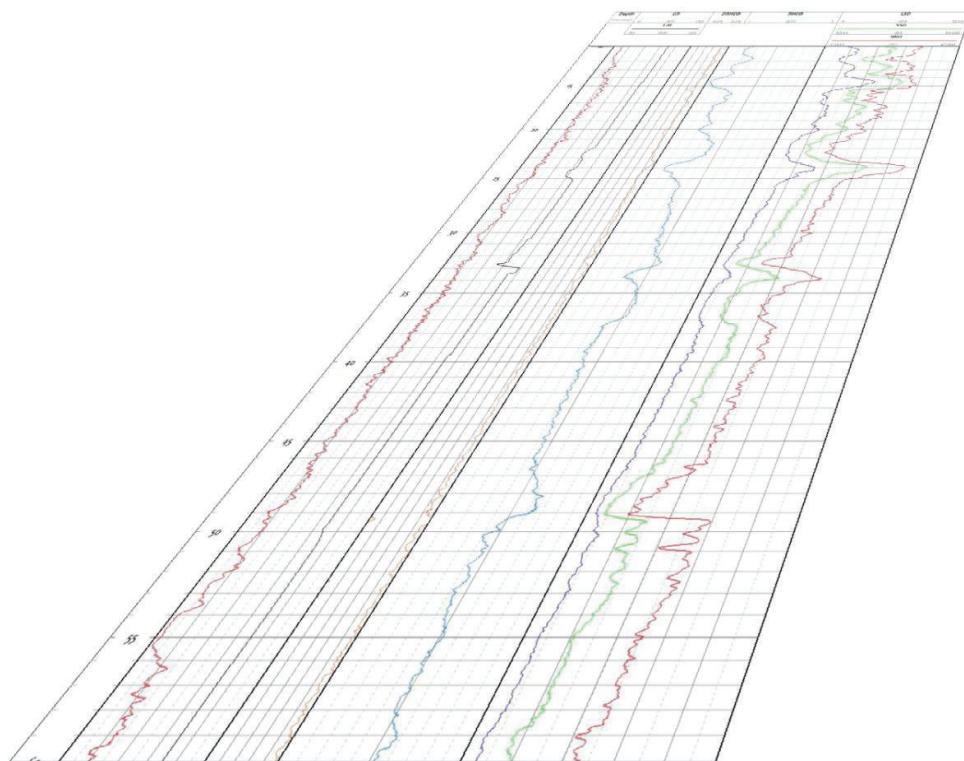


Figure 6 Vertical Response with  $\lambda = 58\text{cm}$

## **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



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## 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.

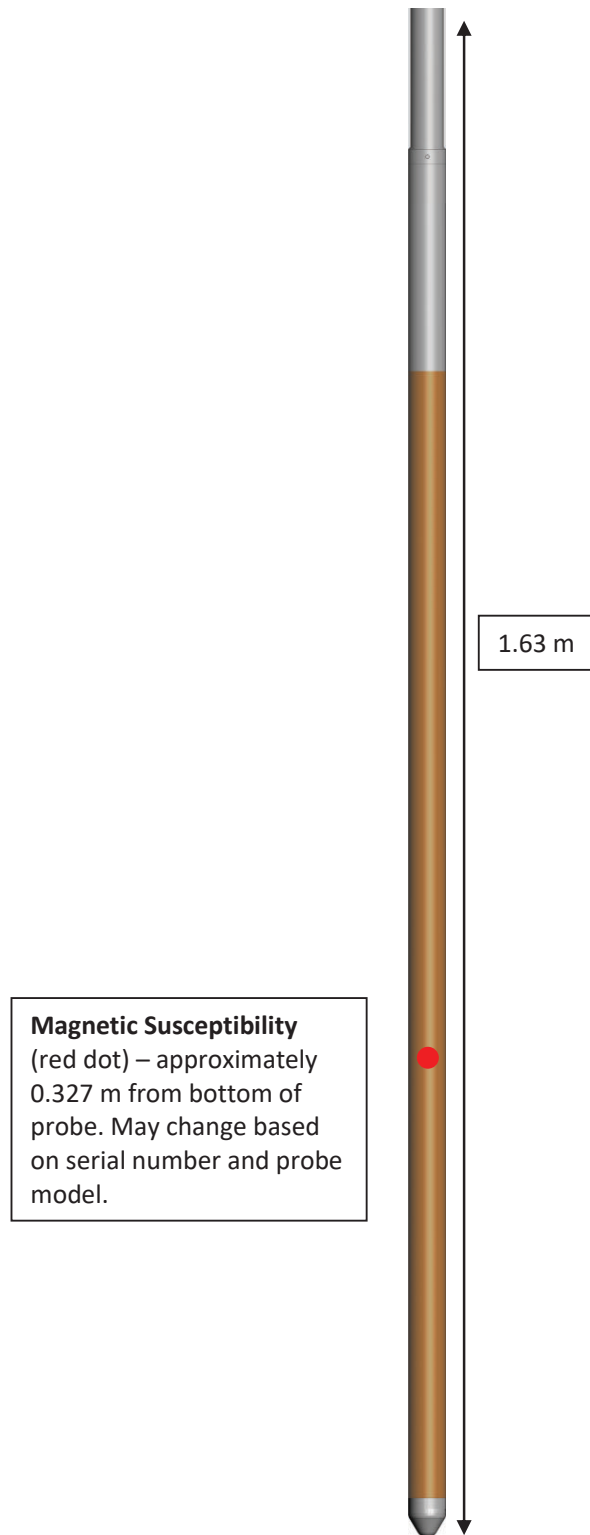
The QL40-HM-453 bottom sub can be operated as a stand-alone probe or can be stacked below inline subs. The stack is completed by adding a Tool Top sub. Varied tool top subs are available. Top subs include an MSI single conductor, GO4 conductor, GOI Single conductor and GO7 conductor. Consult the factory 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<br>Two coil system<br>HMM-453, Four coil system  |
| Intercoil Spacing:              | HM-453, 25 cm<br>HM-453E, 30 cm<br>HMM-453, 25 cm and 30 cm  |
| Operating Frequency:            | 1935 Hz  |
| Estimated Range:                | HM-453, $10^{-5}$ – 0.5 SI<br>HM-453E, $10^{-4}$ – 2 SI<br>HMM-453, $10^{-5}$ – 0.5 SI and $10^{-4}$ – 2 SI<br>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<br>Max 160 VDC<br>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). Anomously 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.

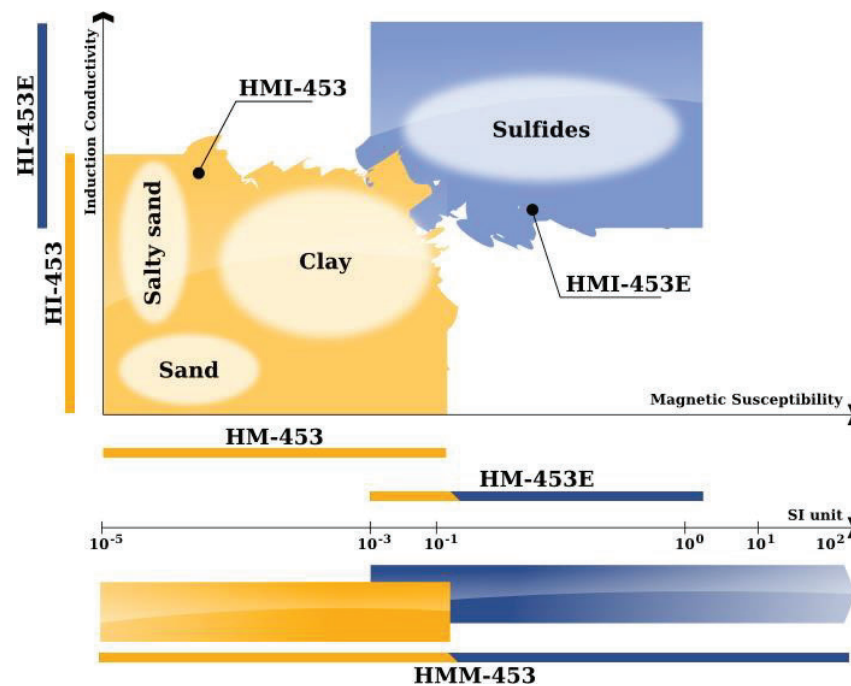


Figure 2-1 Diagram of Mag. Susc. and Induction tools with corresponding ranges of measurement.

### RANGES OF MAGNETIC SUSCEPTIBILITY PROBES

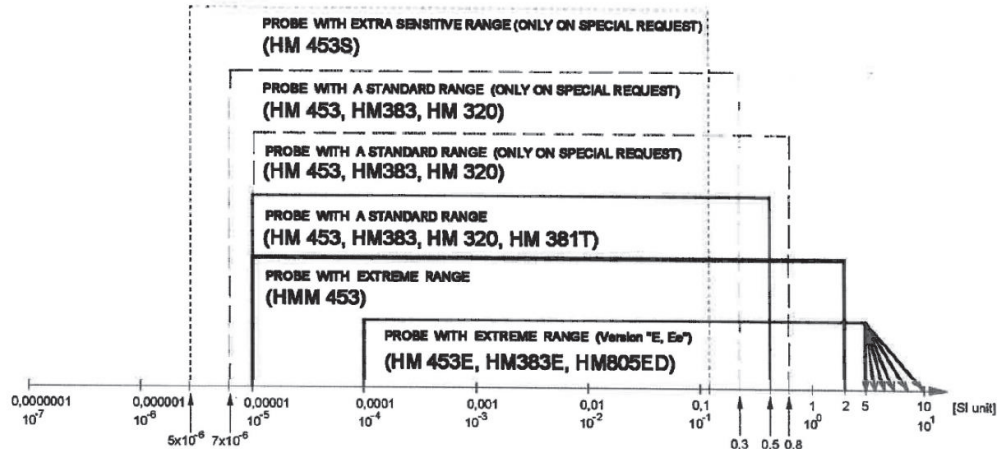


Figure 2-2 Diagram of Mag. Susc. tools with corresponding ranges of measurement.

## 3 QL40 HM 453 Assembly and Set up

**QL** stands for **Quick Link** 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.

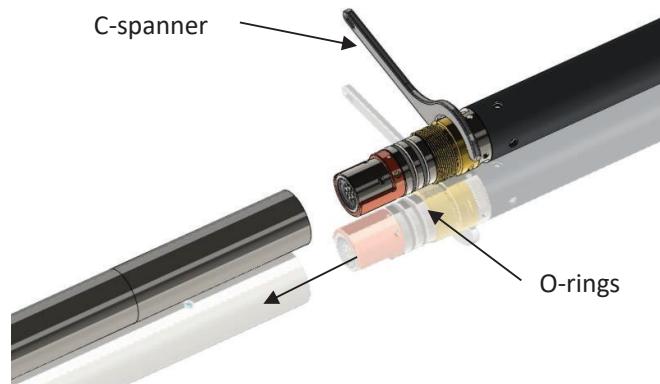
### 3.1 QL40 Tool Stack Assembly

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.

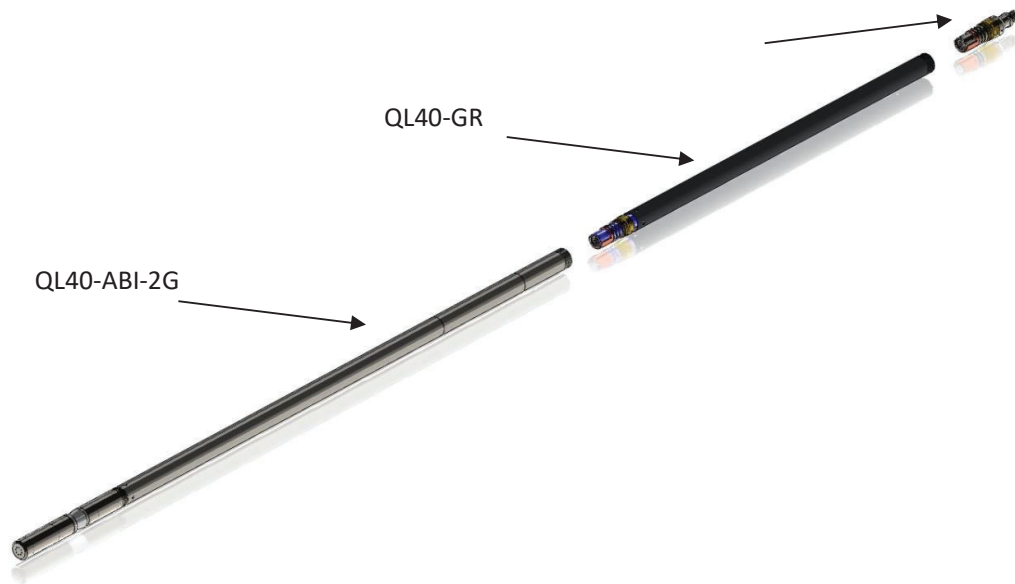
To assemble and disassemble the subs or top, the C-spanner delivered with the tool must be used (**Figure 3-1**). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with a small amount of the silicon grease that was supplied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

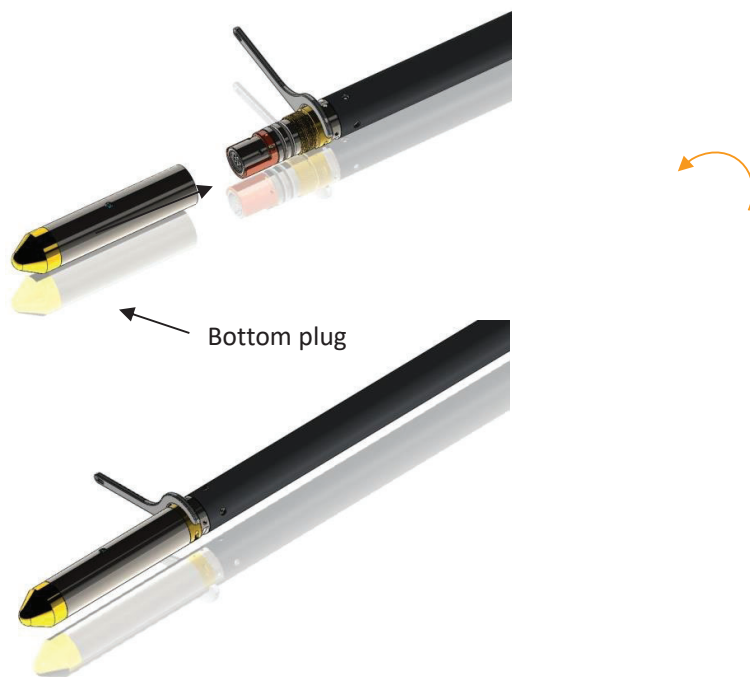
To remove the QL40-ABI-2G televiewer sub from the QL40-GR gamma sub, attach the C-spanner to the thread ring as shown in **Figure 3-3**, unscrew the threaded ring, (counter-clockwise about the tool axis when looking towards the bottom of the tool), and remove the QL40-ABI-2G bottom sub.

Thread ring



**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 threaded 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

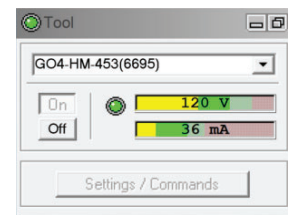
## 4 Operating Procedure

**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**).

☐

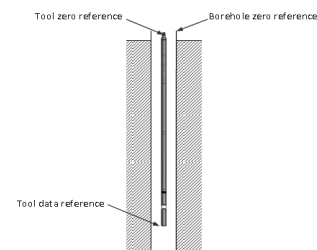
5. ☐ The tool should be allowed to warm-up in the borehole fluid for at least 15 minutes before calibrating, so it is at the borehole temperature. This will provide the most accurate calibrations.

☐

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.



**Figure 4-2** Correct tool positioning when zeroing depth



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).

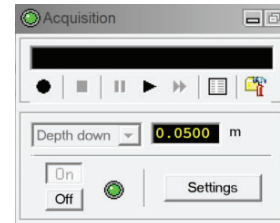


Figure 4-3 Acquisition panel

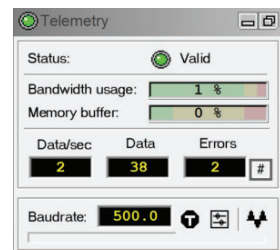
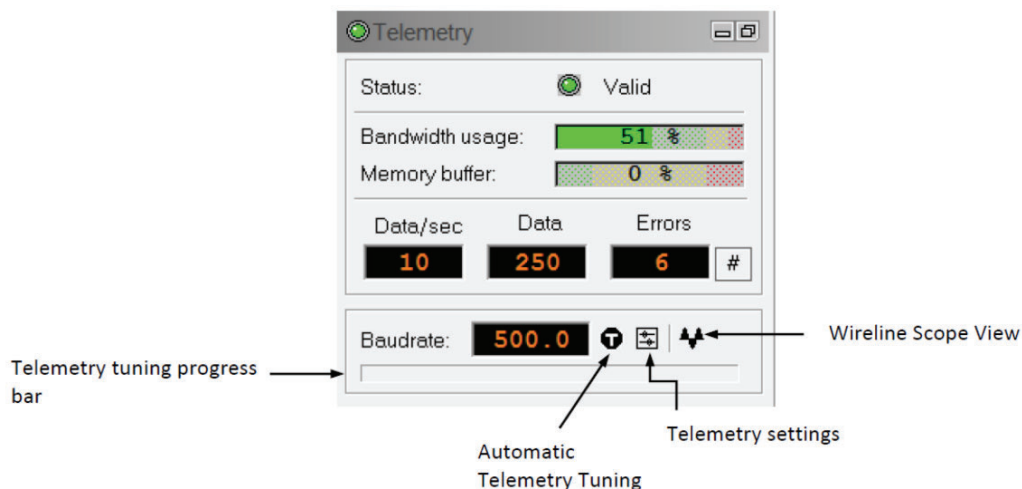


Figure 4-4 Scout Telemetry panel


## 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.

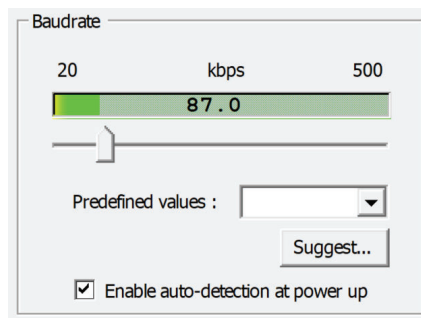



Figure 4-2 Scout baudrate settings

### 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.

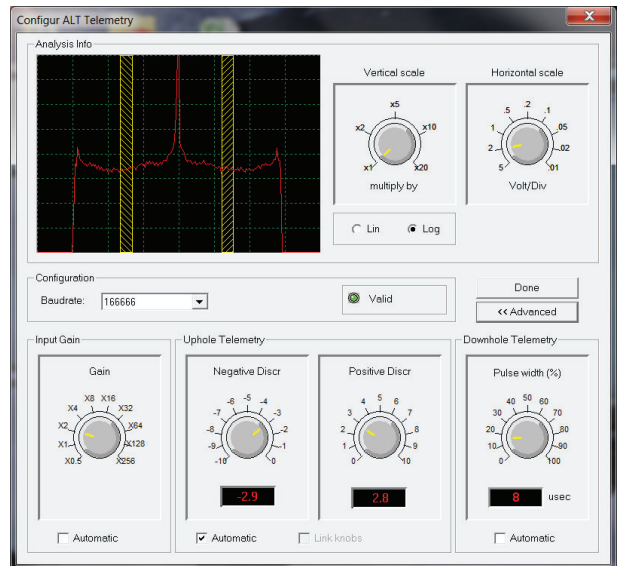
The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **linear / logarithmic** scale buttons.

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

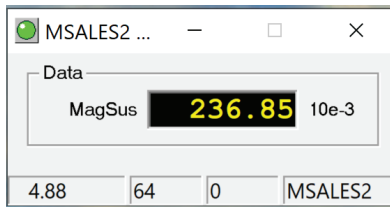
The following channels are recorded by the QL40-HM-453 tool:

|                         |  |
|-------------------------|--|
| <b>Time</b>             | Sampling Time [seconds]                          |
| <b>TCPU</b>             | Temperature (recorded on CPU board) [ degrees C] |
| <b>COUNT</b>            | Magnetic Susceptibility Counts                   |
| <b>MagSus</b>           | Magnetic Susceptibility [ 10e-3 SI Units]        |
| <b>Speed</b>            | Logging Speed in [meters/minute or feet/minute]  |
| <b>ToolPowerVoltage</b> | DC Voltage supplied to the probe [Volts]         |
| <b>ToolPowerCurrent</b> | Electrical Current supplied to the probe [mAmps] |
| <b>Tension</b>          | Wireline Tension [daN]                           |


*Table 1* QL40-HM-453 recorded channels

#### 4.4.2 MChNum Browser

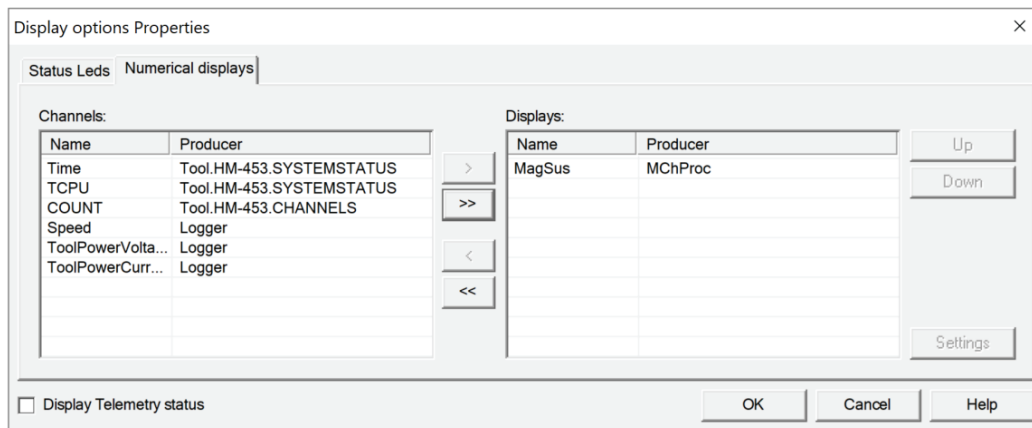
**Figure 4-7** shows a typical example of the numerical value displayed in the MChNum browser window during operation.



**Figure 4-7** MChNum browser window

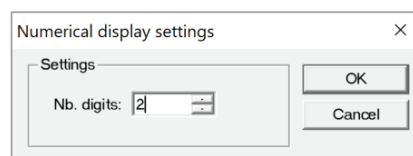
The other parameters listed in **Table 1** can be displayed in real time if required. To do this, click on the MChNum browser green LED  and click on **Display options...** from the menu.

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**).

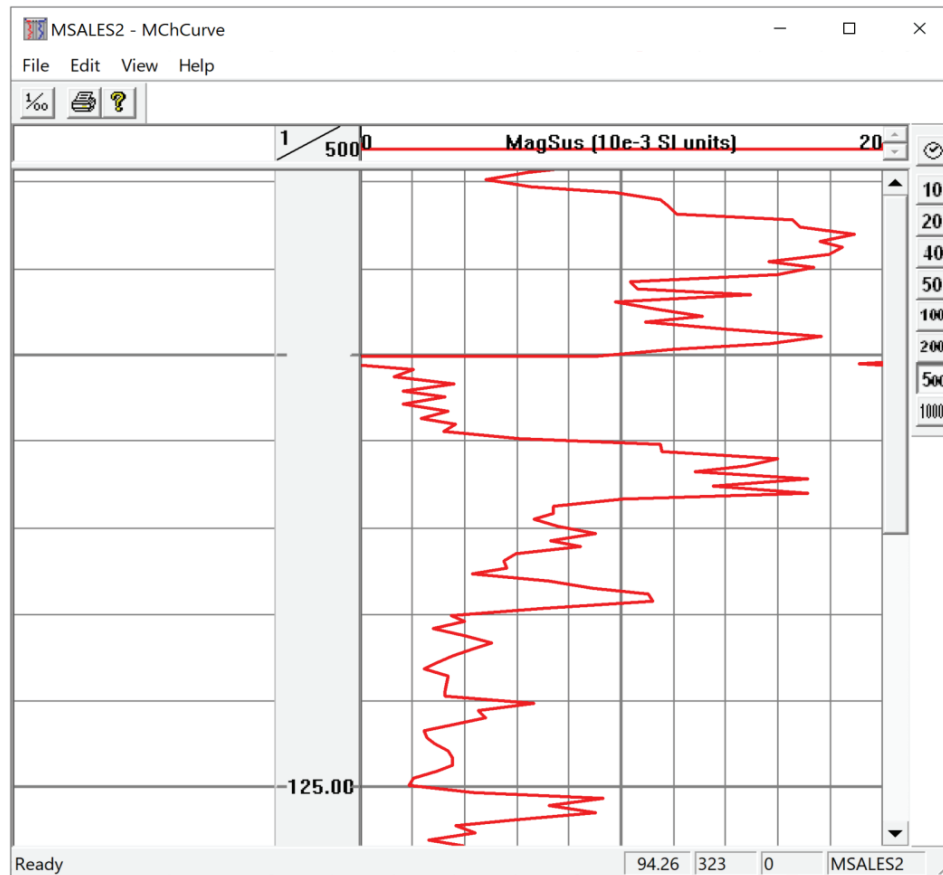


**Figure 4-9** Numerical Display Settings window

#### 4.4.3 MChCurve Browser

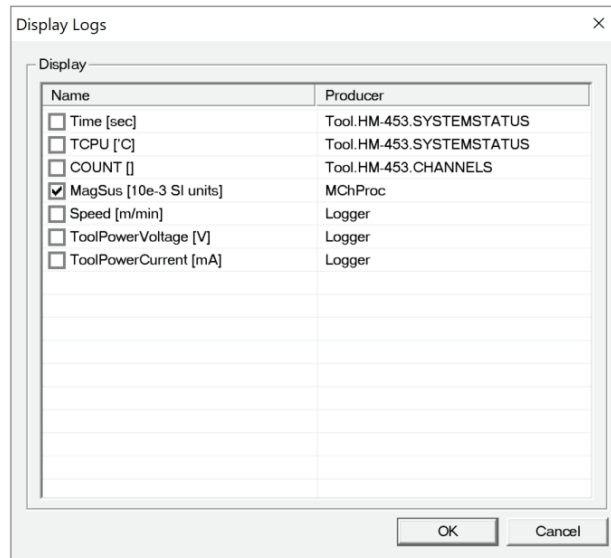
The MChCurve browser (**Figure 4-10**) displays the recorded parameters by means of curves in real time.

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  $5.0 \times 10^{-3}$  SI Units and  $2.4 \times 10^{-3}$  SI Units.



*Figure 4-13 QL40-HM-453 calibration mount and pucks*


If required, two other calibration pucks are available for purchase:  $0.5 \times 10^{-3}$  SI Units and  $2 \times 10^{-1}$  SI Units (see **Appendix**). The QL40-HM-805ED probe comes with 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 in 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).

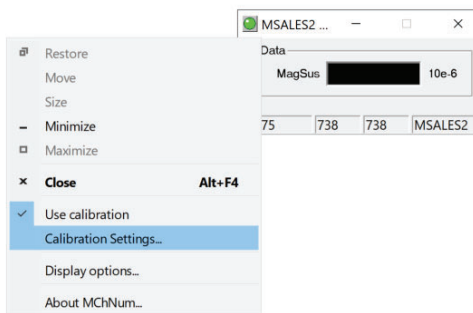


Figure 4-15 Open Calibration Settings window from MChNum



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**.

Calibration Settings

MChProc

MagSus

MagSus

First Point

Reference: 0 10e-6 SI

Value: 398.7395

Sample...

Second Point

Reference: 5000 10e-6 SI

Value: 3556.1623

Sample...

Channel Calibration Factors

MagSus(10e-6 SI) = 1.58357 x MagSus(cps) + -631.432

Compute

Unit

Calibration date: 27/02/18 12:38

☐ Show all channels

Options... Export... Apply Close

**Figure 4-16** Calibration Settings window

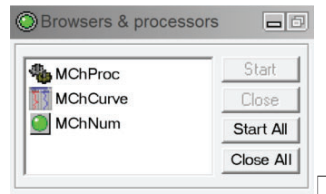
5. ☐ Screw the high calibration puck into the calibration plate.
6. ☐ Slide the calibration plate onto the probe until the calibrator is centered on the red dot (**Figure 4-17**).



**Figure 4-17** QL40-HM-453 with  $5 \times 10^{-3}$  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  $2.4 \times 10^{-3}$  SI puck (**Figure 4-20**). When using both pucks together, you will need to add the reference numbers (e.g.  $5.0 \times 10^{-3}$  SI +  $2.4 \times 10^{-3}$  SI =  $7.4 \times 10^{-3}$  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  $2.4 \times 10^{-3}$  SI and  $5 \times 10^{-3}$  SI calibration pucks in place. □



**Figure 4-20** QL40-HM-453 with  $2.4 \times 10^{-3}$  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.

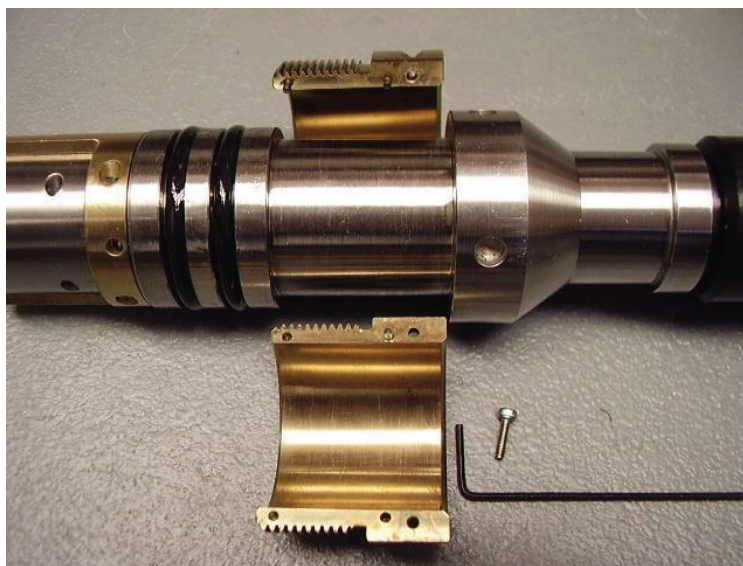
Four guide pins align the two ring halves and tend to hold them together after the screws are removed.

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   |
|--|---|
| <i>Tool not listed in Tool panel drop down list.</i>               | <ul style="list-style-type: none"> <li>- Do you have a configuration file?</li> <li>- Has the configuration file been installed with the LoggerSettings application (refer to LoggerSettings and LoggerSuite manuals for more information)</li> </ul>   |
| <i>Tool configuration error message when powering on the tool.</i> | <ul style="list-style-type: none"> <li>- Check all connections.</li> <li>- 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.</li> </ul>  |
| <i>Tool panel - No current.</i>                                    | <ul style="list-style-type: none"> <li>- 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.</li> <li>- Verify cable head integrity. Cablehead should have more than 20 Mega Ohm resistance electrical isolation.</li> <li>- Check wireline conductor and armor continuity.</li> <li>- Verify DC voltage output at the cable head (it should be 120V).</li> </ul>   |
| <i>Tool panel - Too much current (red area).</i>                   | <p><b>! Immediately turn off the tool !</b></p> <ul style="list-style-type: none"> <li>- Possible shortcut (voltage low, current high): Check for water ingress and cable head integrity.</li> <li>- Verify cable head isolation integrity. Cablehead should have more than <b>20 Mega Ohm</b> resistance electrical isolation.</li> <li>- 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.</li> <li>- If the above shows no issues, use test cable (optional) provided by ALT or MSI to verify tool functionality.</li> <li>- If the problem still occurs, please contact service centre.</li> </ul> |
| <i>Telemetry panel - status shows red.</i>                         | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 4.2 and 4.3).</li> <li>- If problem cannot be resolved, contact support@alt.lu or tech.support@mountsopris.com</li> </ul>   |

|   |  |
|---|--|
| <i>Telemetry panel - memory buffer shows 100%.</i>                                | - Indicates that the systems internal memory buffer is full. PC cannot receive incoming data streams fast enough. Ensure your PC has enough resources available. |
| <i>Telemetry panel – bandwidth usage shows 100%.<br/>(Overrun error message.)</i> | - Set the baudrate to highest value allowed by your wireline configuration.<br>- Reduce logging speed or increase vertical sample step.                          |
| <i>Telemetry panel - large number of errors.</i>                                  | - Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3).<br>- Check bandwidth usage and telemetry error status.                 |

## 7 Appendix

### 7.1 Replacement Parts

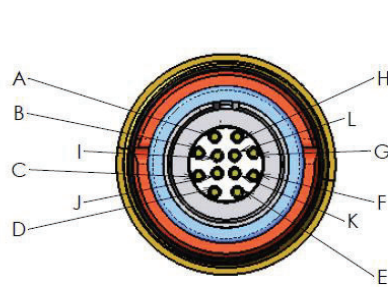
| Item No. | Qty | MSI Part No. | Description                                     |
|----------|-----|--------------|---|
| 1        | 1   | 17-202-160   | Mag Susc. Calibration Puck, .5 x 10-3 SI units  |
| 2        | 1   | 17-202-175   | Mag Susc. Calibration Puck, 2.4 x 10-3 SI units |
| 3        | 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

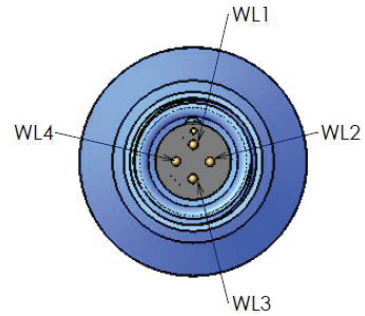
| Item No. | MSI Part No. | Description       |
|----------|--------------|-------------------|
| 1        | QL40-GO1     | QL40-Go1 tool top |
| 2        | QL40-GO4     | QL40-Go4 tool top |
| 3        | QL40-GO7     | QL40-Go7 tool top |
| 4        | QL40-MS1     | QL40-MSI tool top |

## 8 Probe Tops - Standard Configurations

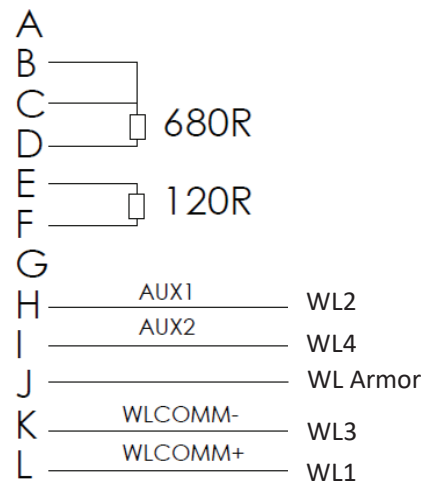
### 8.1 QL40-GO4 Four Conductor Tool Top



**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

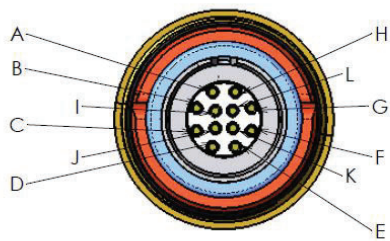


Figure 9-3 QL40-IS1 and IS2 Bridle bottom connection to tool      Figure 9-4 QL40-IS1 Bridle top connection to cable head

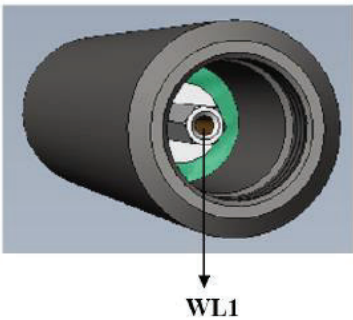
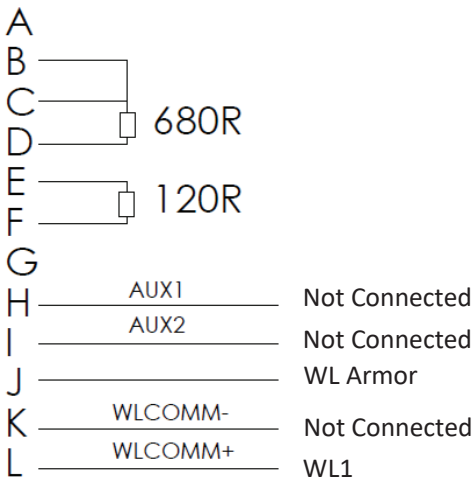


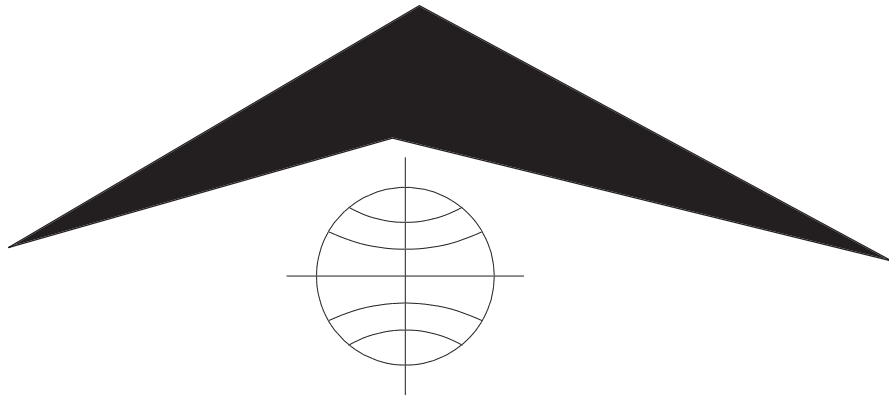
Figure 8-5 QL40-IS2 Bridle top connection to cable head





# 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.

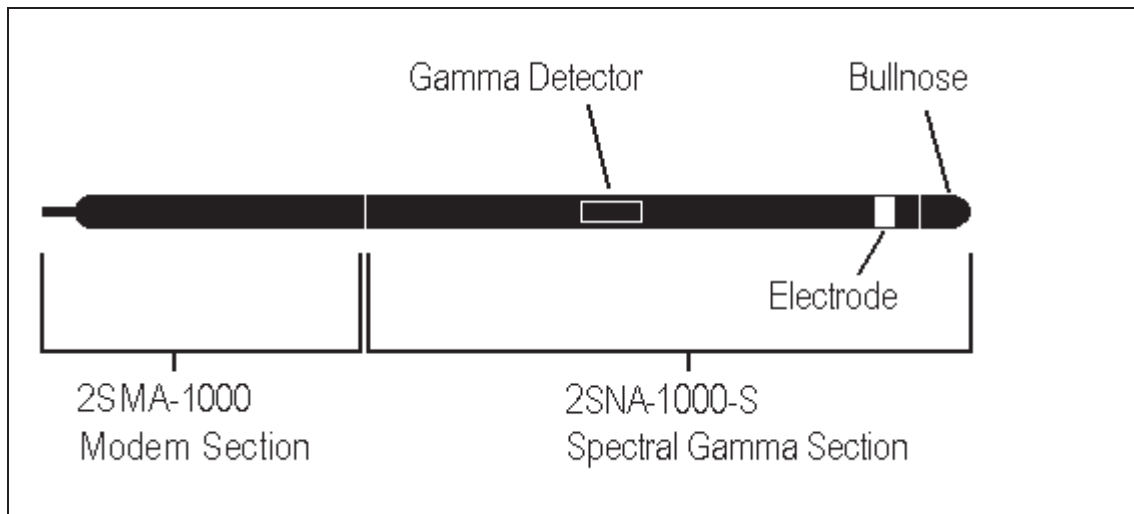


Figure 1: Diagram of the 2SNA-1000-S probe.

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 its energy will be less than its pre-reaction energy. Figure 2 shows the resultant spectrum from a standard  $^{137}\text{Cs}$  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.

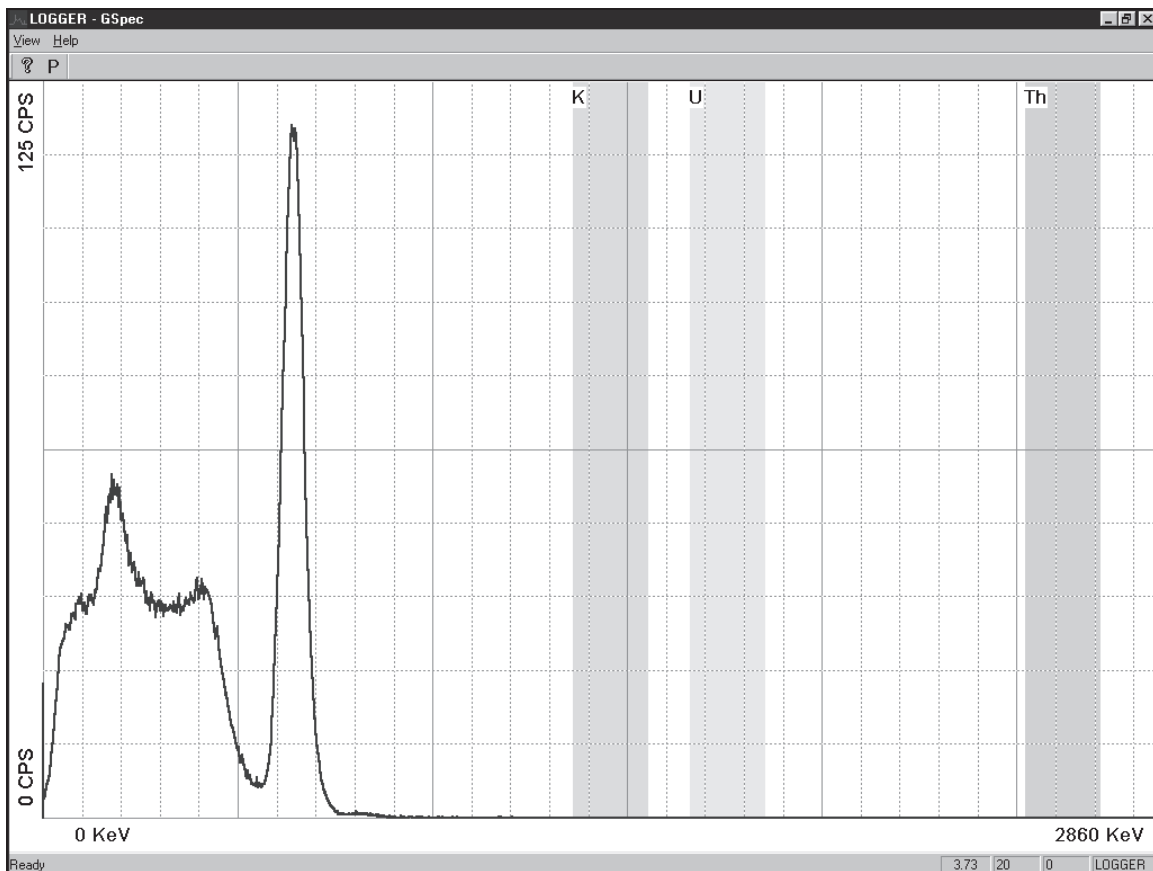


Figure 2: A typical spectrum from  $^{137}\text{Cs}$  standard source showing a peak at 662 KeV.

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.

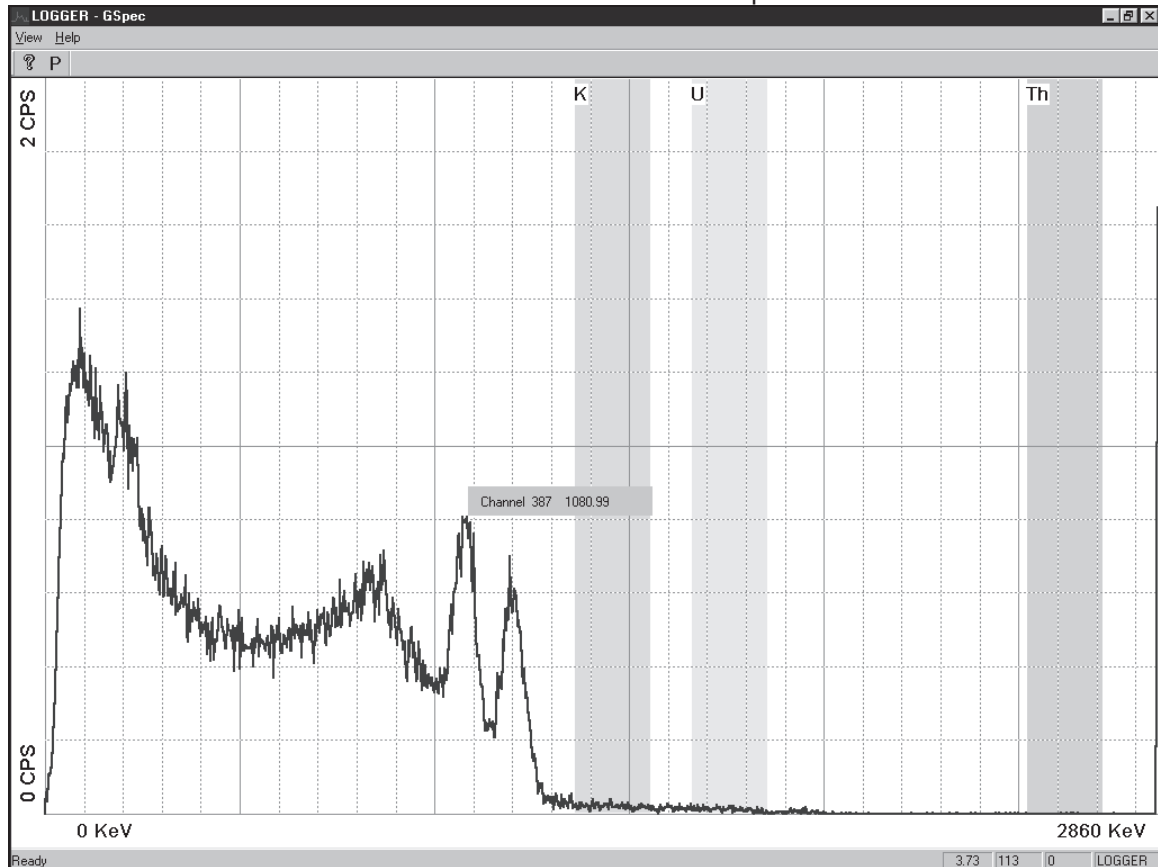


Figure 3: A typical spectrum from  $^{60}\text{Co}$  standard source showing a peak at 1173 and 1333 KeV.

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  $^{137}\text{Cs}$ ). Enter the window number recorded in step 3 in the 'First Calibration Point' 'Channel' field (i.e. 222 for  $^{137}\text{Cs}$ ). Enter the energy for the second calibration source in the 'Second Calibration Point' 'Energy' field (i.e. 1173 for  $^{60}\text{Co}$ ). Enter the window number recorded in step 5 in the 'First Calibration Point' 'Channel' field (i.e. 387 for  $^{60}\text{Co}$ ). See figure 4.

**Process Parameters**

**Spectrum Calibration**

|                          | Energy  | Channel |
|--------------------------|---------|---------|
| First Calibration Point  | 662     | 226     |
| Second Calibration Point | 1173    | 401     |
| Multiplier               | 2.92    |         |
| Offset                   | 2.07997 |         |

Buttons: Apply Calibration Points, Apply Offset and Multiplier

**Energy Window Definitions**

|         | Name | Low Energy Cutoff | High Energy Cutoff |
|---------|------|-------------------|--------------------|
| Channel | K    | 1360              | 1560               |
| Channel | U    | 1660              | 1860               |
| Channel | Th   | 2520              | 2720               |
| Channel | Ch4  | 1500              | 2000               |
| Channel | Ch5  | 2200              | 3000               |

Buttons: OK, Cancel

**Summing**

☐ Depth

☒ Time

Depth: 0.25

Time Interval: 30

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 not recommended. 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

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2SNA-1000-S

Drawing Number

Title

## Appendix

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### Suggested QA Procedure

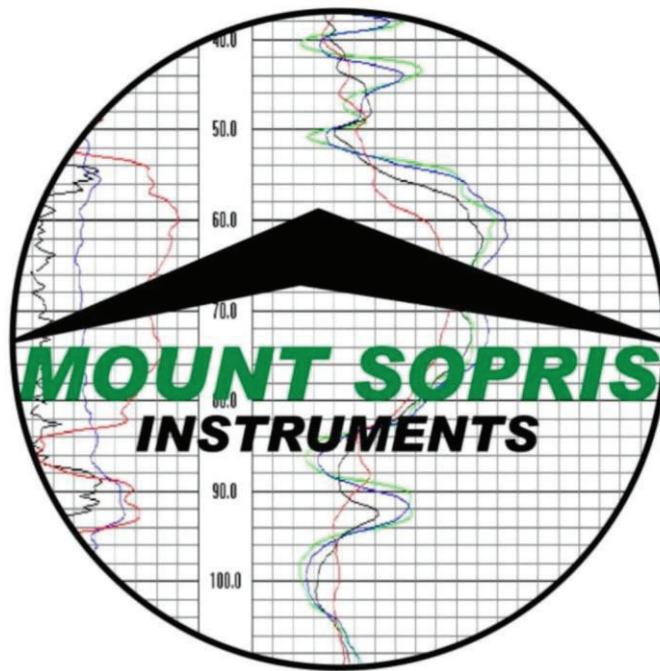
General notes for Quality Assurance (QA) are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be 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.  
April 14, 2005

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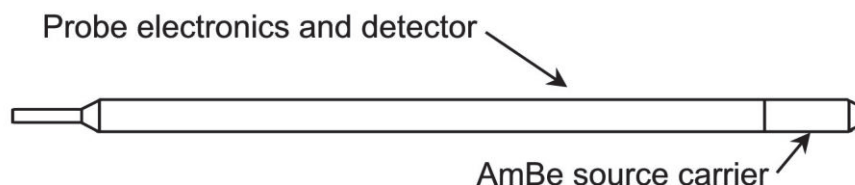
## General Information

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### Overview

The LLP-2676 thermal neutron probe is a simple analog pulse probe, which measures the output of a  $\text{He}^3$  detector inside the probe. The  $\text{He}^3$  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  $\mu\text{sec}$  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  $\text{He}^3$  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  $\text{He}^3$  detector, which detects thermal neutrons quite efficiently.

When high energy neutrons are scattered by target nuclei, but only lose 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  $^{241}\text{Am}$  Americium and Beryllium are used to produce neutrons for thermal and epithermal logging by bombarding the Beryllium with alpha particles supplied by the  $^{241}\text{Am}$  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)  $^{241}\text{AmBe}$  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) $^{241}\text{AmBe}$ |
| Detector                       | $^3\text{He}$ 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 be 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](mailto:tech.support@mountsopris.com)).

### **Preventative Maintenance**

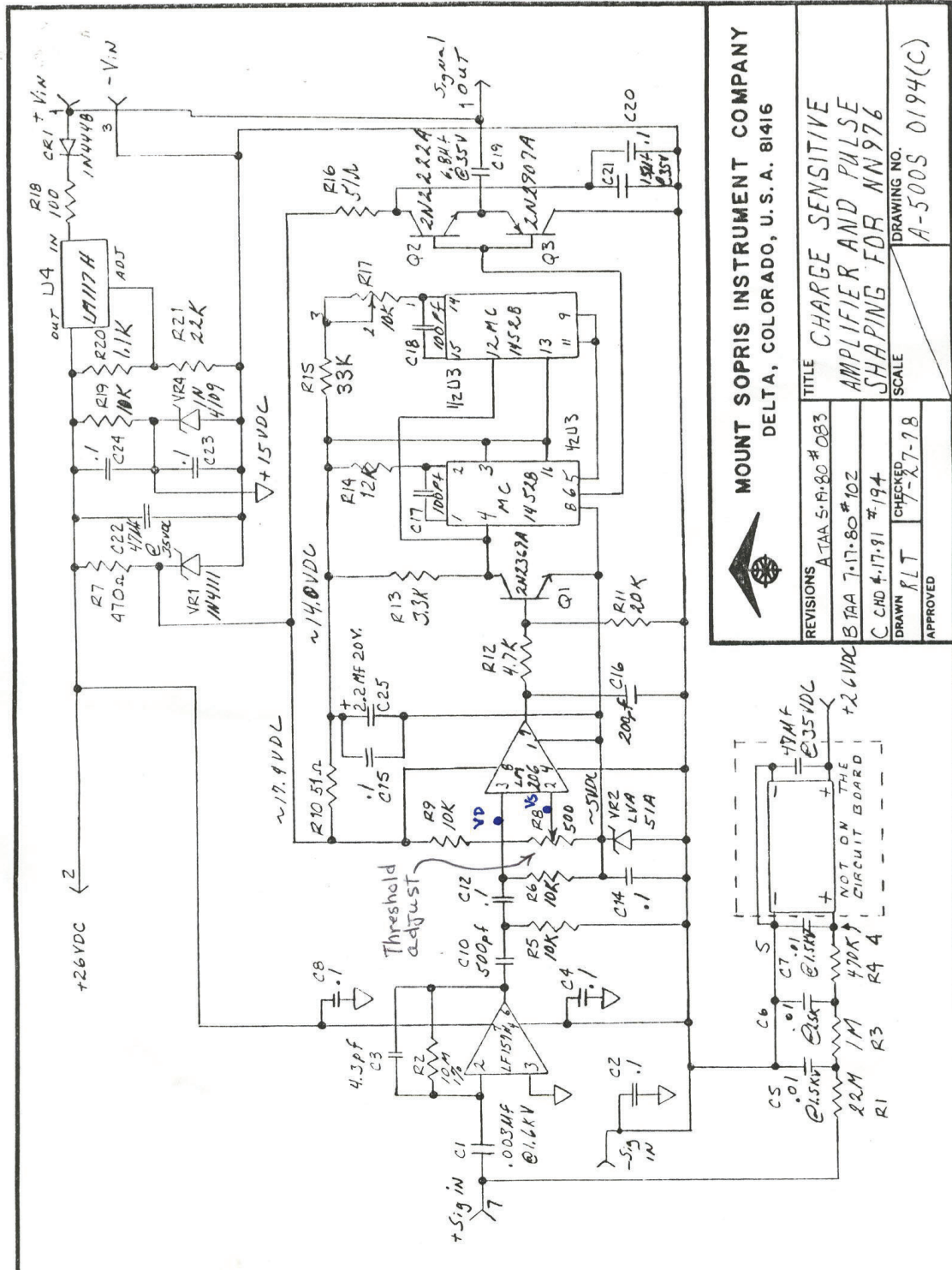
The LLP-2676 has no moving parts, and the only maintenance required is to clean and dry all thread surfaces after each use. This is particularly important on the source end of the probe, to make sure that there will be no problem screwing the source into the female probe thread. The o-ring seal area 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.

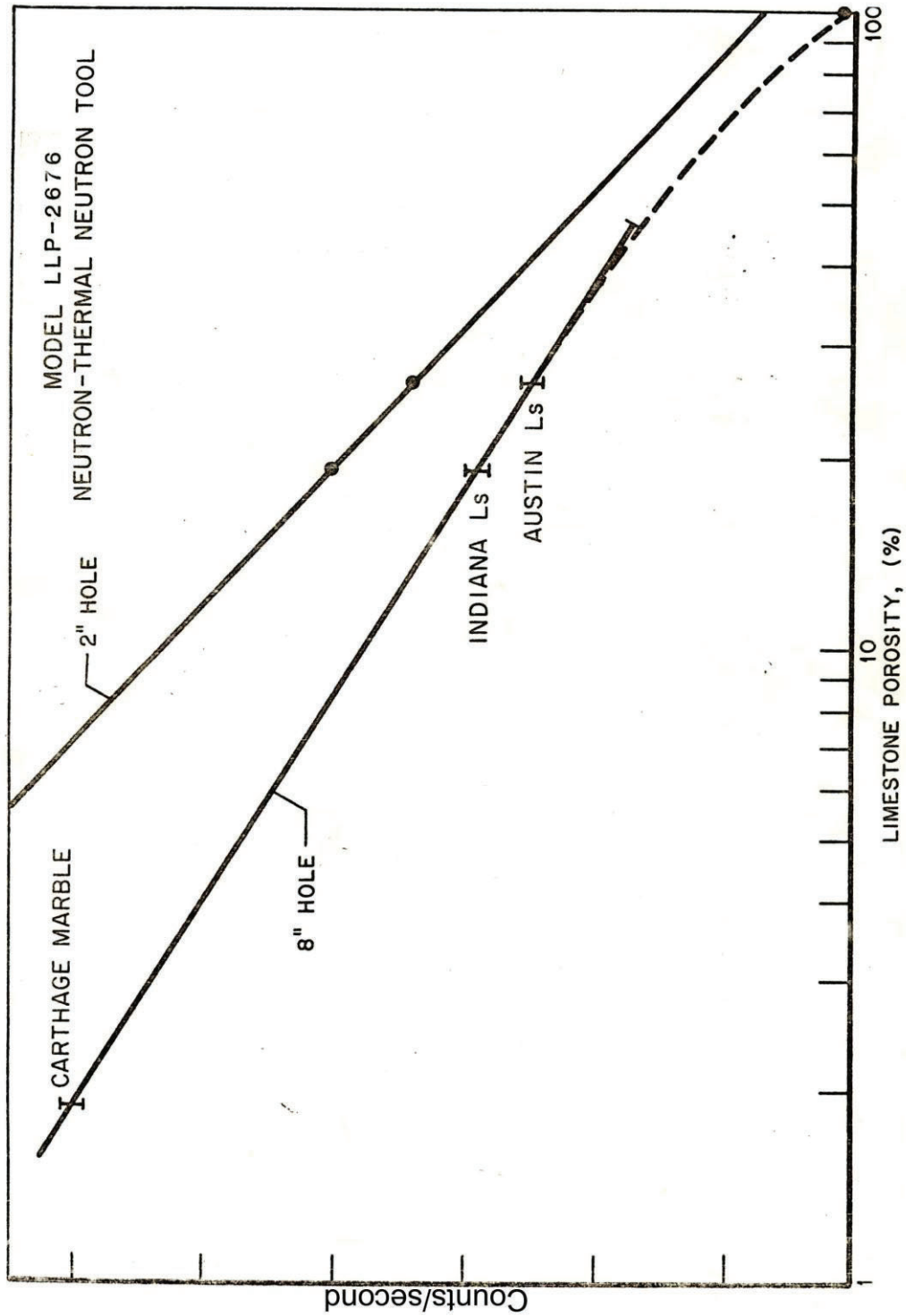
# Schematics

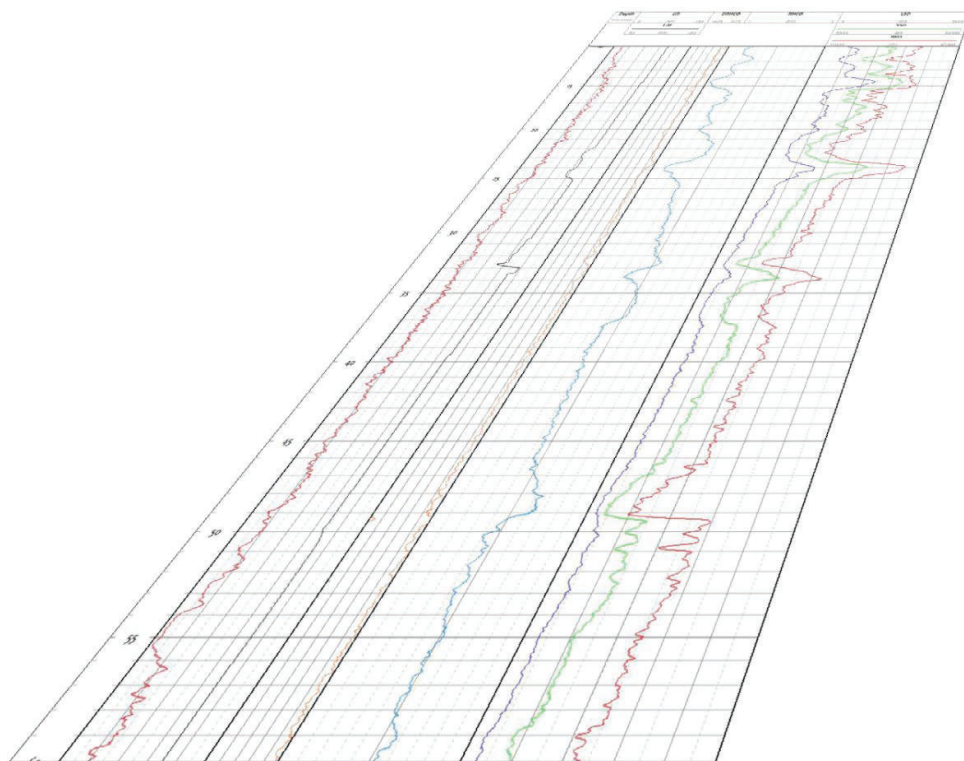
Drawing Number 500S-0194 Title Charge sensitive amplifier and pulse shaper



## Appendix

Example of neutron porosity calibration from Houston API models.





# User Guide

## QL40 DEN – Compensated Dual Density



---

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---

## 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<sup>1/2</sup> to 11<sup>1/2</sup> 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 <sup>1/2</sup> " )     |
| 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: □

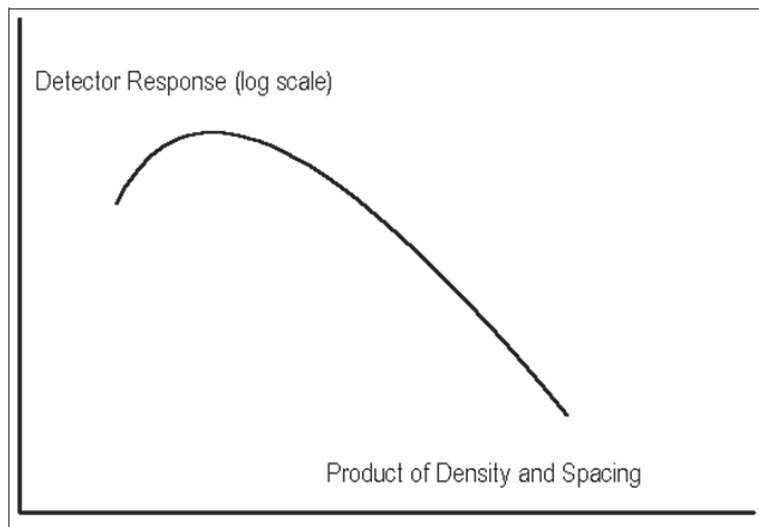
|                          |  |
|--------------------------|--|
| DC voltage at probe top: | Min 80 VDC<br>Max 160 VDC<br>Nominal 120 VDC |
| Current:                 | Nominal 25mA                                 |

## 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 4<sup>th</sup> or 5<sup>th</sup> 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.

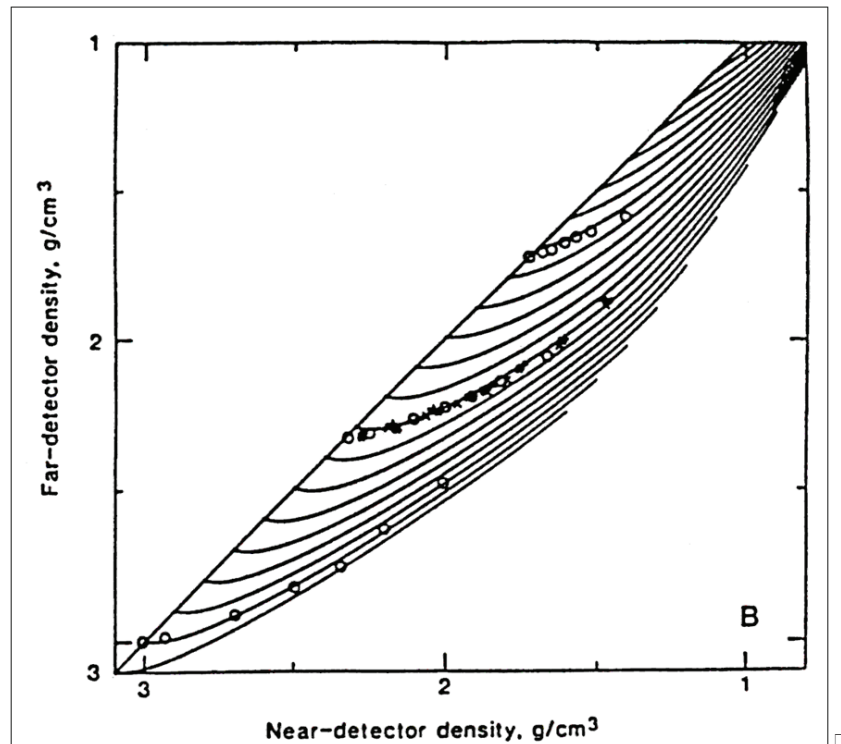


Figure 2-2 Typical density compensation

## 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 **Quick Link** 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.

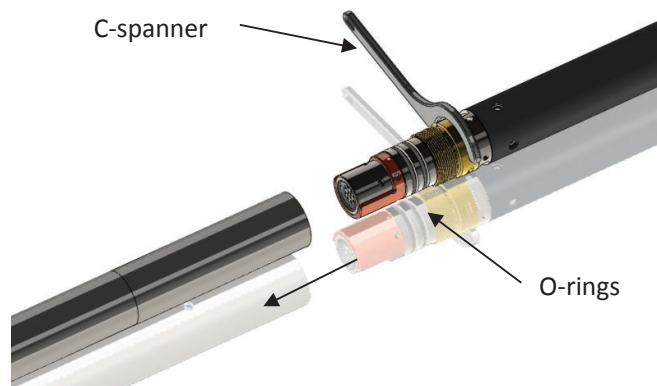
#### Mid Sub

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.

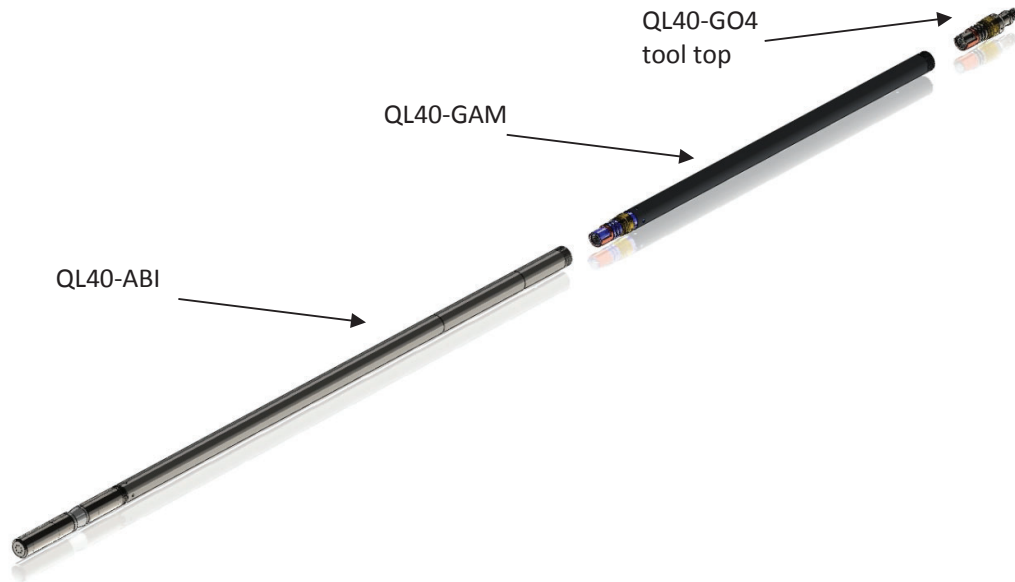
To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.



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

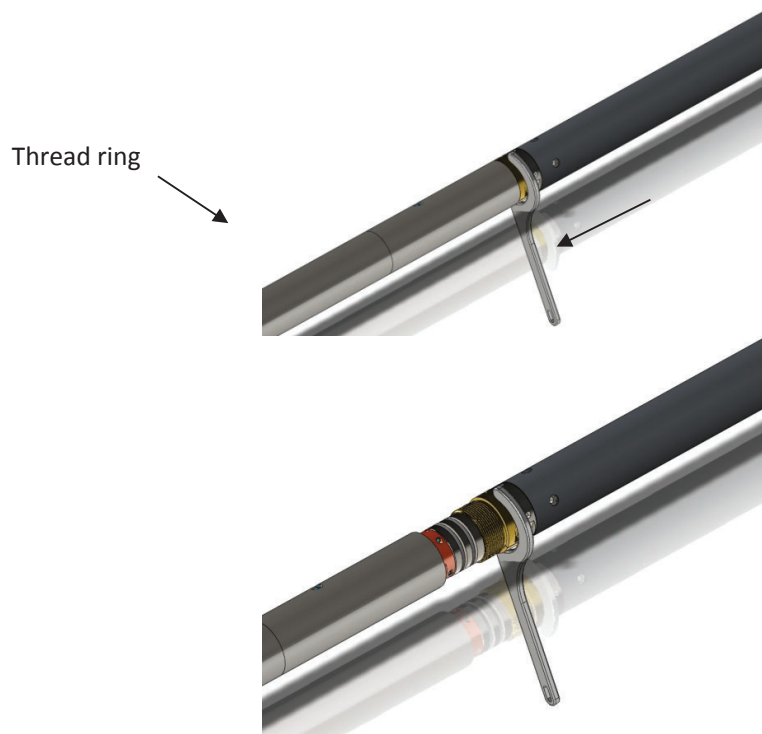


The following example of a QL40-ABI, QL40-GAM and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GAM sub stand-alone.



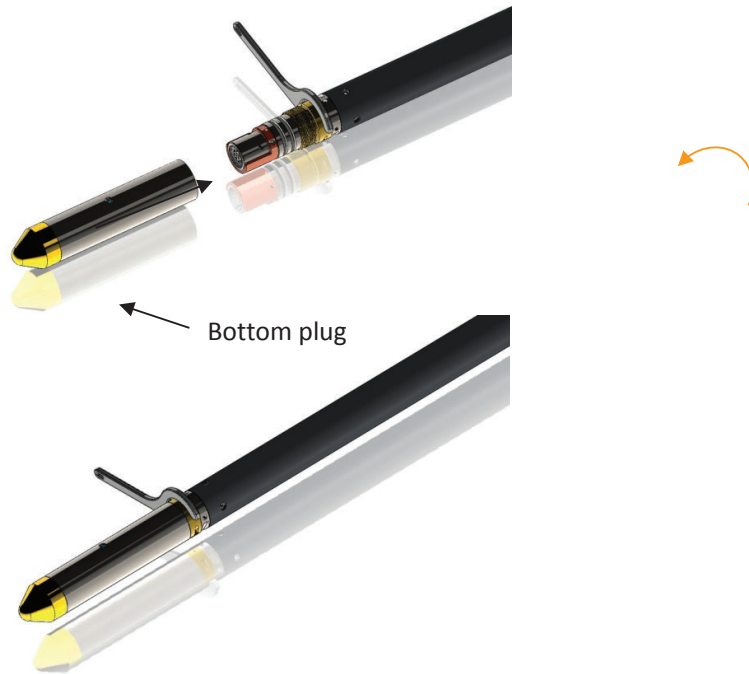
**Figure 3-2** Tool stack example □

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

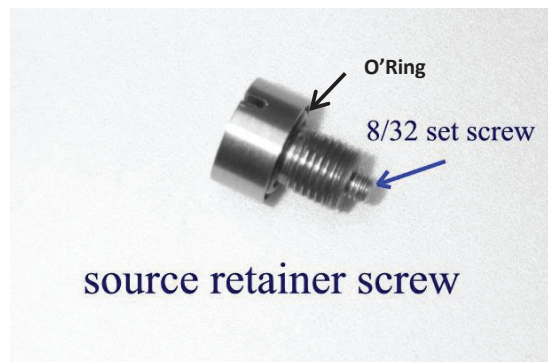
If the radioactive source has not been installed in the source carrier, it should be done using the following procedure. Handling of radioactive materials is normally only allowed by persons trained and authorized by government license. It is assumed that this task, and insertion and removal of the source 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.
- 

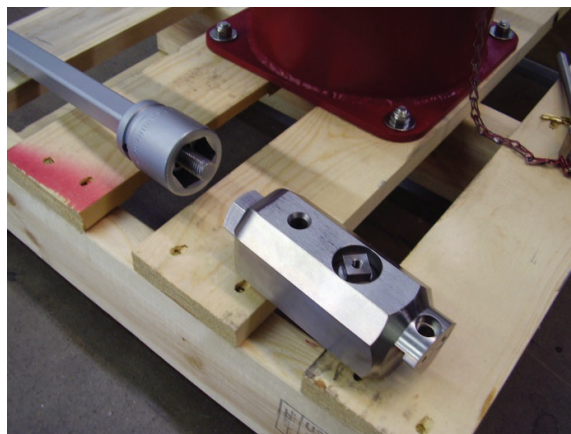


**Figure 3-11** Retainer Screw with Source being screwed into Source Carrier

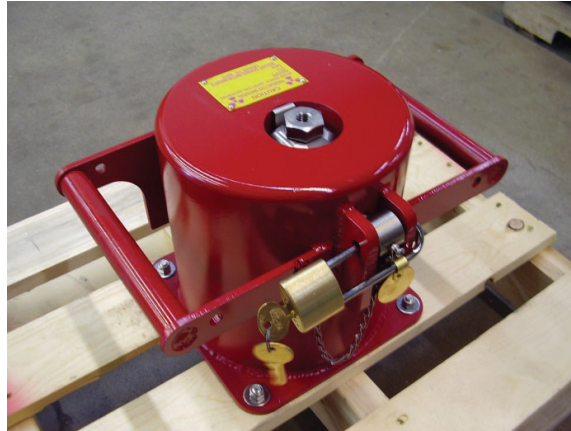


**Figure 3-12** Source carrier with Source Installed

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  $^{137}\text{Cs}$  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  $\sim 0.2$  mRem/hr. At the source spacer end it is  $\sim 1$  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


1. ☐ 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).
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 **NOT** 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).
8. ☐ Press the **Record** button in the **Acquisition** panel (**Figure 4-2**), specify a file name and start the logging.



Figure 4-1 Tool panel

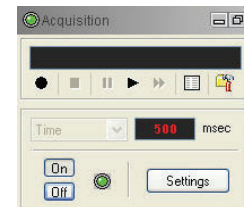


Figure 4-2 Acquisition panel

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%;

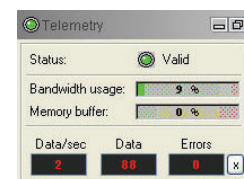



Figure 4-3 Telemetry panel

- ☐ Number of **Data** increases and number of **Errors** 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.

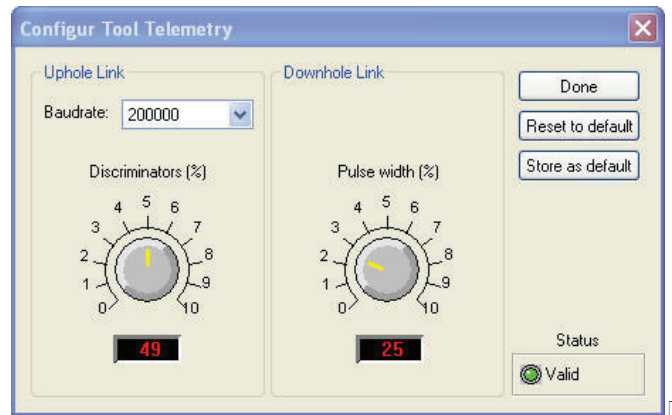



Figure 4-4 Tool communication settings

### 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 **linear / logarithmic** 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.

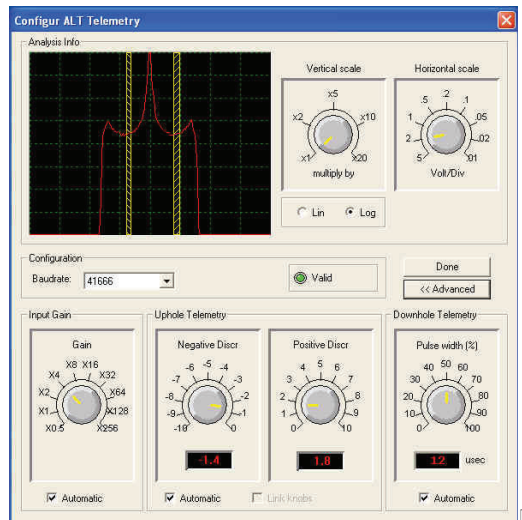


Figure 4-5 Matrix telemetry settings

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

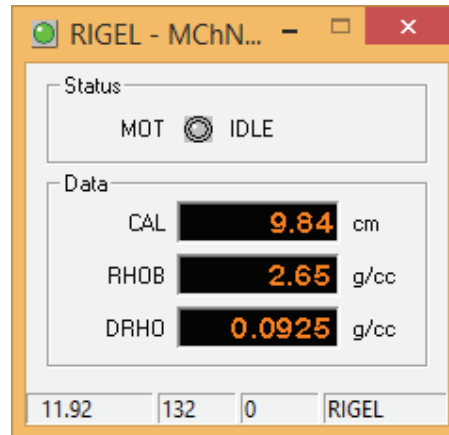
The following channels are recorded by the QL40-DEN tool:

|               |  |
|---------------|--|
| <b>RHOB</b>   | <b>Compensated Density calculated from short and long detectors - g/cc</b> |
| <b>DRHO</b>   | <b>Compensated Density minus Long Spaced Density (RHOB-RHOLSD) - g/cc</b>  |
| <b>CAL</b>    | <b>Caliper - cm</b>  |
| <b>RHOSSD</b> | Short Spaced Density - g/cc  |
| <b>RHOLSD</b> | Long Spaced Density - g/cc   |
| <b>Time</b>   | Sampling Time - sec  |
| <b>TCPU</b>   | Temperature (recorded on CPU board) - °C                                   |
| <b>MOT</b>    | Caliper Motor Status - Opening/Closing/Idle                                |
| <b>HV</b>     | High Voltage monitor   |
| <b>SSDCNT</b> | Short spacing Density Counts   |
| <b>LSDCNT</b> | Long spacing Density Counts  |
| <b>CALCNT</b> | Caliper Counts   |
| <b>SSDCPS</b> | Short spacing Density - counts per second                                  |
| <b>LSDCPS</b> | Long spacing Density - counts per second                                   |
| <b>CALCPS</b> | 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

|             |   |
|-------------|---|
| <b>MOT</b>  | Caliper Motor Status                                    |
| <b>CAL</b>  | Borehole diameter (in centimeters)                      |
| <b>RHOB</b> | Compensated Density (in g/cc)                           |
| <b>DRHO</b> | 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.).

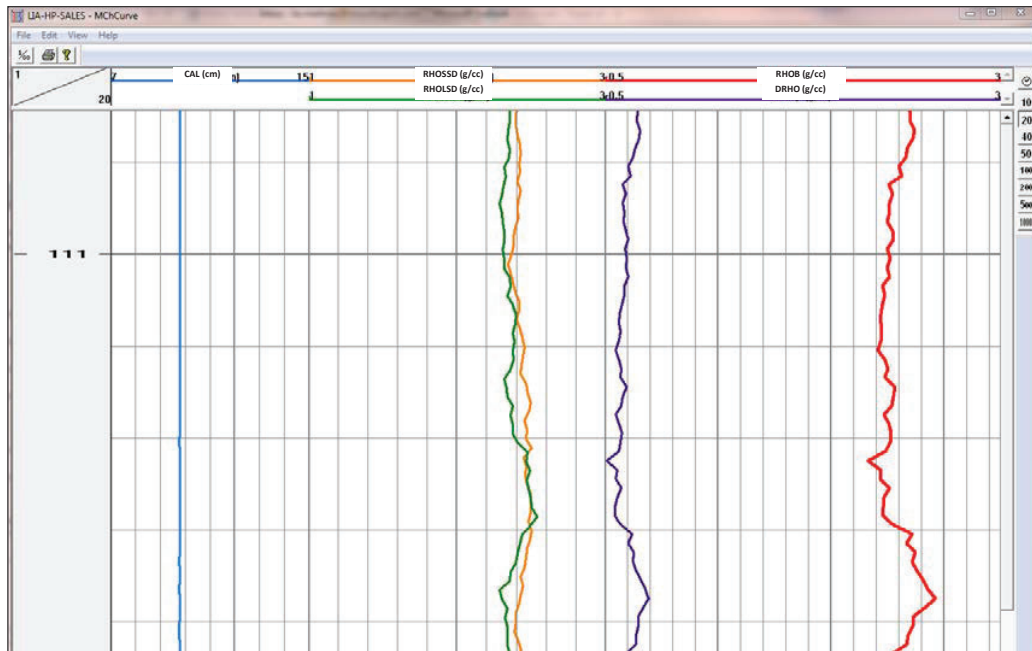


Figure 4-7 QL40-DEN MChCurve browser

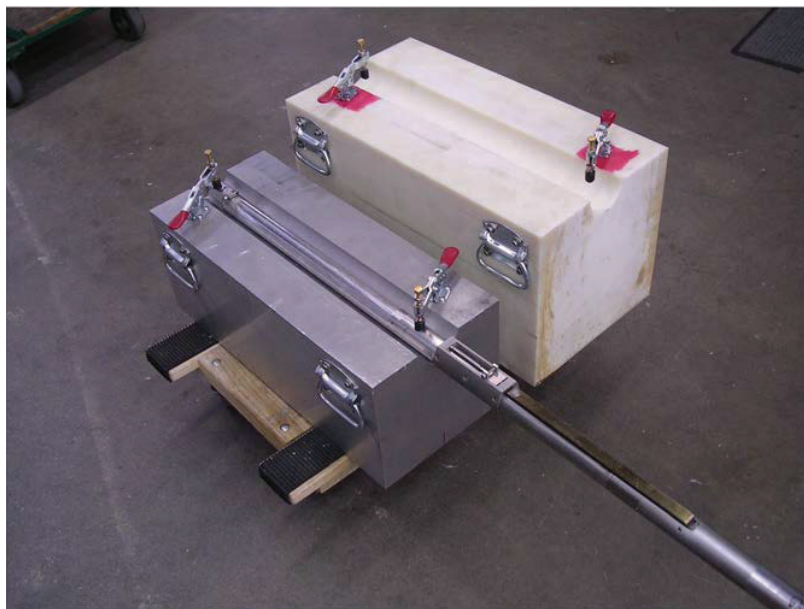


## 5 Performance Check & Calibration

### 5.1 Density

Good practice requires regular validation of the measurements. This 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:

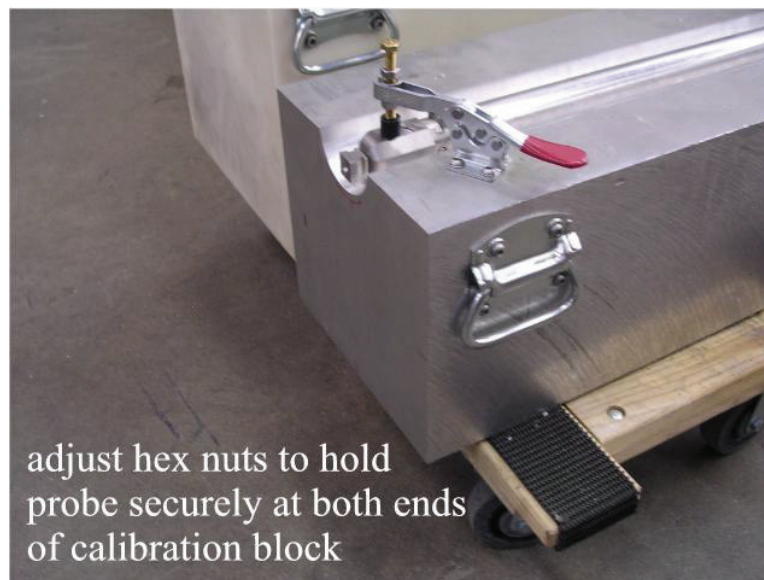


*Figure 5-1 QL40-DEN resting on its calibration block*

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 probe rests perfectly flat in the grooved radius in the block.



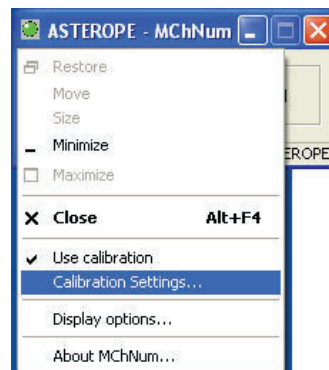
5. ☐ Use the clamps to secure the probe to the calibration block. They can be adjusted by turning the hex nuts to allow a secure lock when the handles are pressed down. See detail in the next figure.



*Figure 5-2 Probe secured on the calibration block*

**IMPORTANT:** The probe ***MUST*** 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 on 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 RHOSD 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 RHOSD & 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.

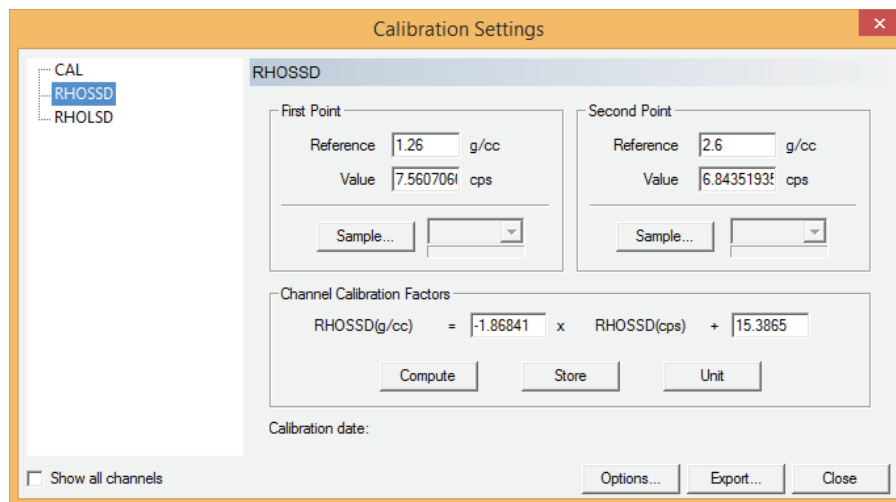


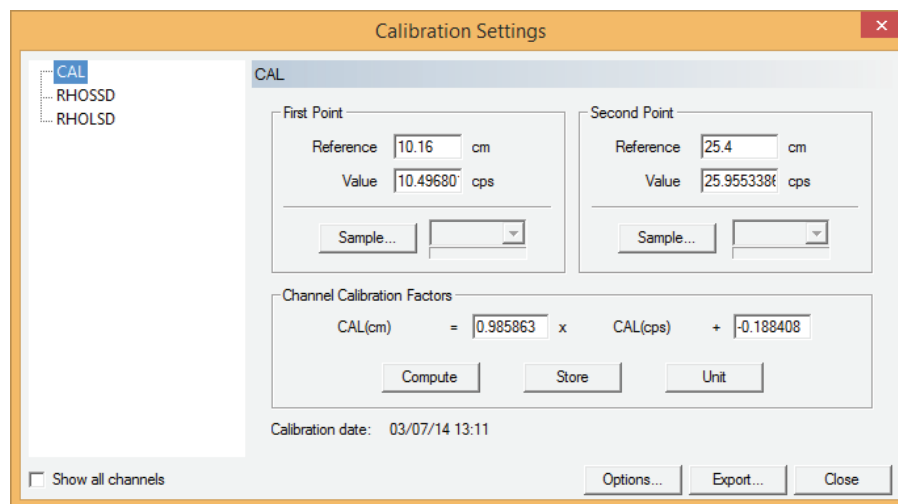
Figure 5-4 calibration example

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:

$$(2.975327597445237 \times \text{RHOLSD}) - (1.971171233098749 \times \text{RHOSSD}) - 0.014985496037274$$

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:  $(\text{RHOB} - \text{RHOLSD})$

---

## 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.

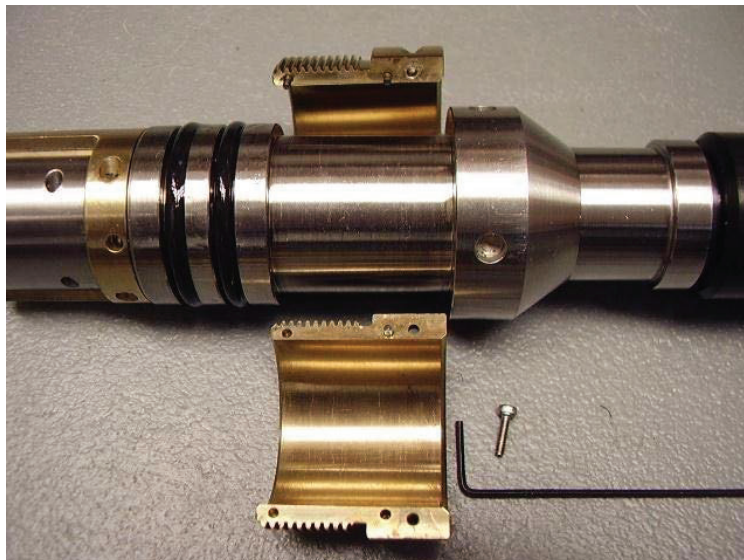
*Do this carefully to prevent bending the guide pins.*



**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).

☐

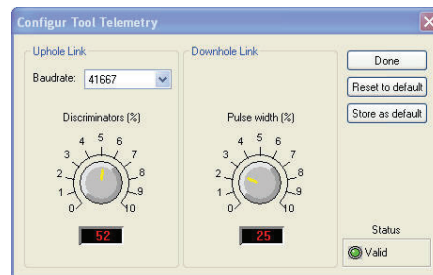


Figure 6-3 Tool communication settings - ALTLog

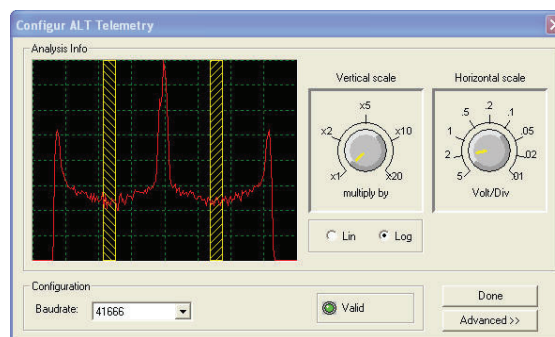


Figure 6-4 Tool communication settings - Matrix

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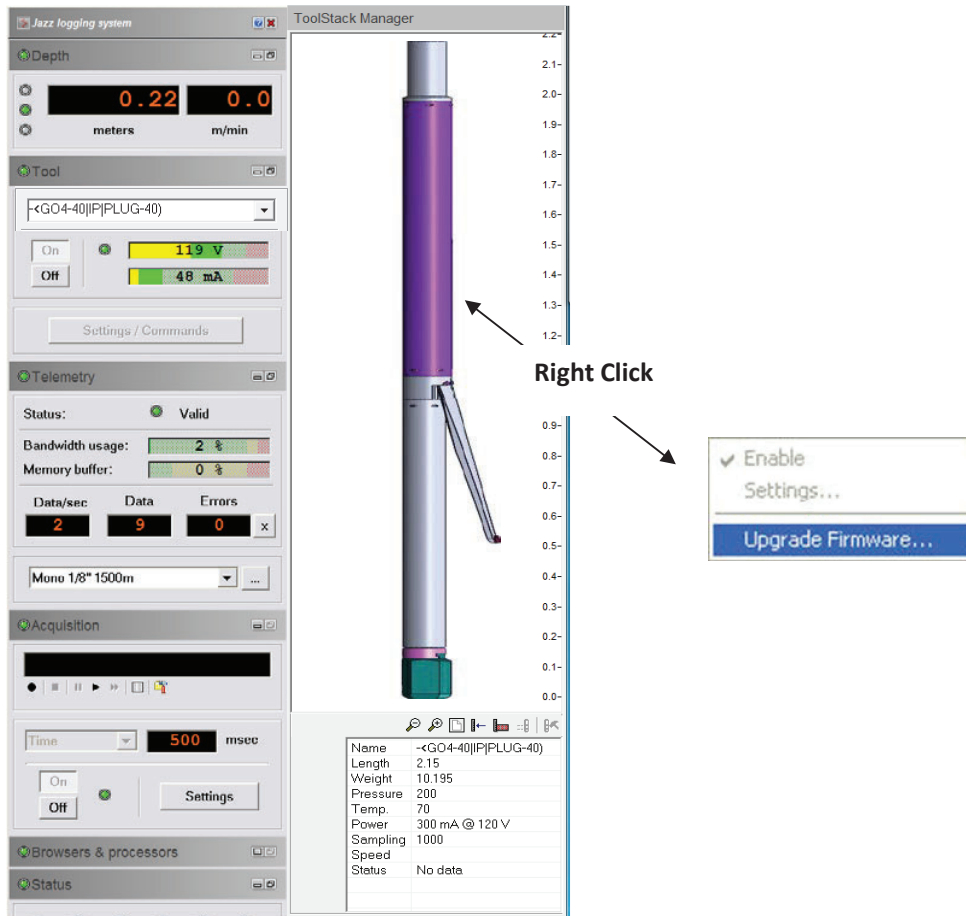
**Warning: Telemetry must be tuned properly. Bad communication may abort the upgrade of the firmware!**

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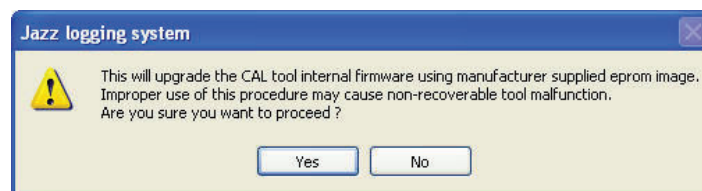


### 6.3.2 Upgrading the firmware

1. ☐ **Right Click** on the tool preview in the **ToolStack Manager** view and select **Upgrade Firmware** from the context menu.



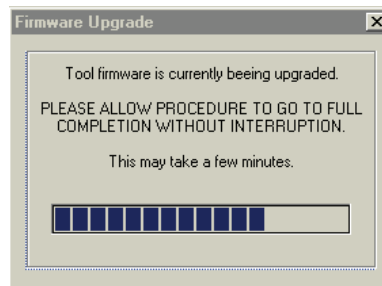
2. ☐ The following message will appear (Figure 6-5). Click **Yes** to validate your choice.



*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

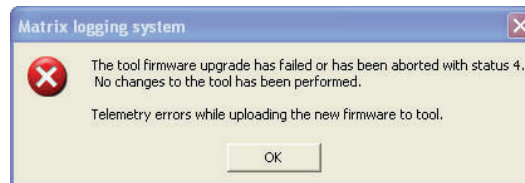
5. □ Once the upgrade has been successfully completed (Figure 6-7), click on **OK** to turn off the tool.



**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   |
|---|---|
| <i>Tool not listed in Tool panel drop down list.</i>                              | <ul style="list-style-type: none"> <li>- Do you have a configuration file?</li> <li>- Has the configuration file been installed with the LoggerSettings application (refer to LoggerSettings and LoggerSuite manuals for more information)</li> </ul>   |
| <i>Tool configuration error message when powering on the tool.</i>                | <ul style="list-style-type: none"> <li>- Check all connections.</li> <li>- 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).</li> </ul>   |
| <i>Tool panel - No current.</i>   | <ul style="list-style-type: none"> <li>- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system.</li> <li>- Verify cable head integrity.</li> <li>- Verify voltage output at the cable head (it should be 120V).</li> </ul>  |
| <i>Tool panel - Too much current (red area).</i>                                  | <p><b>! Immediately switch off the tool !</b></p> <ul style="list-style-type: none"> <li>- Possible shortcut (voltage low, current high): Check for water ingress and cable head integrity - wireline continuity.</li> <li>- 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.</li> <li>- If the above shows no issues, use test cable provided by ALT to verify tool functionality.</li> <li>- If the problem still occurs, please contact service centre.</li> </ul> |
| <i>Telemetry panel - status shows red.</i>  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3).</li> <li>- If problem cannot be resolved contact support@alt.lu or tech.support@mountsopris.com</li> </ul>   |
| <i>Telemetry panel - memory buffer shows 100%.</i>                                | <ul style="list-style-type: none"> <li>- 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.</li> </ul>   |
| <i>Telemetry panel – bandwidth usage shows 100%.<br/>(Overrun error message.)</i> | <ul style="list-style-type: none"> <li>- Set the baudrate to highest value allowed by your wireline configuration.</li> <li>- Reduce logging speed or increase vertical sample step.</li> </ul>   |
| <i>Telemetry panel - large number of errors.</i>                                  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3).</li> <li>- Check bandwidth usage and telemetry error status.</li> </ul>  |

## 8 Appendix

### 8.1 Replacement Parts

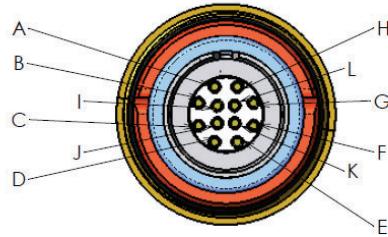
| Item No. | Qty | MSI Part No. | Description                           |
|----------|-----|--------------|---------------------------------------|
| 1        | 1   | Q40DEN-0560  | Caliper Wear Button                   |
| 2        | 1   | 16-201-007   | Silicone Lubricant Cartridge 14.1 oz. |
| 3        | 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

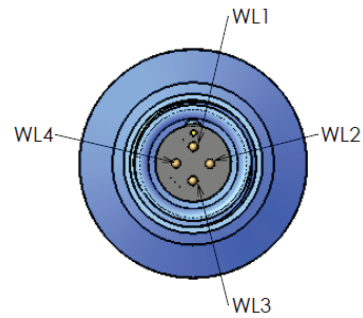
| Item No. | MSI Part No. | ALT Part No. | Description                |
|----------|--------------|--------------|----------------------------|
| 1        | 17-202-092   | ALT 26312-A  | QL40-Go1 tool top          |
| 2        | Q40GO4-1000  | ALT 26074-A  | QL40-Go4 tool top          |
| 3        | 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

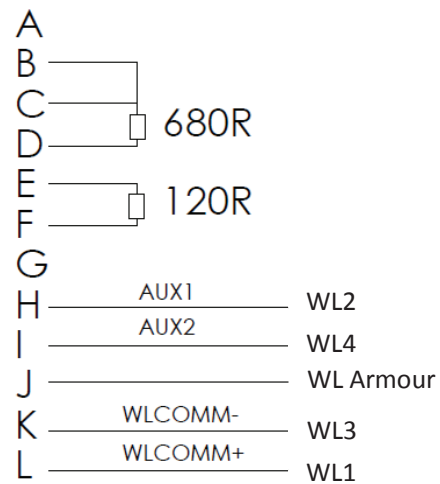
### 9.1 QL40-GO4 four conductor tool top



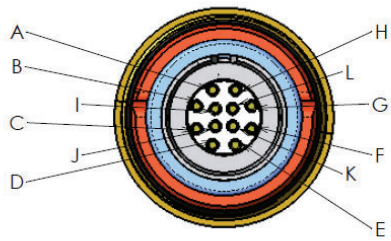
**Figure 9-1** Bottom connection to tool



**Figure 9-2** Top connection to cable head



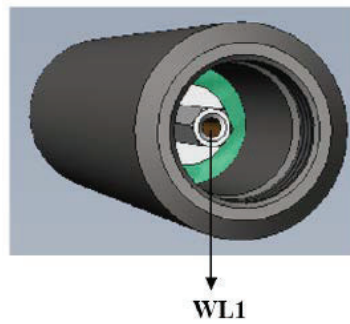
## 9.2 QL40-MSI and QL40-GO1 single conductor tool tops



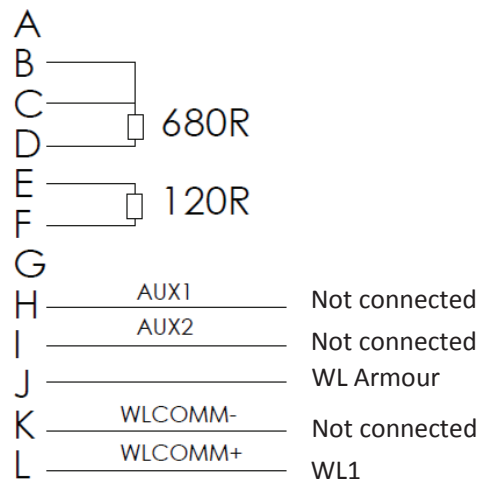
**Figure 9-3** MS1 and GO1 bottom connection to tool

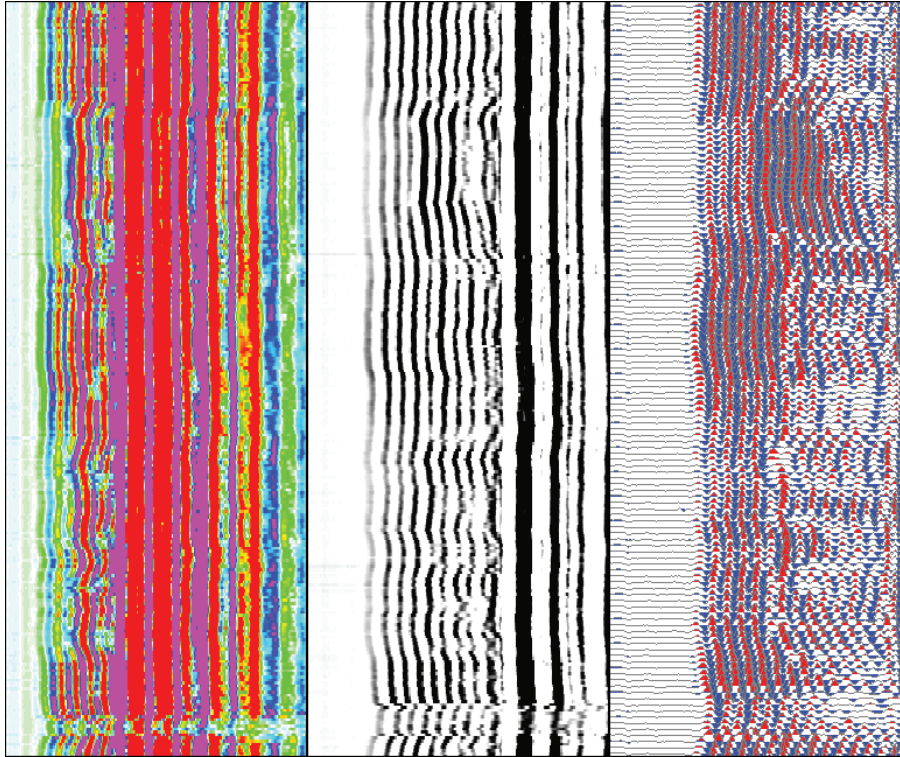


**Figure 9-4** MS1 top connection to cable head



**Figure 9-5** GO1 top connection to cable head





# User Guide

QL40 FWS – Full Waveform Sonic

Advanced Logic Technology sa

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V13.12.06

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## 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

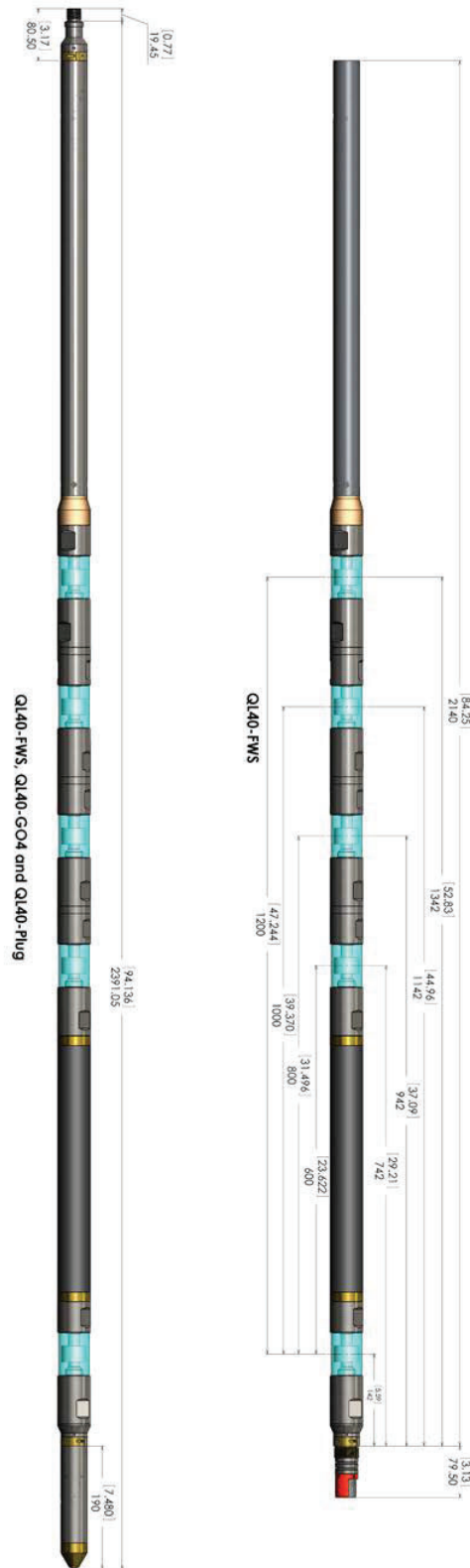


Figure 1-1 QL40-FWS dimensions

## 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

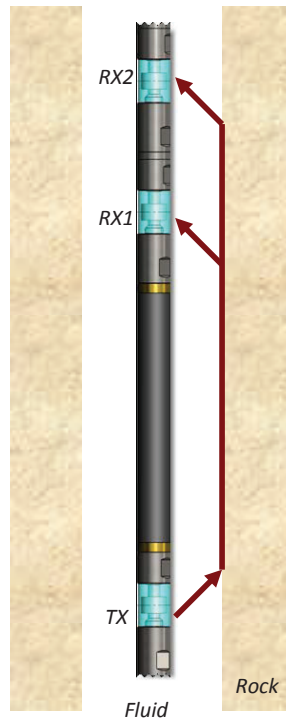
### Sensors:

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

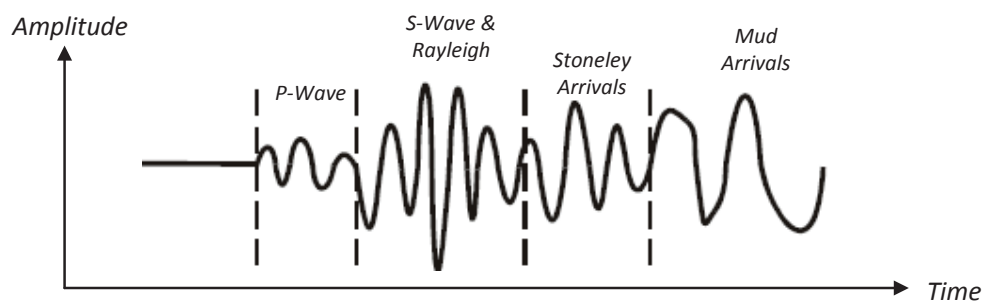
The QL40-FWS tool measures the time it takes for a sound pulse to travel from a piezo electric transmitter to a receiver at a defined distance. Transmitter and receiver are mounted on the same tool. The acoustic pulse generated by the transducer travels through borehole fluid and rock in various different 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

---

**Note on centralisers :** 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.

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. 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.)

---

**Note on tool handling :** 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.

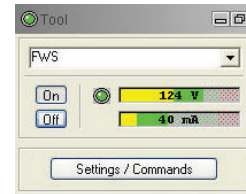
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## 3.2 Quick Start

**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).

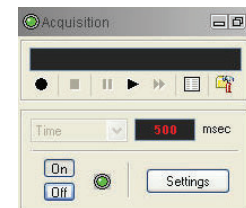


**Figure 3-1** Tool panel

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).

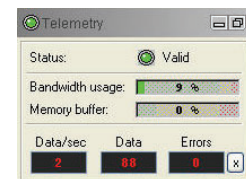


**Figure 3-2** Acquisition panel/

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.

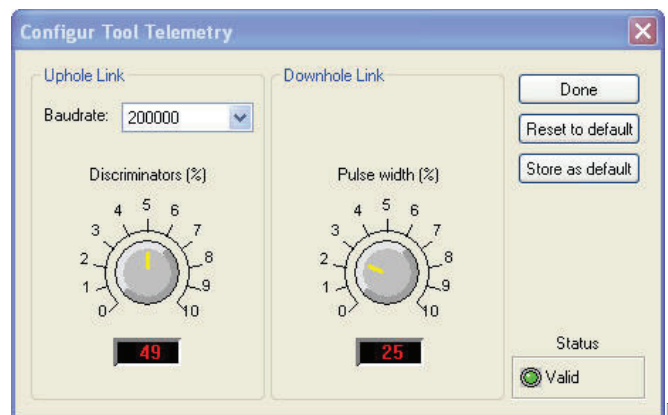


Figure 3-4 Tool communication settings

### 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.

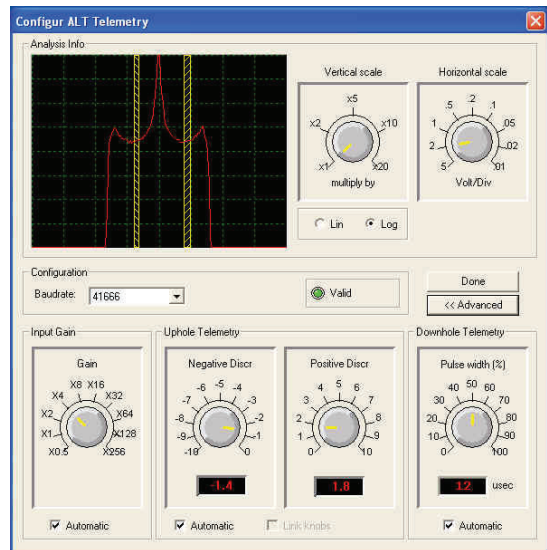
The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **linear / logarithmic** scale buttons. The status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

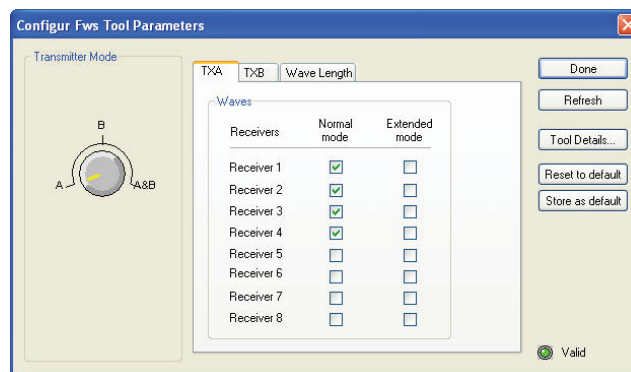
The **Configure FWS Tool Parameters** dialog box (**Figure 3-6**) can be accessed by clicking on the **Settings / Command** button on the dashboard's **Tool** panel (**Figure 3-1**).

#### 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  $\mu$ s 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  $\mu$ s steps up to the maximum recording length. This might be useful when looking for reflected tube waves.

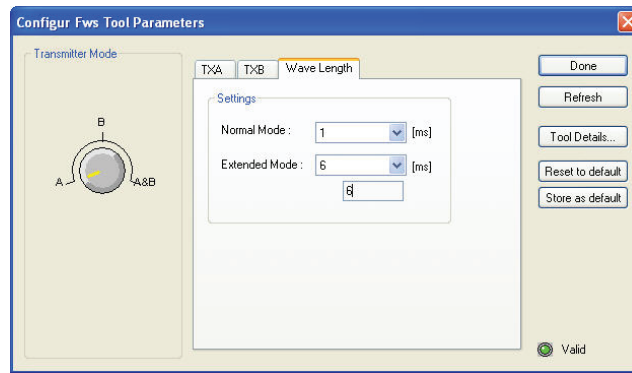
---

**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:

#### ***RXn-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.

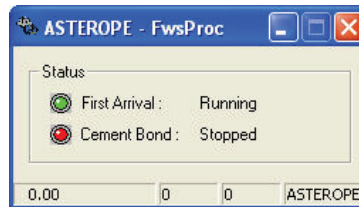


Figure 3-9 FwsProc window

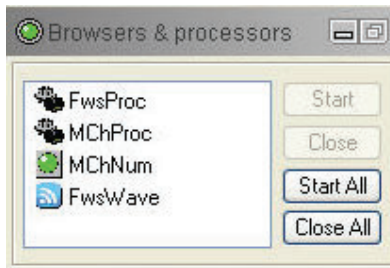


Figure 3-10 Start the processor from the Browser & processors panel

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).

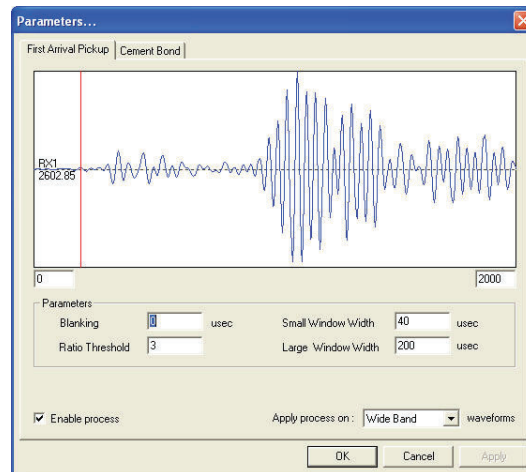
### **First Arrival Pickup**

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 $\mu\text{s}$ ) at receiver 1 |
| RX2-1A - dt | First arrival pick (in $\mu\text{s}$ ) at receiver 2 |
| RX3-1A - dt | First arrival pick (in $\mu\text{s}$ ) at receiver 3 |
| RX4-1A - dt | First arrival pick (in $\mu\text{s}$ ) 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).

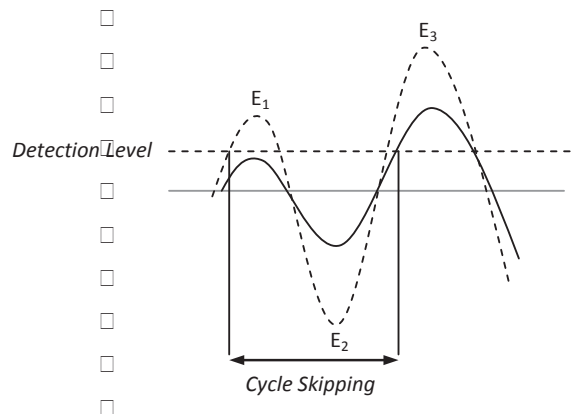


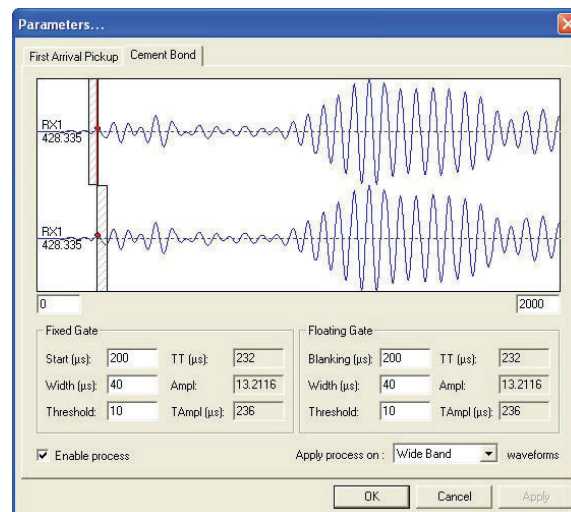
Figure 3-12 Naming of signal peaks and principle of cycle skipping

It is the goal of the Cement Bond processing to extract the amplitude of the  $E_1$  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  $E_3$  instead of  $E_1$ . 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.

**For the Fixed Gate configuration you can enter:**

**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.

**For the Floating Gate configuration you can adjust the following parameters:**

**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.

|               |   |
|---------------|---|
| <b>TT0</b>    | Start time of fixed gate (in μs)                          |
| <b>TAmpl0</b> | Time at which fixed gate amplitude was derived (in μs)    |
| <b>Ampl0</b>  | Amplitude from fixed gate                                 |
| <b>TTX</b>    | Start time of floating gate (in μs)                       |
| <b>TAmplX</b> | Time at which floating gate amplitude was derived (in μs) |
| <b>AmplX</b>  | Amplitude from floating gate                              |

the cement bond process:

The following additional data channels will be created by



### 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.



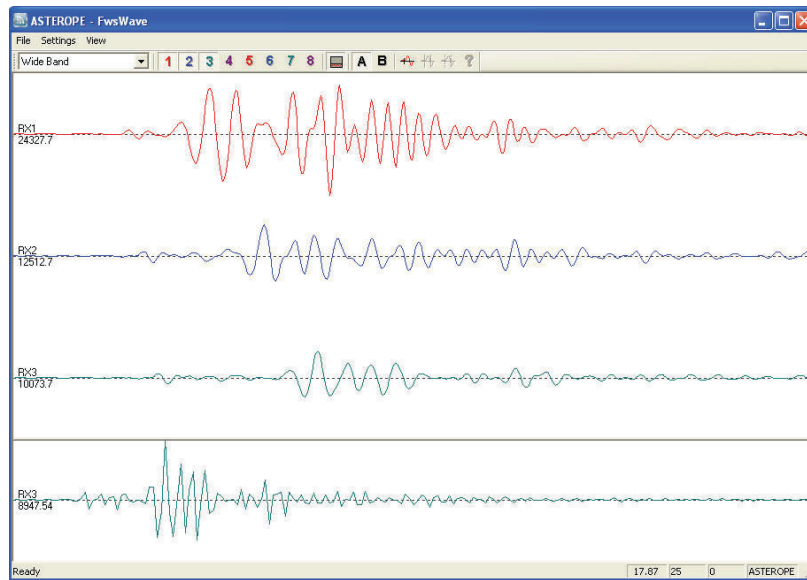
*Figure 3-14 FwsProc version and channels produced*

### 3.6.3 FwsWave Browser

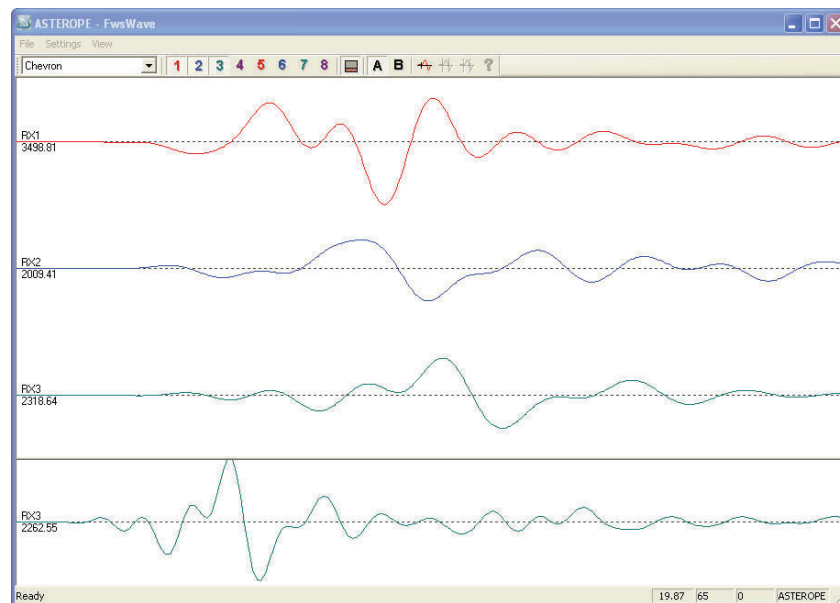
The FwsWave browser displays the waves acquired on each receiver in real time. The **1**, **2**, ... **8** toolbar buttons allow selection of the waves detected by the different receivers to be displayed. The **A** and **B** toolbar buttons allow display of the received waves fired by the transmitter **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).

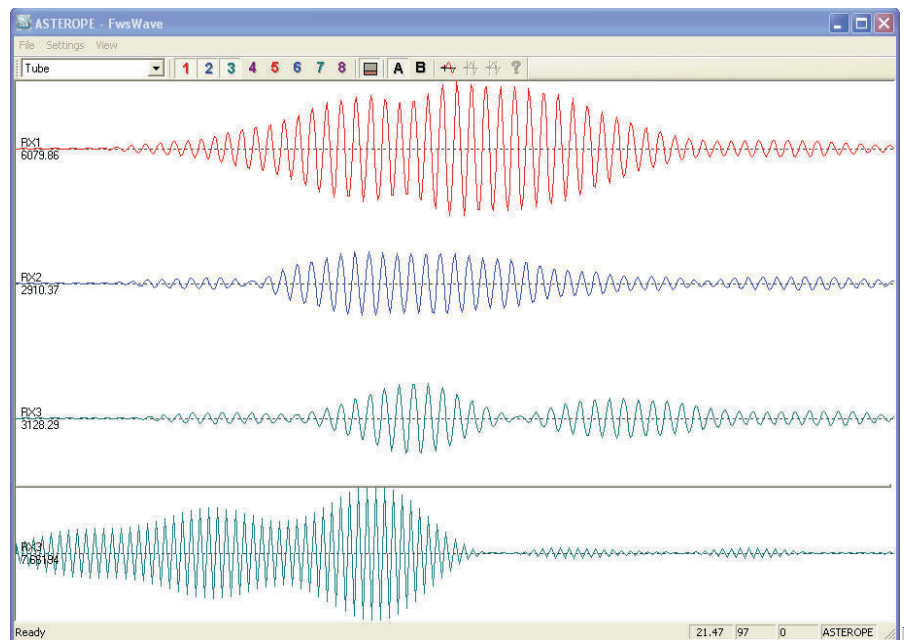
All these options are either available from the toolbar or from the menu.



**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



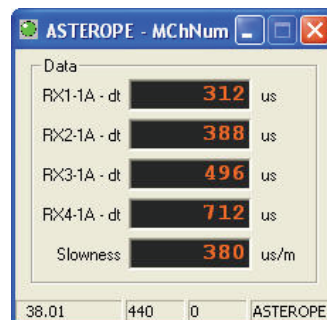
**Figure 3-17** FwsWave browser - Receivers 1 to 3 from Transmitter A – Extended mode on Rx3 – “Tube” wave output

### 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)

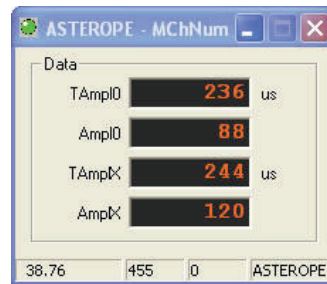


Figure 3-19 MChNum browser (Cement Bond display) □

### 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.

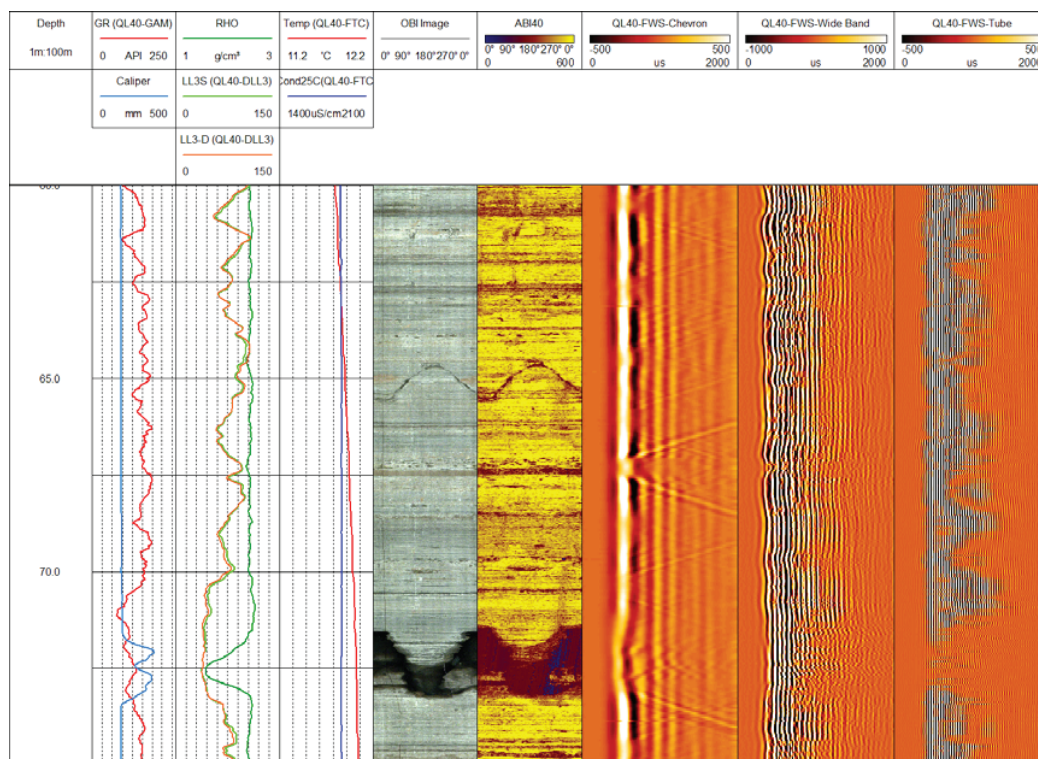


Figure 3-20 Example of WellCad browser display

---

## 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

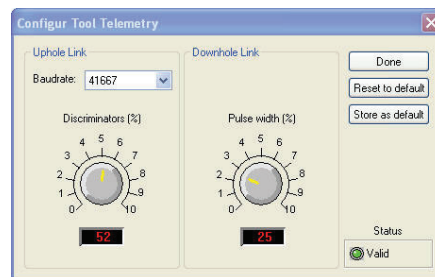
In accordance with the ALT policy of continuous development the QL40-FWS has been designed to allow firmware upgrades. The current version of firmware installed in a tool may be verified in the **Tool Details** window opened from the **Tool Settings** dialogue box.

*Firmware upgrade procedure is as follows:*

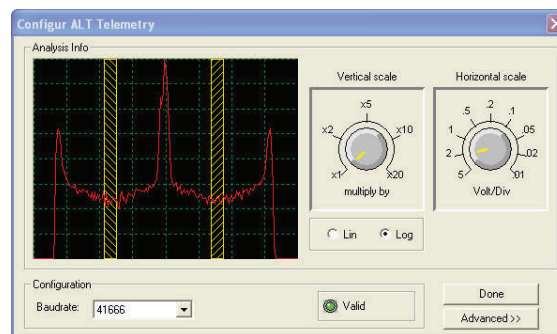
1. **Checking the communication is valid.**
2. **Upgrading firmware**

#### 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 5-1** Tool communication settings - ALTLog



**Figure 5-2** Tool communication settings - Matrix

---

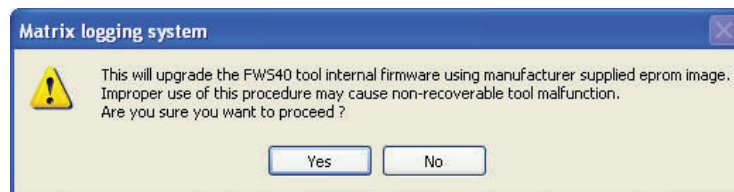
**Warning: Telemetry must be tuned properly. Bad communication may abort the upgrade of the firmware!**

---

### 5.1.2 Upgrading the firmware

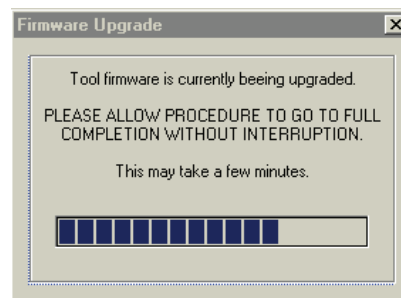
In the **Tool** panel, select **Tool settings/commands**. Check that the communication status is valid.

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.



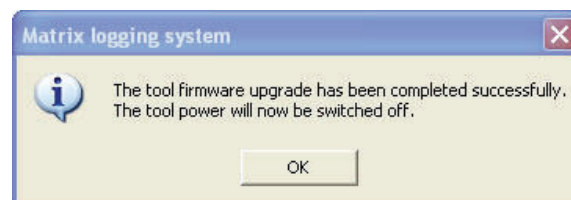
*Figure 5-3 Warning Message during firmware upload*

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*

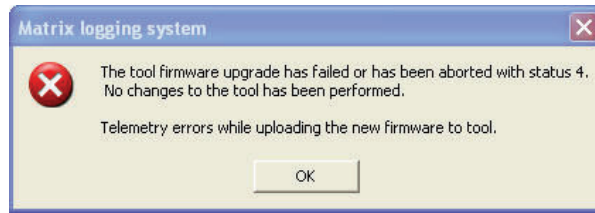
5. ☐ Once the upgrade has been successfully completed, click on **OK** to turn off the tool.



*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  |
|---|--|
| <i>Tool not listed in Tool panel drop down list.</i>                              | <ul style="list-style-type: none"> <li>- Do you have a tool configuration file?</li> <li>- Has the tool configuration file been copied into the correct folder? Refer to LoggerSuite manual about details of the directory structure.</li> </ul>   |
| <i>Tool configuration error message when powering on the tool.</i>                | <ul style="list-style-type: none"> <li>- Check all connections.</li> <li>- 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).</li> </ul>  |
| <i>Tool panel - No current.</i>   | <ul style="list-style-type: none"> <li>- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system.</li> <li>- Verify cable head integrity.</li> <li>- Verify voltage output at the cable head (it should be 120V for ALT tools).</li> </ul>   |
| <i>Tool panel - Too much current (red area).</i>                                  | <p><b>! Immediately switch off the tool !</b></p> <ul style="list-style-type: none"> <li>-Possible shortcut (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity.</li> <li>- 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.</li> <li>- If the above shows no issues, use the test cable provided by ALT to verify the tool functionality.</li> <li>- If the problem still occurs, please contact service centre.</li> </ul> |
| <i>Telemetry panel - status shows red.</i>  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3).</li> <li>- If problem cannot be resolved contact support@alt.lu .</li> </ul>  |
| <i>Telemetry panel - memory buffer shows 100%.</i>                                | <ul style="list-style-type: none"> <li>- 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.</li> </ul>  |
| <i>Telemetry panel – bandwidth usage shows 100%.<br/>(Overrun error message.)</i> | <ul style="list-style-type: none"> <li>- Set the baudrate to highest value allowed by your wireline configuration.</li> <li>- Reduce logging speed, decrease tool resolution, adjust tool parameters and/or increase vertical sample step.</li> </ul>  |
| <i>Telemetry panel - large number of errors.</i>                                  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3).</li> <li>- Check bandwidth usage and telemetry error status.</li> </ul>   |

---

## 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.

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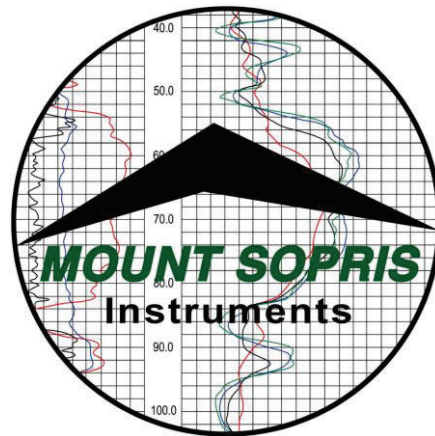
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# QL40-ELOG4/IP

## QL40-Normal Resistivity PROBE

## QL40-Induced Potential PROBE



**Advanced Logic Technology s.à,**  
**Mount Sopris Instrument Co., Inc.**

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## General Information

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### 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:

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### 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:  $\pm 18$  V  
Resolution: 0.5 mV  
Accuracy:  $\pm 2.5$  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:

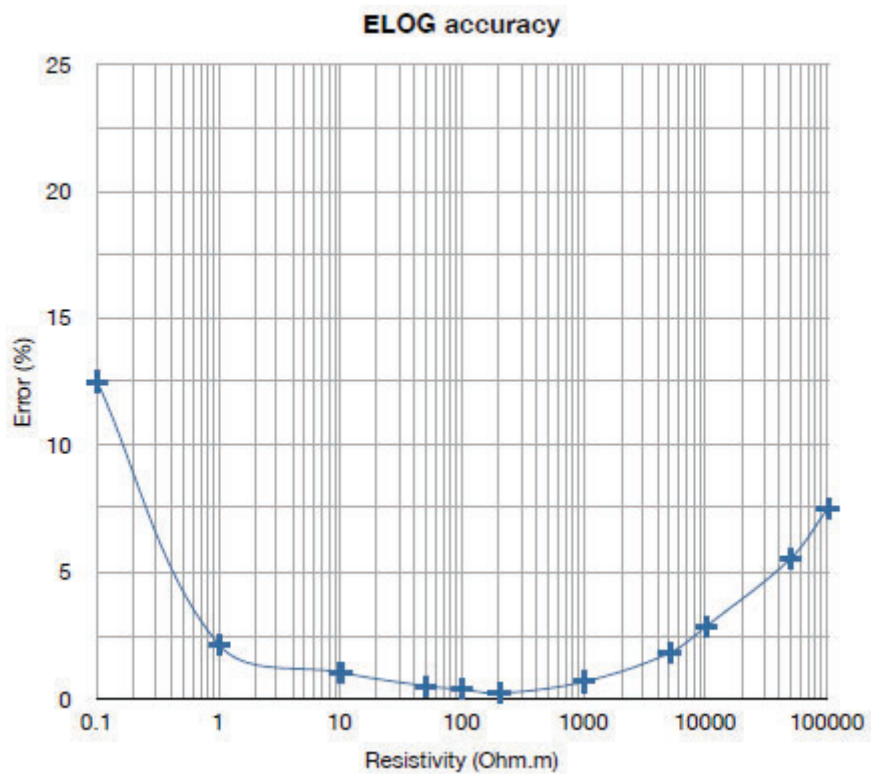


Figure 1



## Principal of Operation-QL40-ELOG in E-LOG mode

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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 ( $I/\text{cross-sectional area}$ ) 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  $12.5 \cdot \text{AM spacing}$ . Note that for normal resistivity measurements, the result is true resistivity,  $\rho$ , expressed in ohm-m<sup>2</sup>/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 same lower configuration 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.



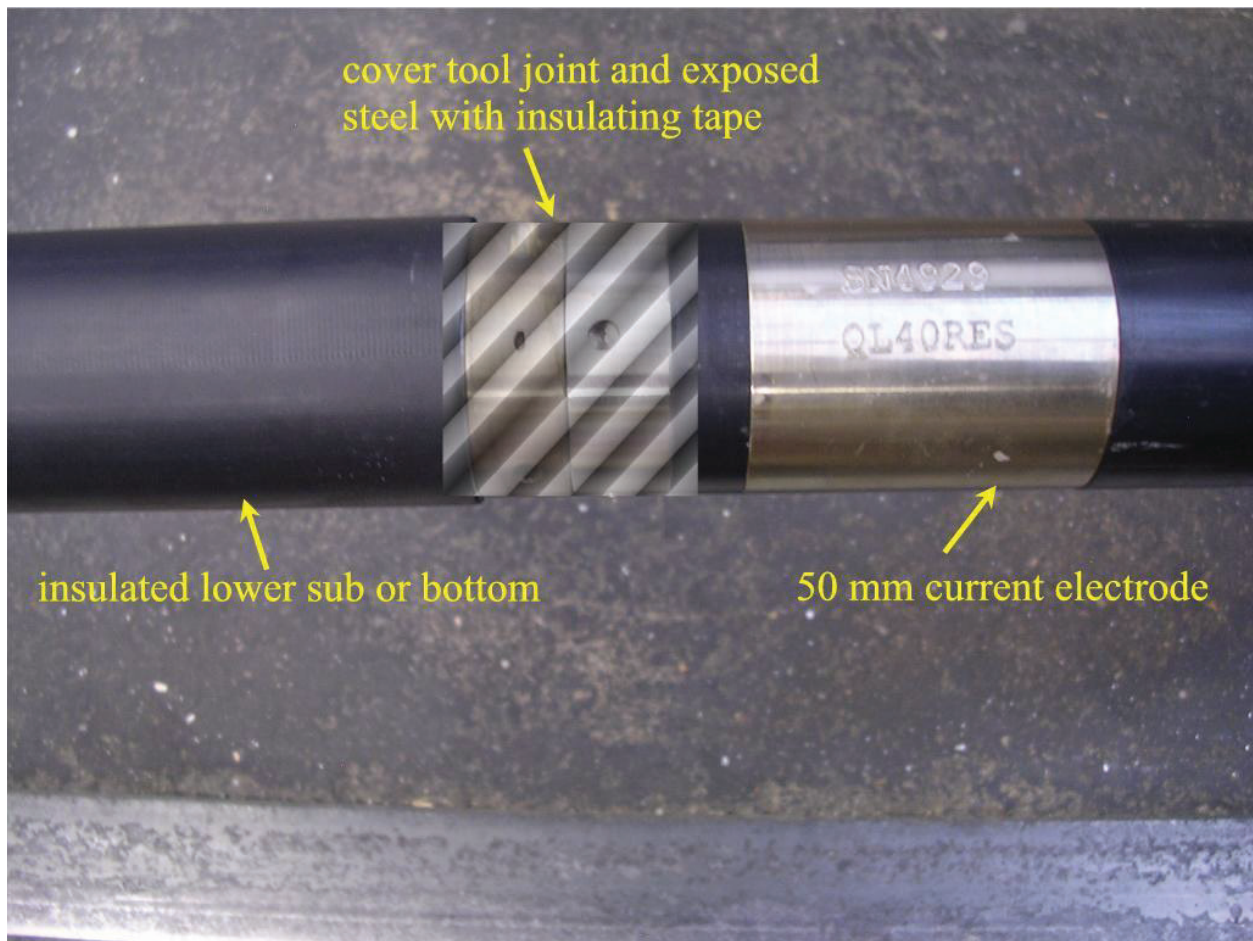
Figure 5

### 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:

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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  $\mu$ volts  
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 **linear / logarithmic 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

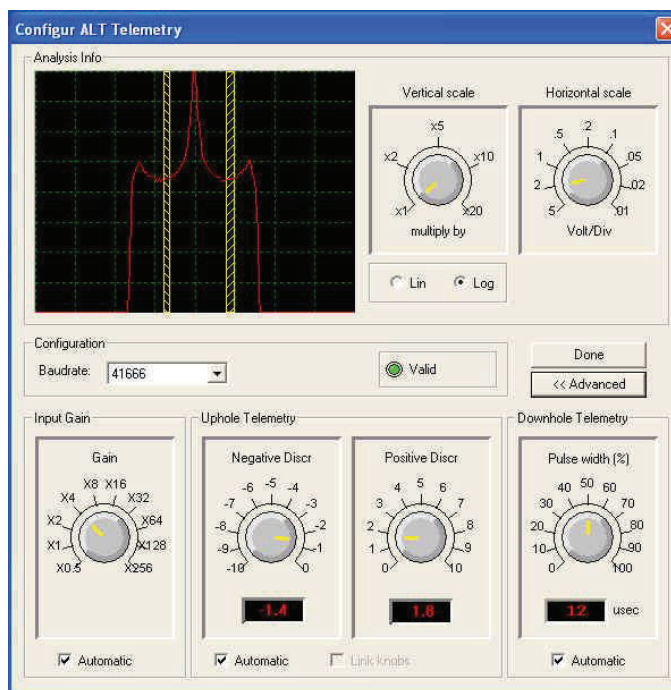


Figure 8

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:

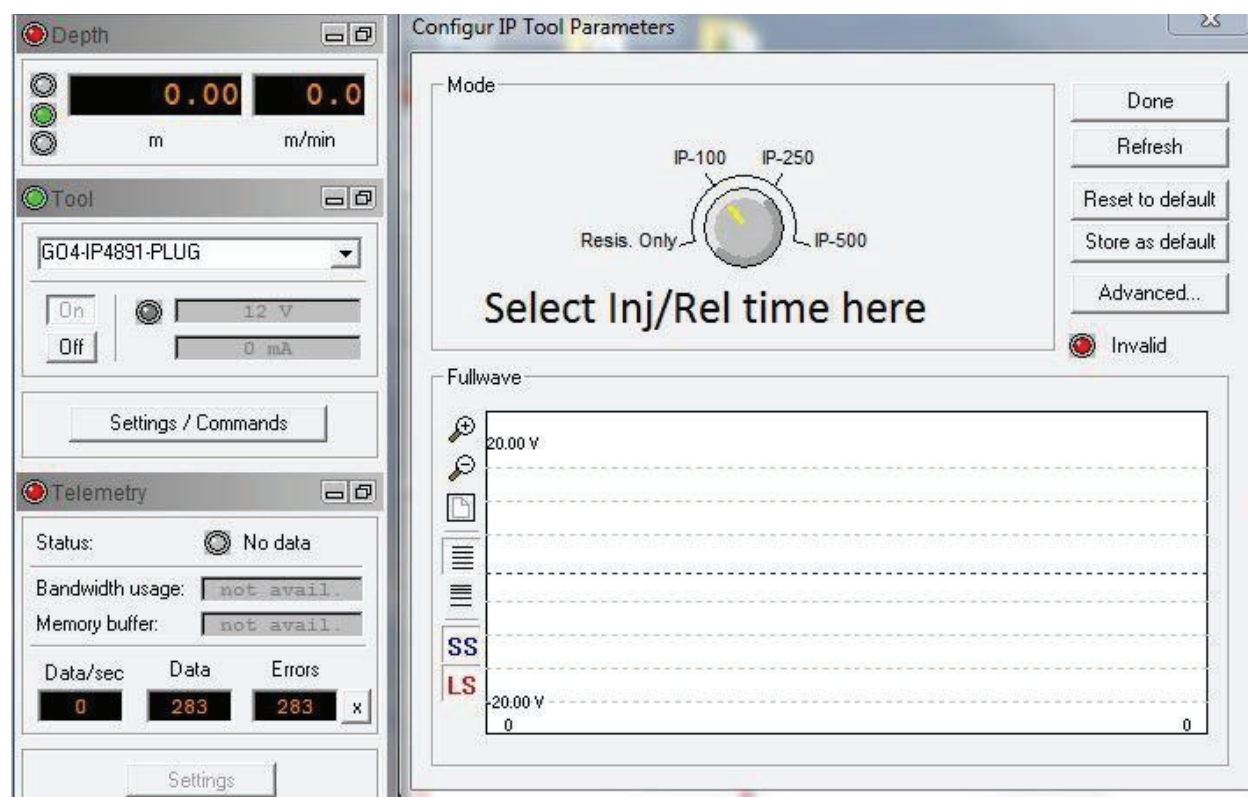


Figure 9

Note: The user can also operate the probe in Resistivity ONLY mode by selecting Res Only on the Configure 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 Config IP Tool Parameters window:

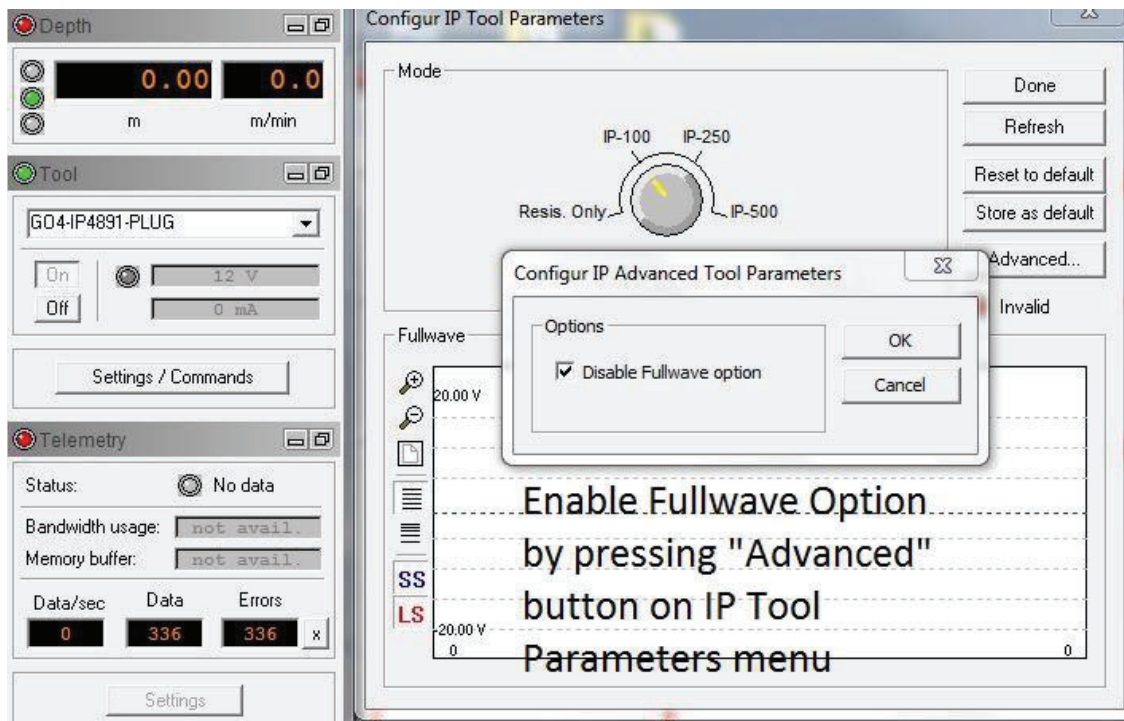


Figure 10

## 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:

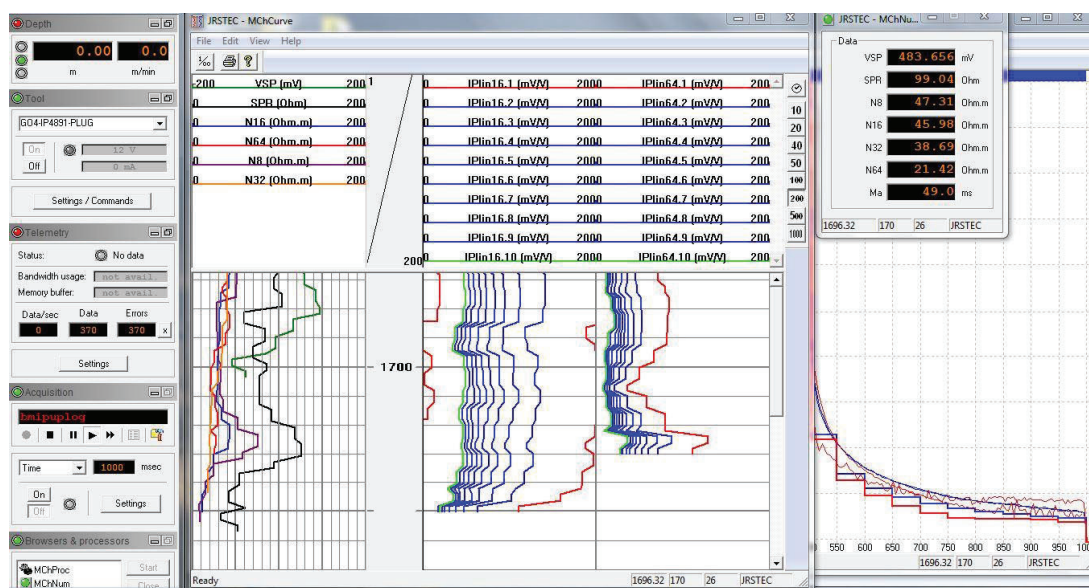


Figure 11

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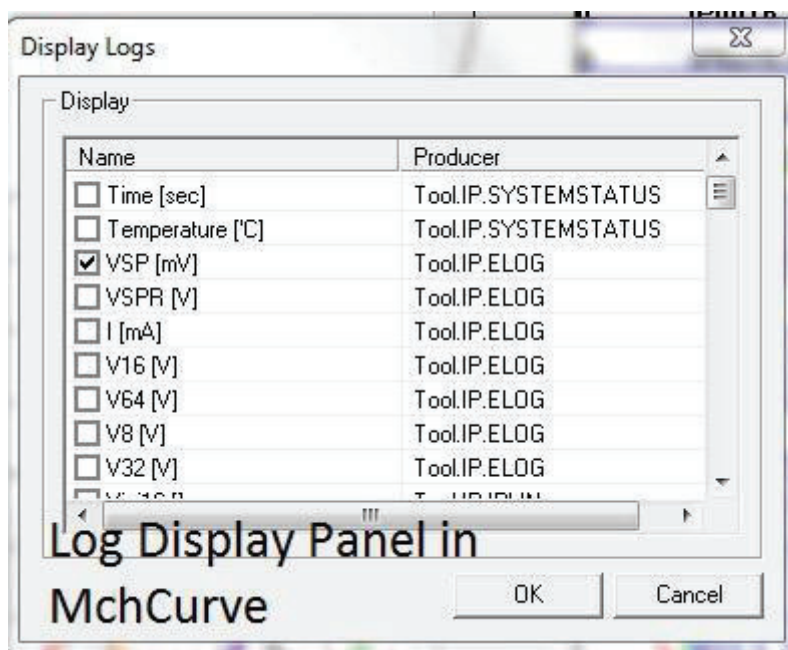


Figure 12

Similarly, the user can select which numerical data values to display in the MchNum browser using the same method:

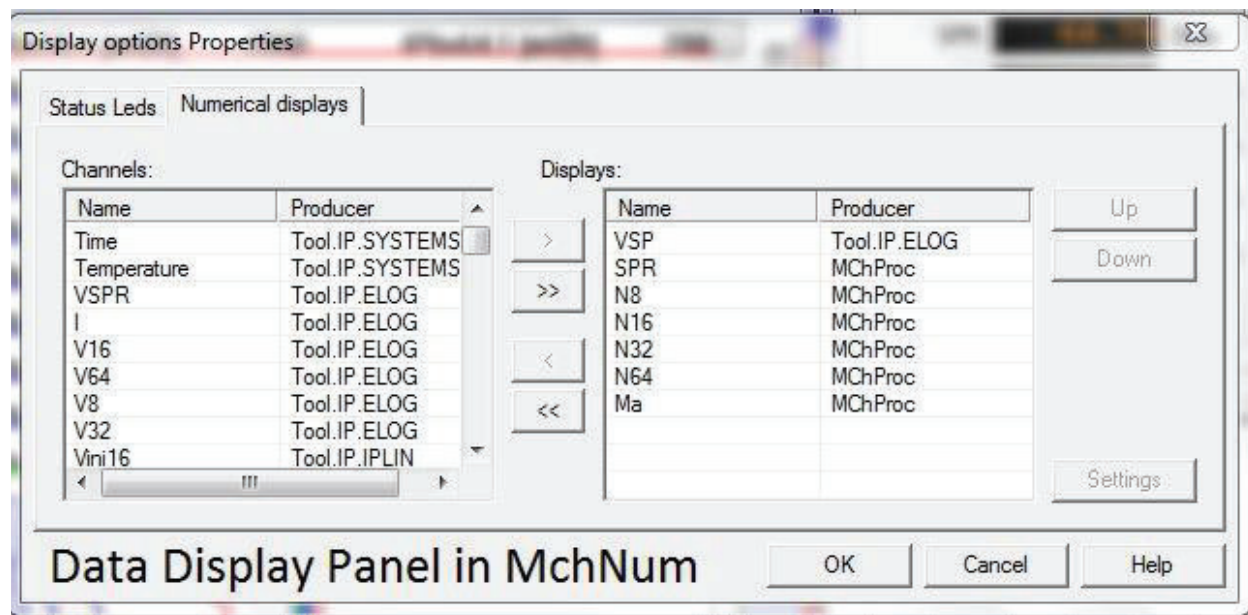


Figure 13

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.

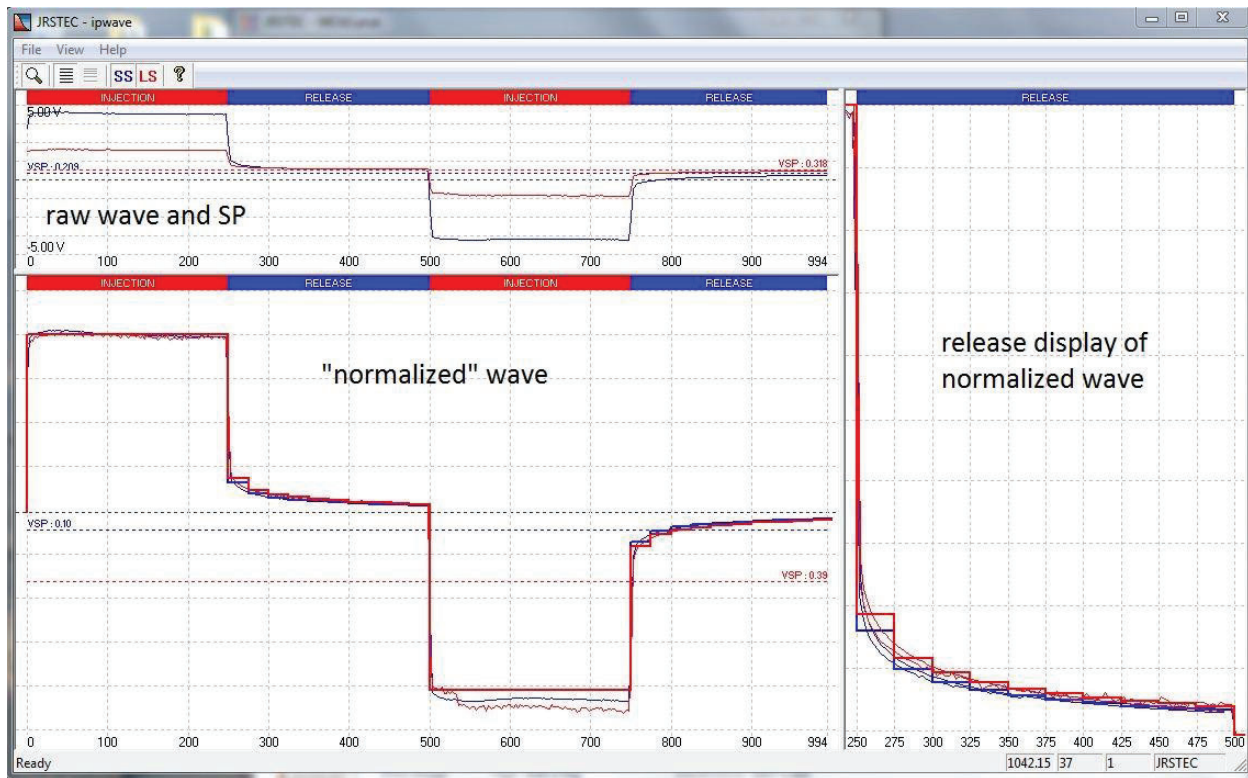


Figure 14

## Calculation of IP Chargeability Response

The chargeability, labeled  $M_a$ , 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  $M_a$  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.

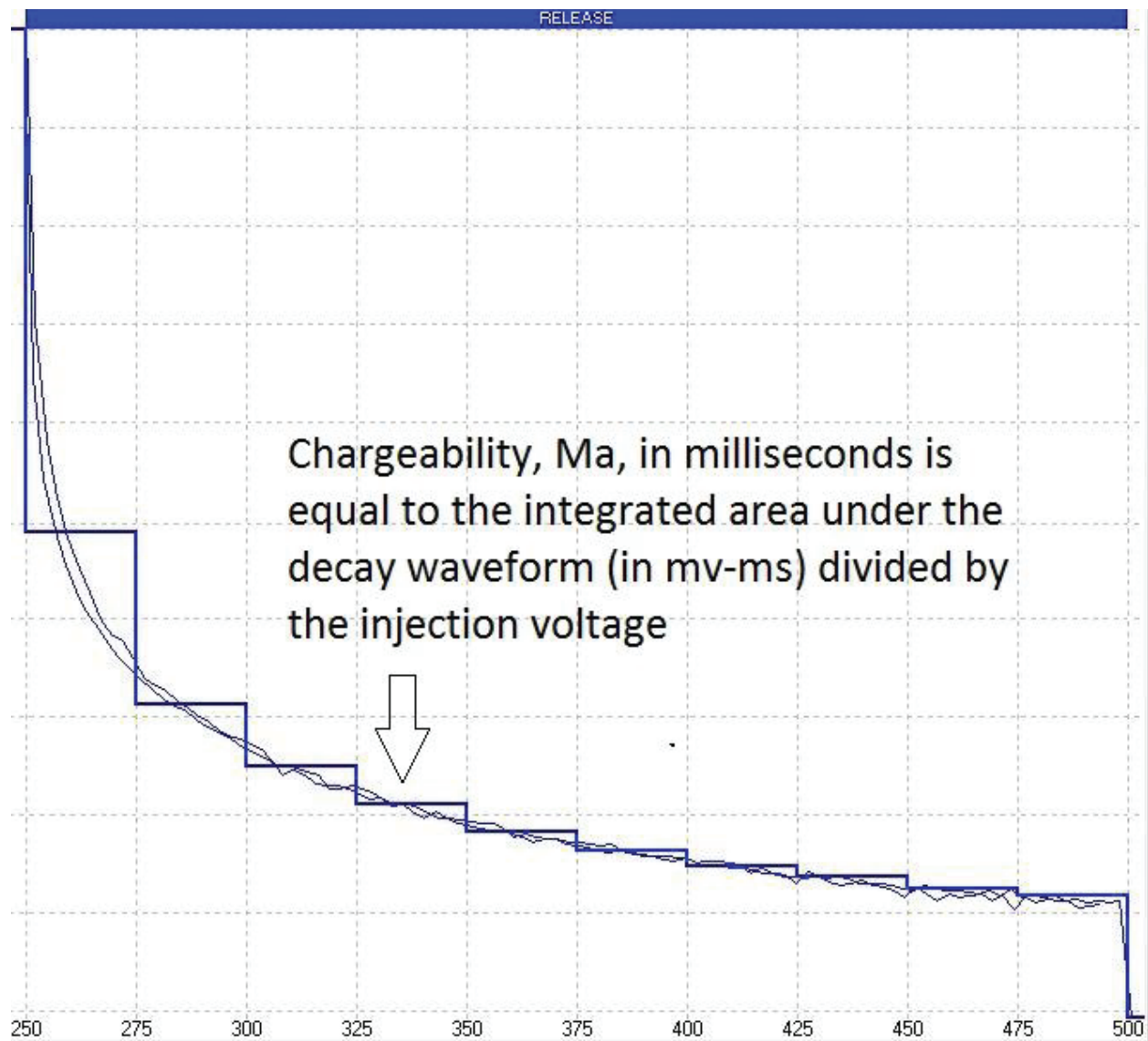
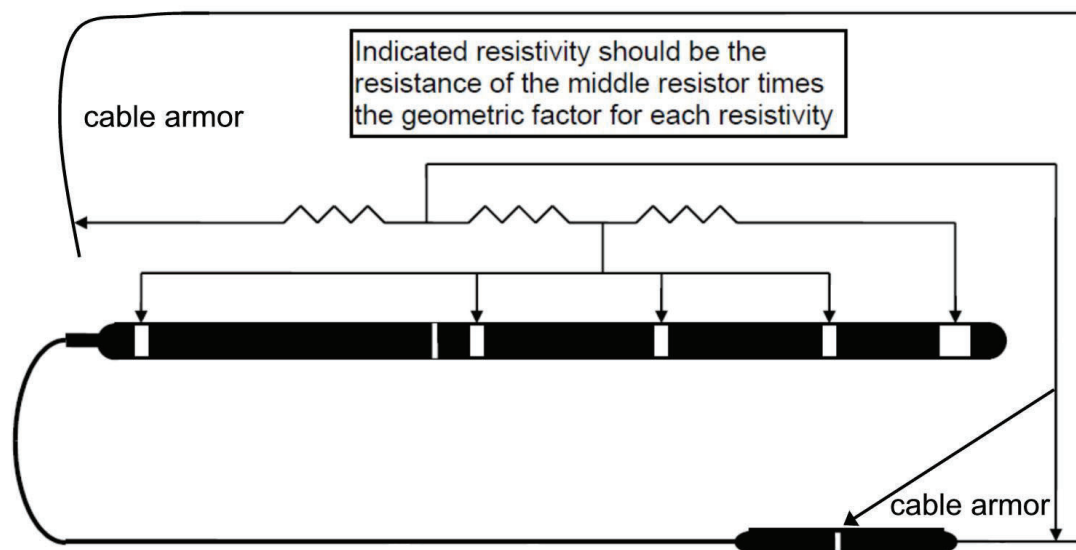


Figure 15

## 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

Calibration Settings

| Time | Temperature | VSP | VSPR | I   | V16 | V64 |
|------|-------------|-----|------|-----|-----|-----|
| V8   | V32         | SPR | N16  | N64 | N8  | N32 |

First Point

Reference: 0.5 Ohm.m

Value: 1.062302 cps

Sample... [Dropdown]

Second Point

Reference: 500 Ohm.m

Value: 0.066623 cps

Sample... [Dropdown]

Channel Calibration Factors

N16(Ohm.m) = 1.00434 x N16(cps) + -0.0669129

Compute Store Unit

Calibration date:

Options... Export... Close

**Figure 17**

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## 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.

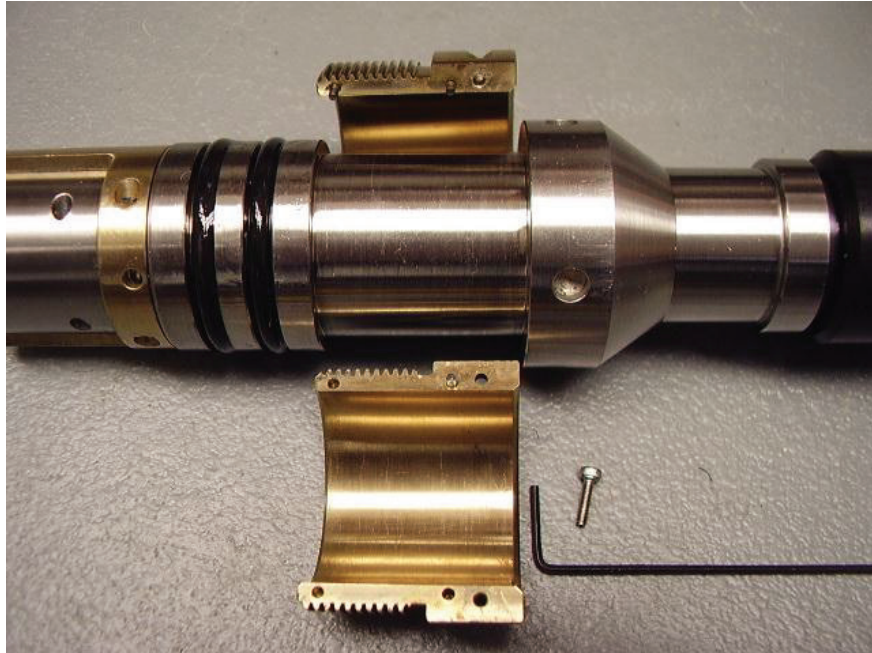
*Do this carefully to prevent bending the guide pins.*



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.

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**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

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### 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, there 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 it is highly recommended that any service be performed by Mount Sopris, ALT or a qualified technician.

## Appendix

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### 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.

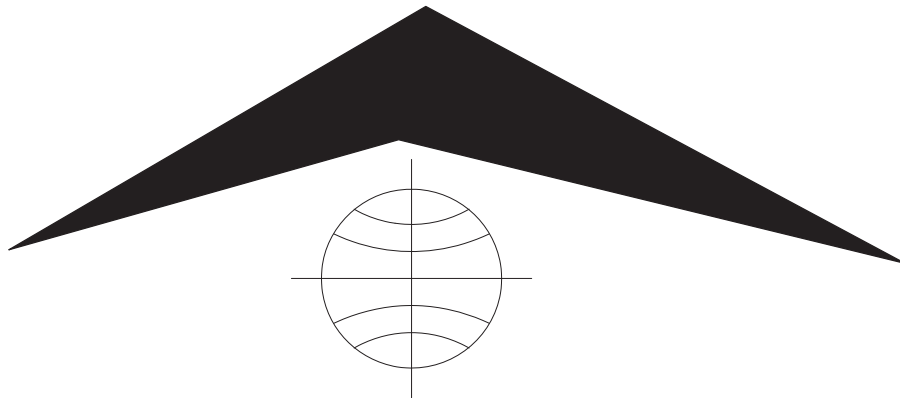
The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter 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

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## **General Information**

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### **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 devices 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:**

| <u>Pin</u>              | <u>Signal</u>       | <u>Origin</u>    |
|-------------------------|---------------------|------------------|
| 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:**

| <u>Pin</u> | <u>Signal</u>           | <u>Origin</u>           |
|------------|-------------------------|-------------------------|
| 1          | Signal from sensors     | Top thermistor          |
| 2          | Connection to heat grid | High voltage capacitors |
| 3          | For future use          |                         |

**BOTTOM BULKHEAD:**

| <u>Pin</u> | <u>Signal</u>            | <u>Origin</u>     |
|------------|--------------------------|-------------------|
| 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**  
○  
**ARMOR**  
○ **SURFACE  
ELECTRODE**

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 from 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 too 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.

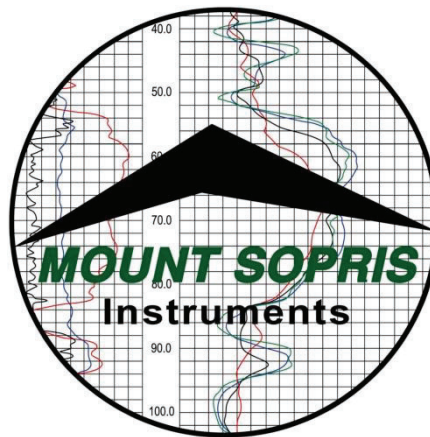
When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper 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.**

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March 21, 2013

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# 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

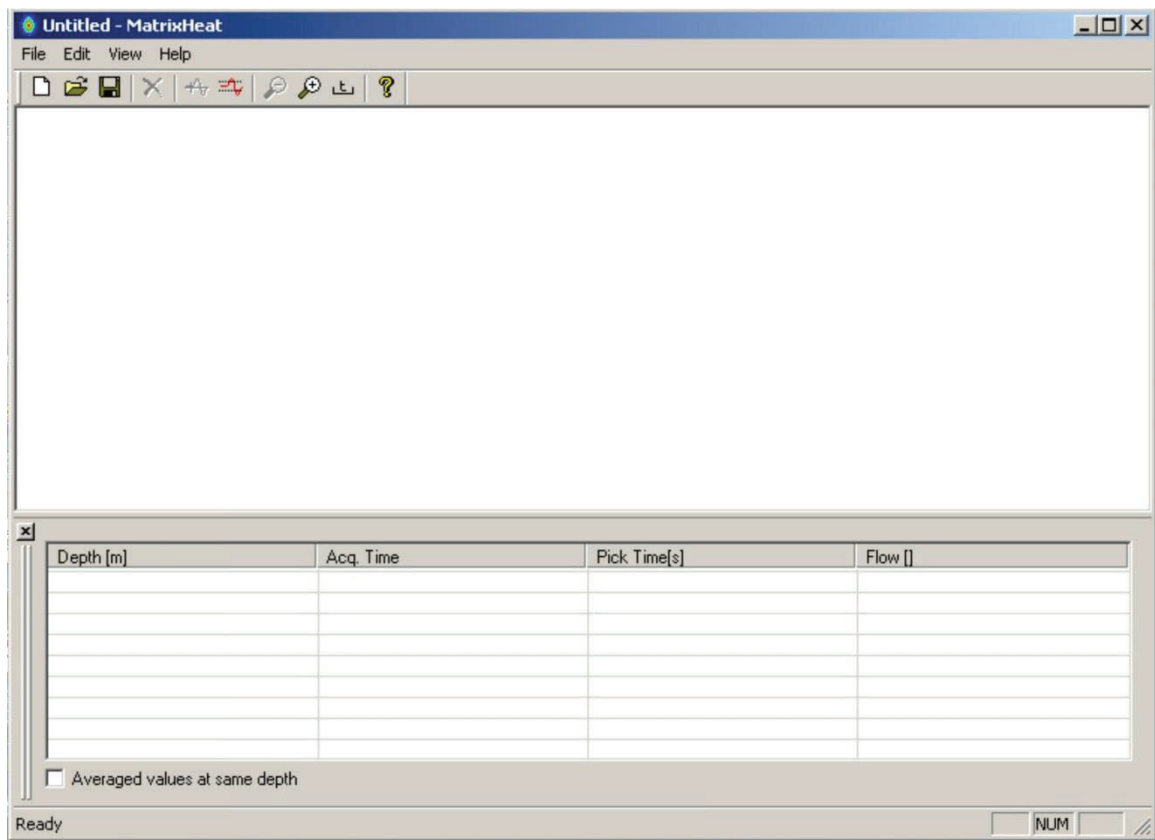
### I. Introduction

The MatrixHeat software is a stand-alone product. It is required when operating the Mount Sopris Heat Pulse flowmeter on the Matrix logger.

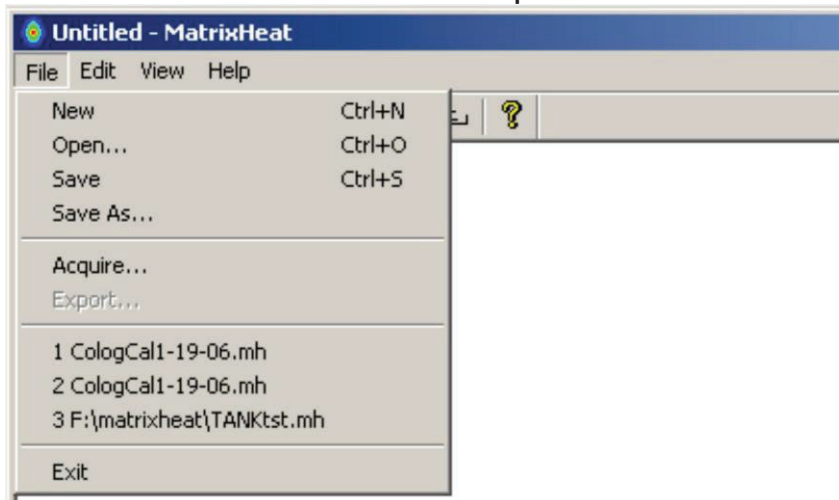
MatrixHeat version 3.2.67 or later is required for operation on Windows 7 and Windows 8.

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:

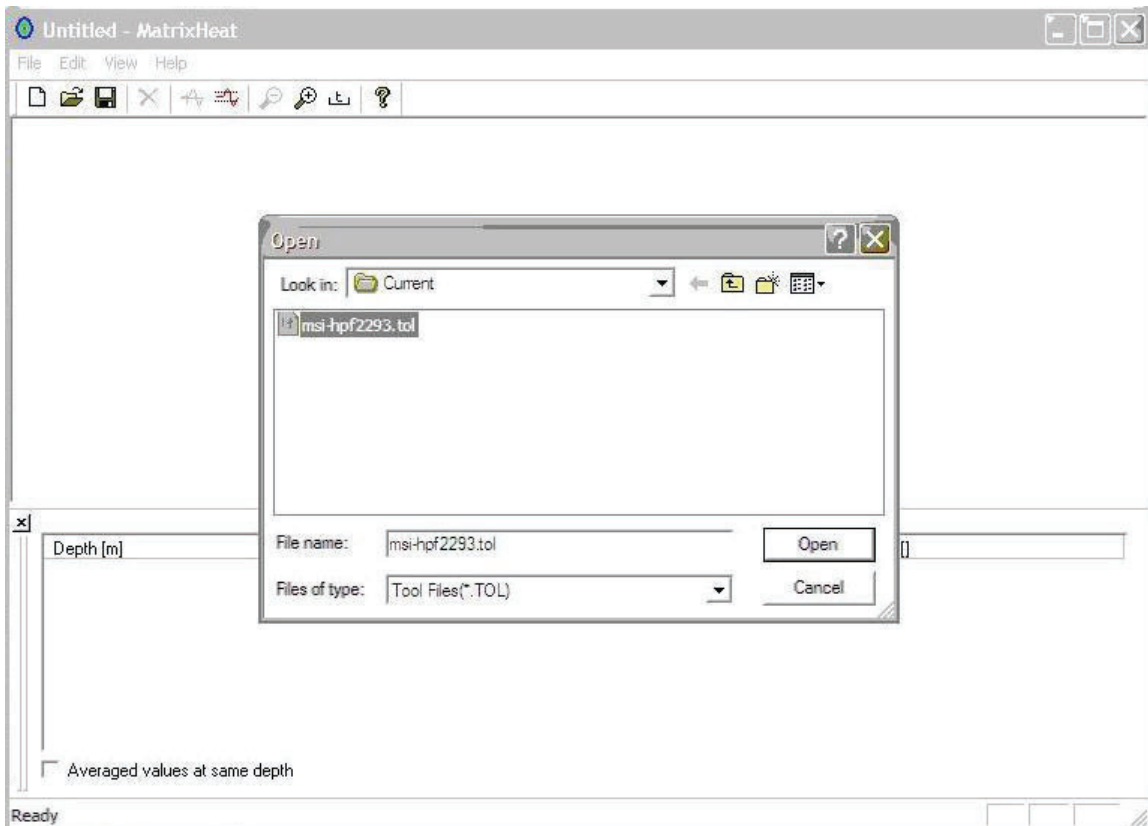


To begin, click on File on the top menu bar:



To connect with the Matrix logger, select **Acquire**.

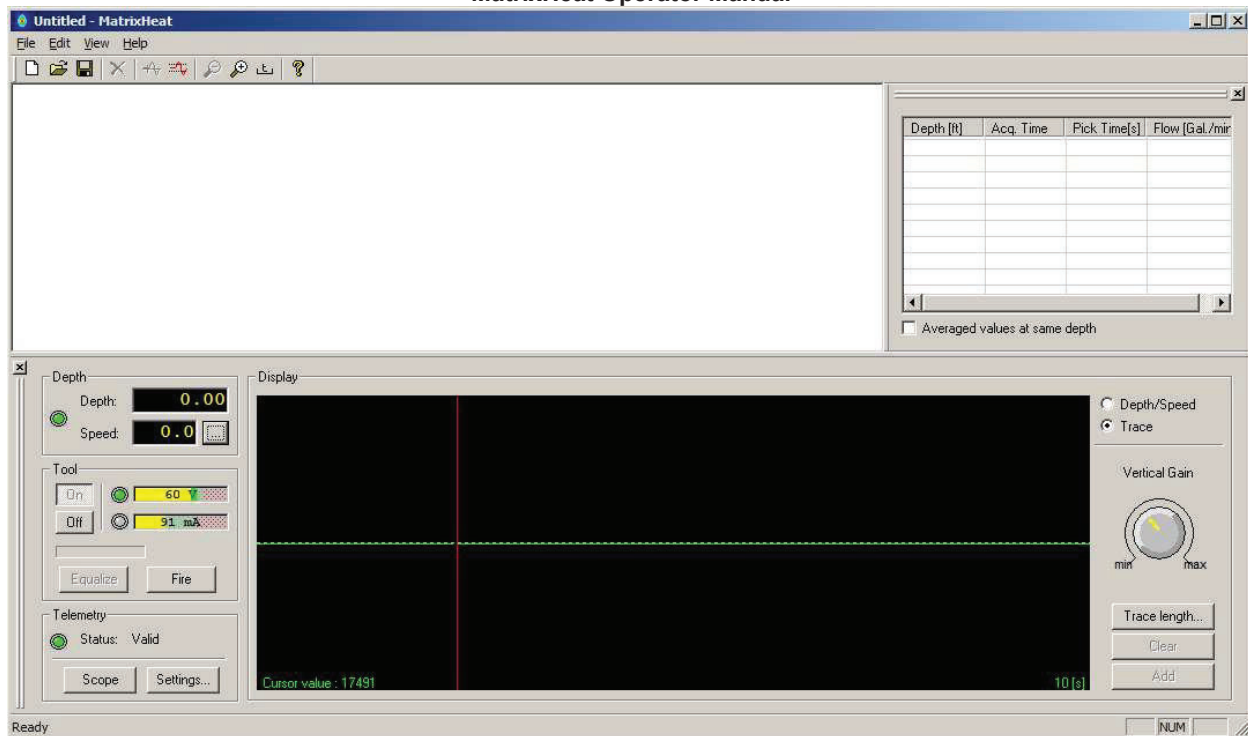
You will be asked to provide a tol file; you should see the HFP2293\_mtx.tol TOL file listed. If not you will need to navigate to /MatrixHeat/Tol/Current. This tol file is specific to MatrixHeat software, and should only be installed in the /MatrixHeat/Tol/Current directory. Do not install any other 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

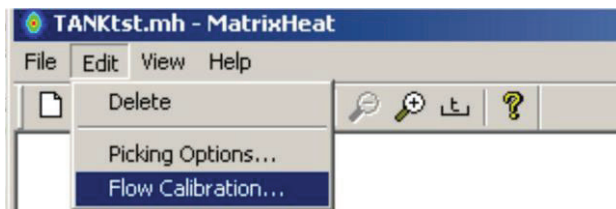
Once all winch settings have been confirmed, the probe may be powered up using the Tool On/Off button on the left side of the screen. The correct power settings are read from the Tol file, and are automatically adjusted depending on the wireline type and length. In general, the probe operates on 60 VDC 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

For the Flow Calibration button to be active the probe must be fired at least one time and the data added (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:

**Flow Process**

Flow =  $K1/DT + K2/DT^2$  Units: Gal./min.

OK  
Cancel

Up Flow Calibration

Flow: 0.1 Delta Time: 0.63 s  
Flow: 0.02 Delta Time: 18.5 s

Compute K1: 0.380823  
K2: -0.200229

Down Flow Calibration

Flow: -1 Delta Time: 0.6 s  
Flow: -0.02 Delta Time: 19.1 s

Rem: Down Flow uses negative flow values

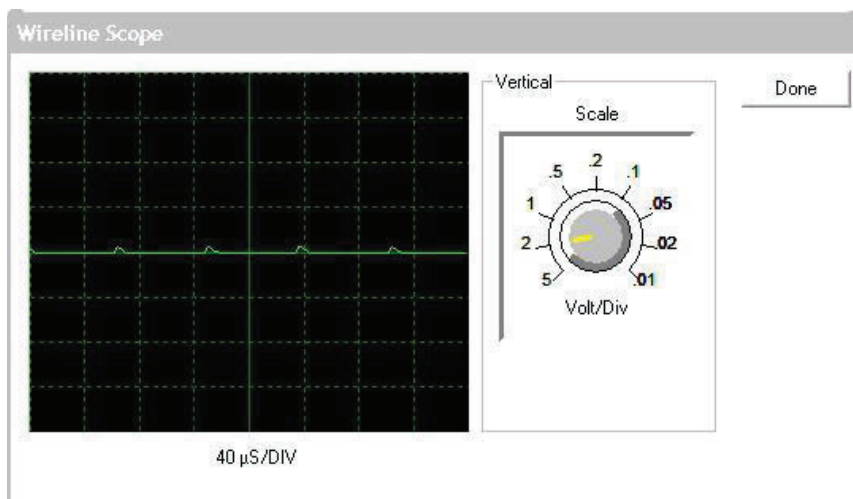
Compute K1: -0.37493  
K2: -0.135042

☐ Update tol file

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:

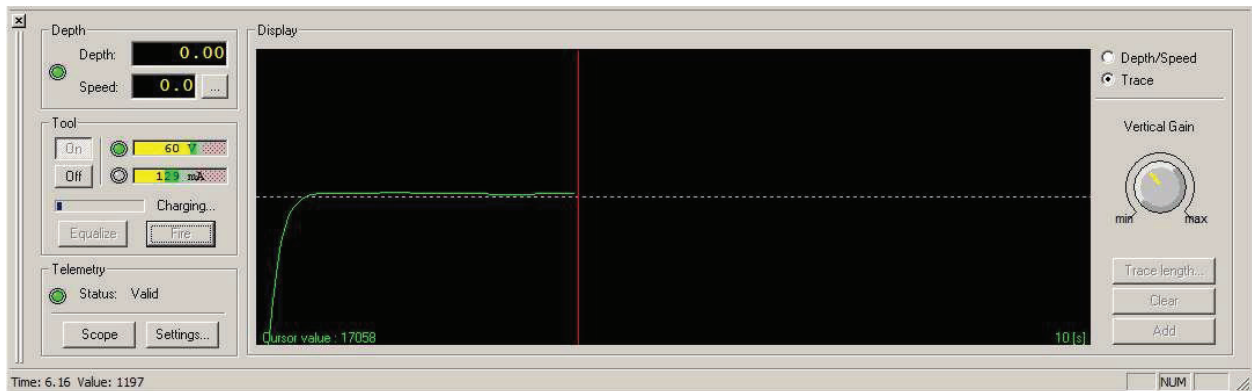


Probe data consists of a ~20 kHz positive pulse stream on the wireline, which will vary with the response of the sensor pairs to presence of a heat pulse moving past. If you don't see this kind of data on the wireline scope screen, the probe is not sending data.

After confirming that the probe is sending data, the user should check the main data display

## MatrixHeat Operator Manual

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.

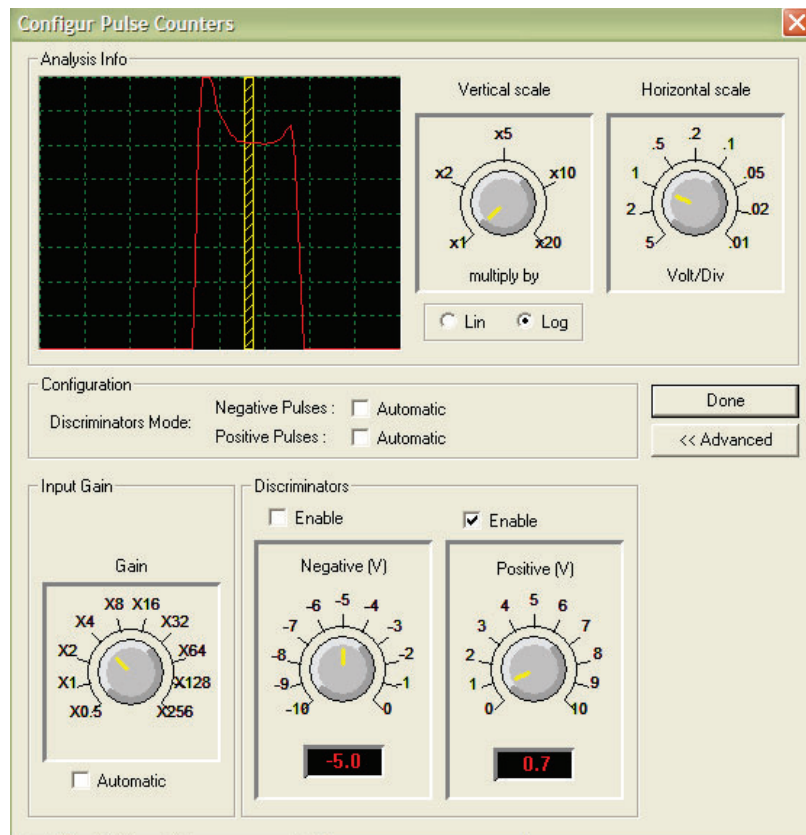


### c) Adjusting the modem

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

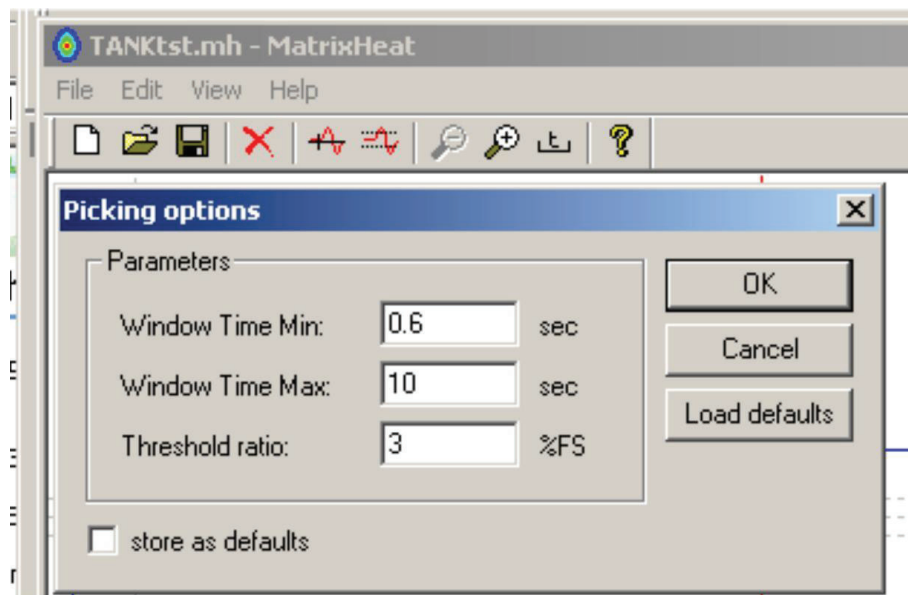
Before firing the probe, the operator should set the picking options to match the estimated heat pulse arrival time. In a new well, with no information, it is best to set the parameters so that a long time interval is available. Two Time Sample settings are required. One is in the Flow Pick window, and 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:

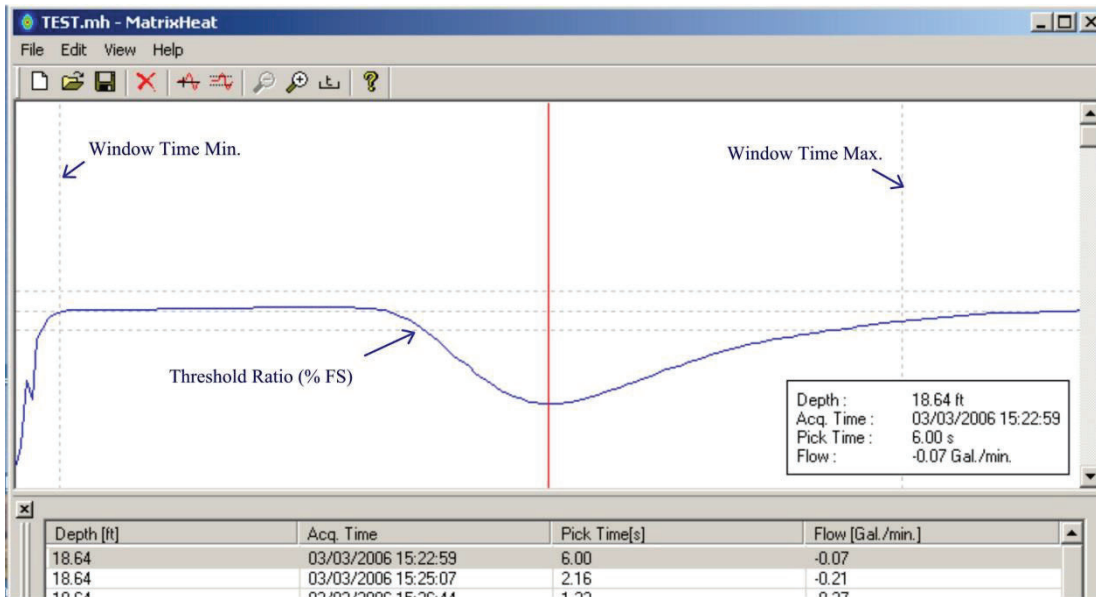


The **Window Time Min** value should be kept low, in general. It is the minimum time after which a pick will be allowed. Normally, there is no measurable flow before 0.6 seconds, as the flow is so fast that the sensors cannot see the heat pulse.

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:

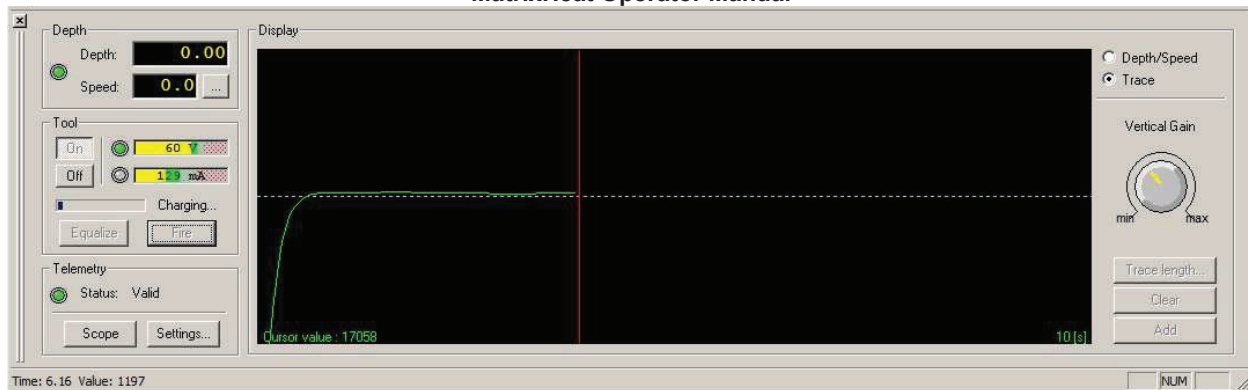
This time scale is the maximum time scale that will be displayed on the Flow Picking screen. This Time Scale is not the same time scale that is presented on the Shot Window, which is described in the following section

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.

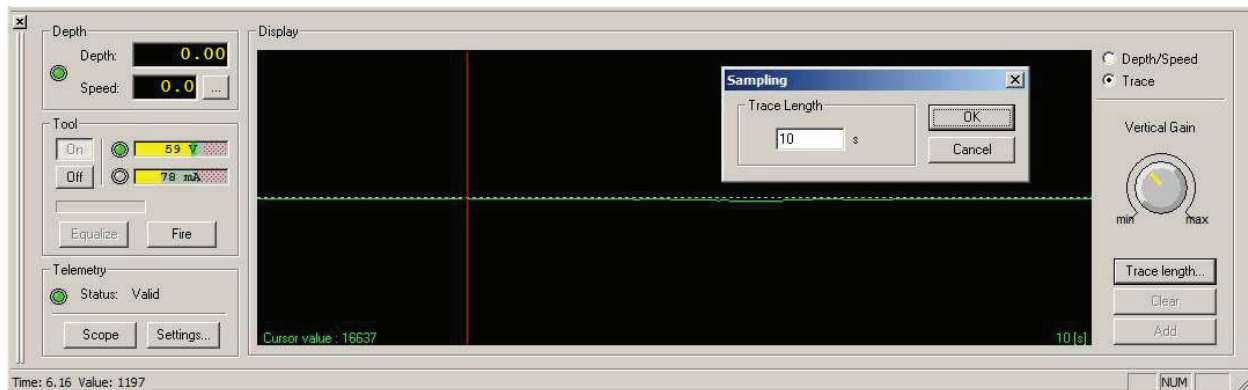
## b) Firing

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.

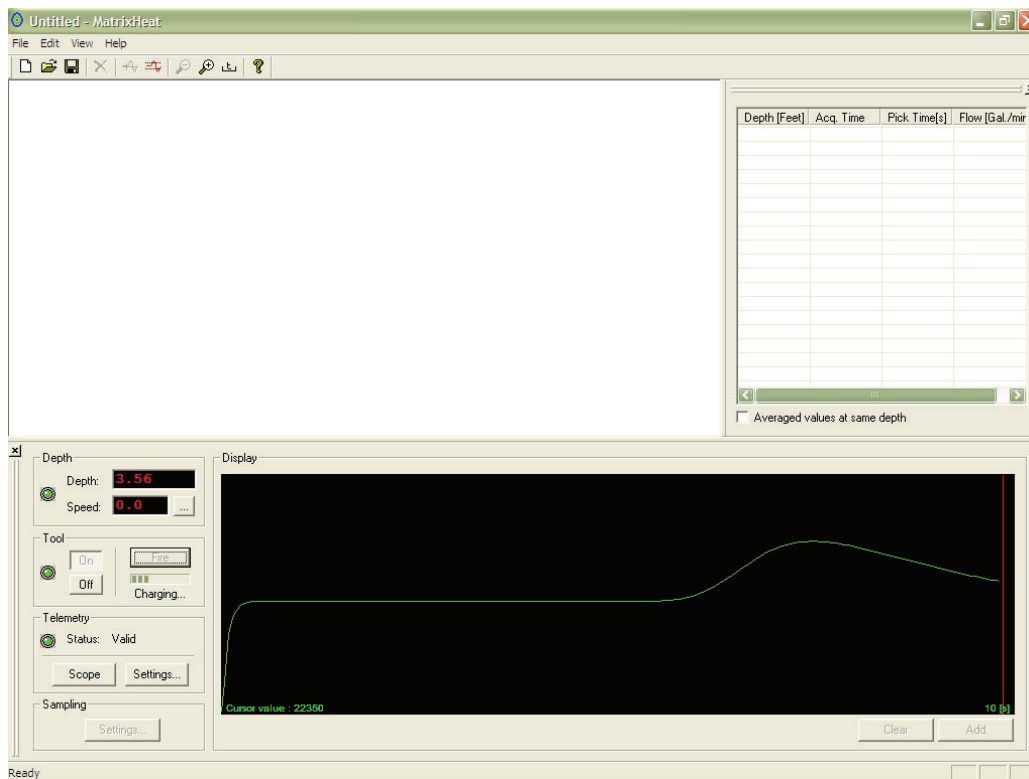
If the trace goes off the top or bottom edge as it draws across the screen turn the Vertical gain dial counter clockwise towards **min** to shrink the trace size. To increase the trace size, turn the dial clockwise towards **max**.

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.

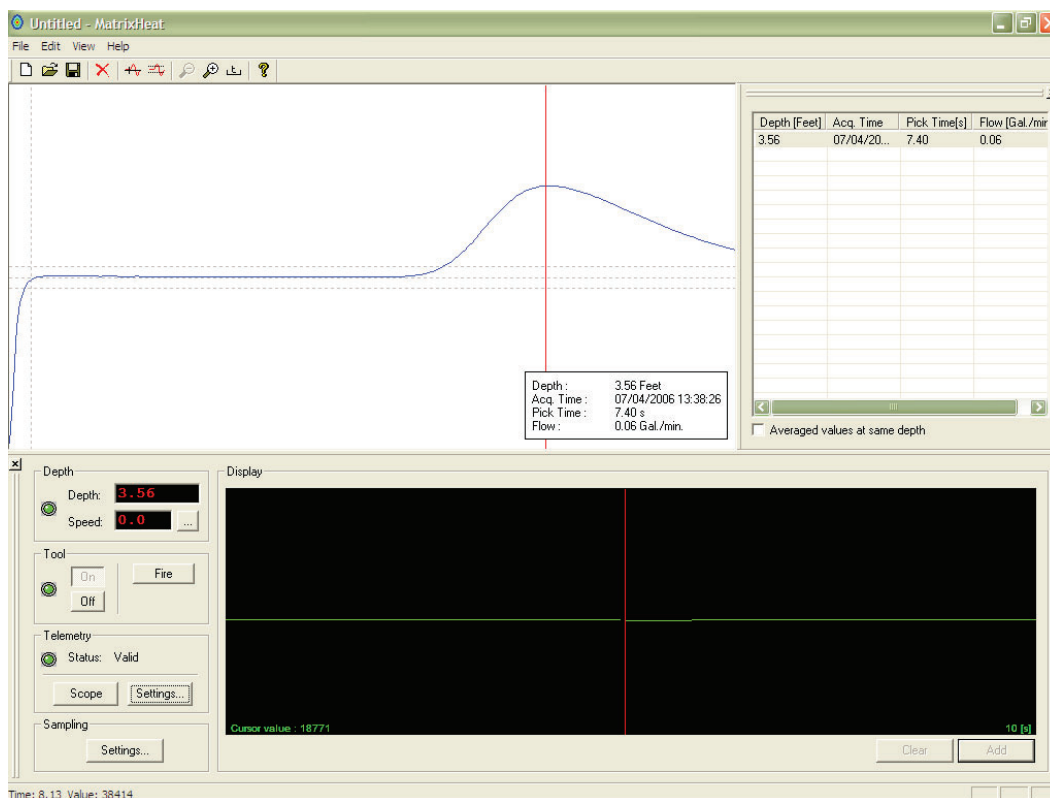
If the shot record appears to indicate a successful flow event, the operator should press the **Add** button at the lower right hand corner of the shot window. If the record is questionable, it can be deleted from the display with the **Clear** button.

An example of a real time shot record is shown on the following page.

## MatrixHeat Operator Manual

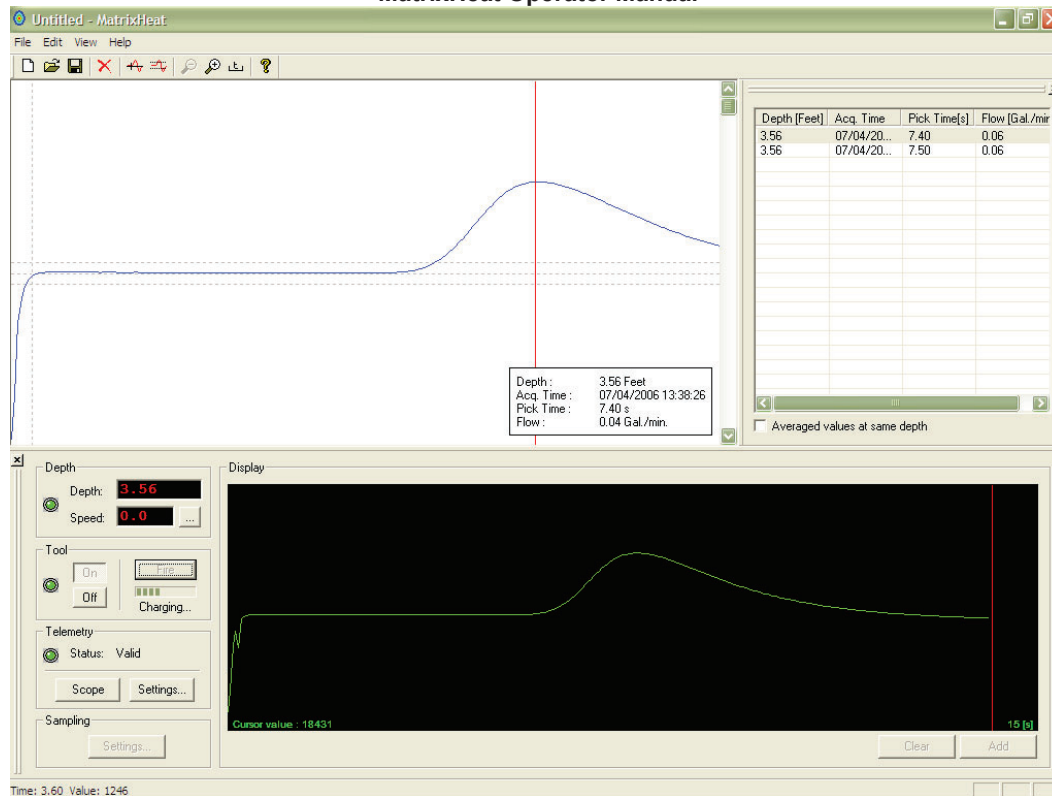


This sample record appears to be valid, so it is added to the Pick Window register by clicking the Add button. The record is then moved into the Pick register table, which shows the pick information and calculated flow rate for the current shot.



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.

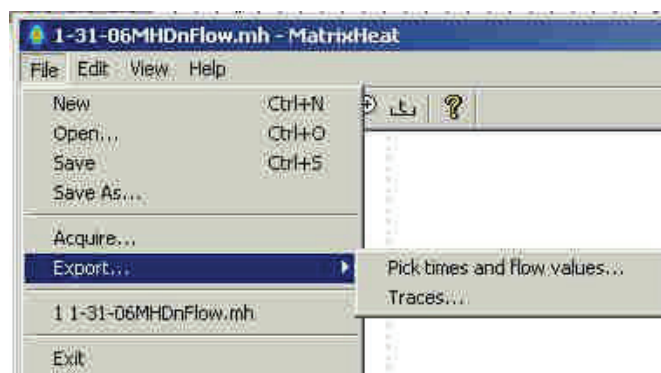
## IV. Exporting Data

After a data file has been created, it should be saved as \*.mh file, by clicking on the task bar File selection, and on Save or Save As. This the data in a binary file that then be displayed or re-processed using MatrixHeat.

To obtain a text version of the results, for use in other programs such as WellCAD, Excel, select File,

Export...Pick times and flow values, as shown in the image below:

Example of exported \*.txt file



an  
main  
then  
saves  
can

data  
or

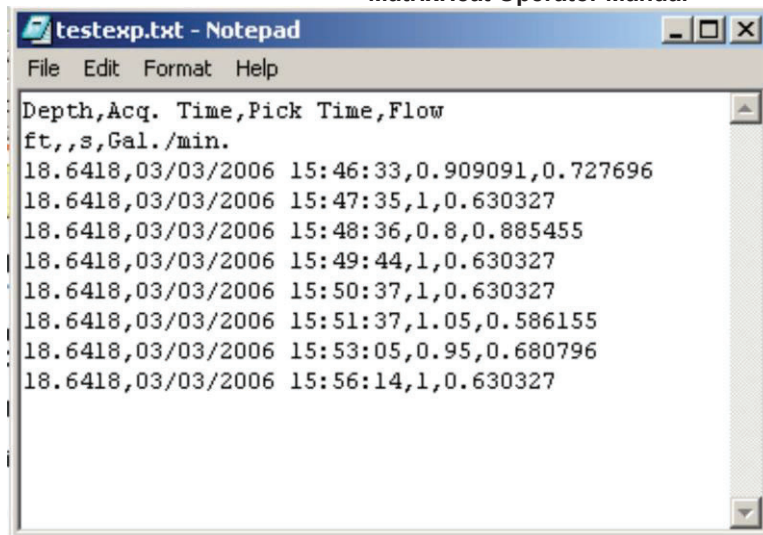


Figure 1 Export Pick times and flow values .txt file

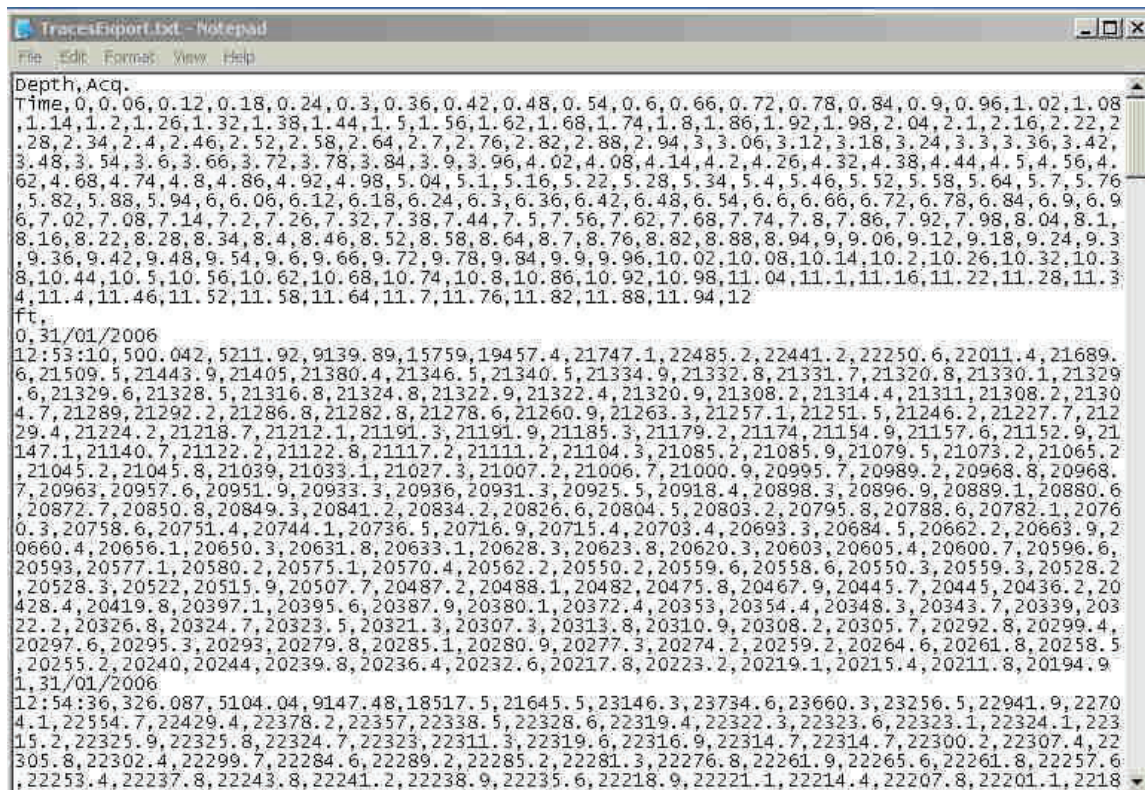


Figure 2 Export Traces .txt file

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.

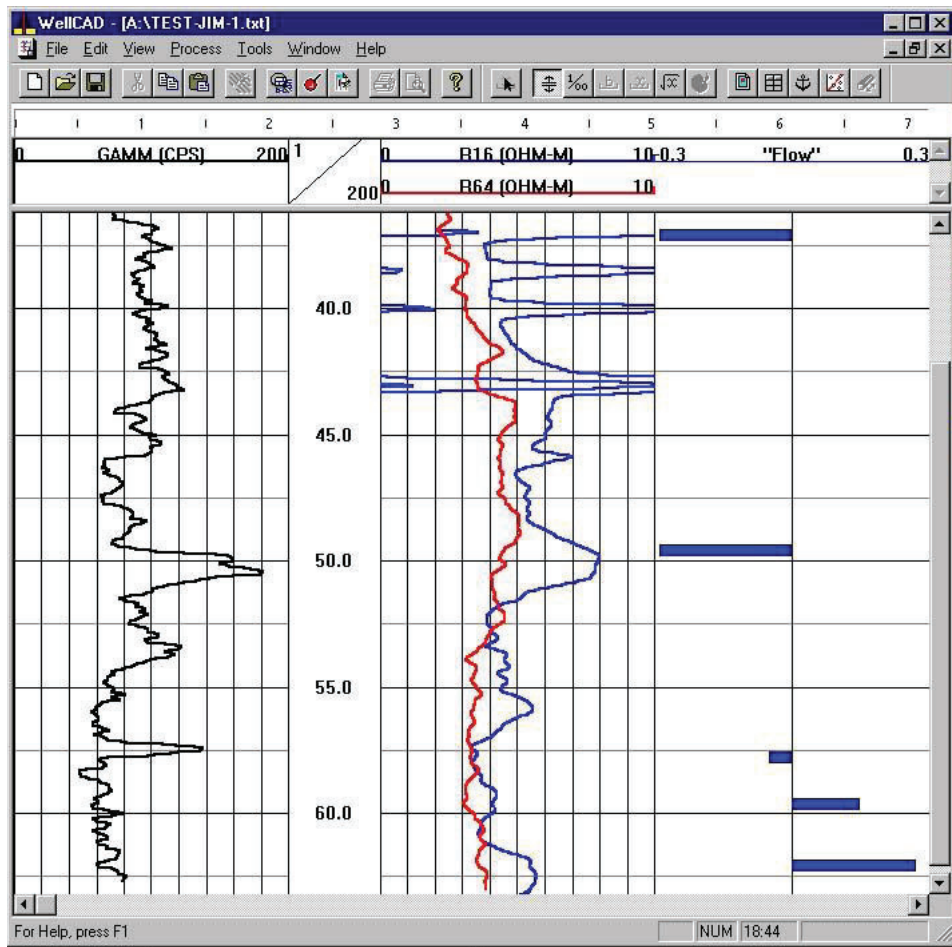
## V. Appendix

### 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.

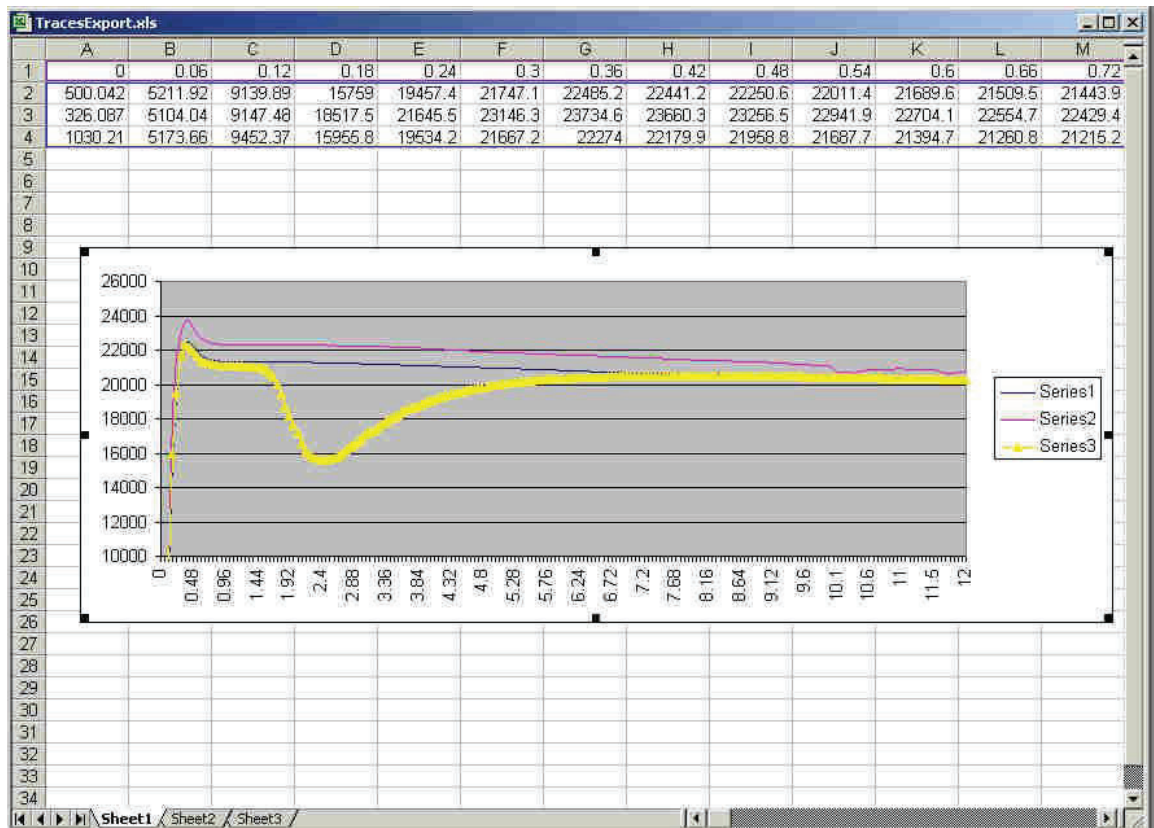
Delete the unnecessary logs (time, speed) if desired. Set the depth scale and track positions as usual. Save the resultant **.wcl** file and plot as usual.

### b) Example of WellCAD presentation of Heat Pulse Flow data as mud log





### c) Example of Excel presentation of exported traces



**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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# 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:

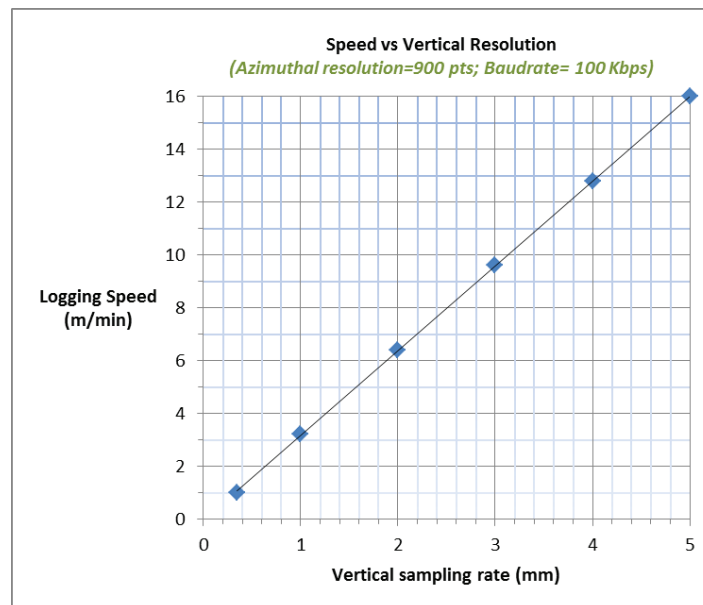
- ☐ *Detailed and oriented structural information*
- ☐ *Reference for core orientation*
- ☐ *Fracture detection and evaluation*
- ☐ *Breakout analysis*
- ☐ *Detection of thin beds*
- ☐ *Determination of bedding dip*
- ☐ *Lithology and mineralogical characterization*
- ☐ *Casing inspection*

## 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

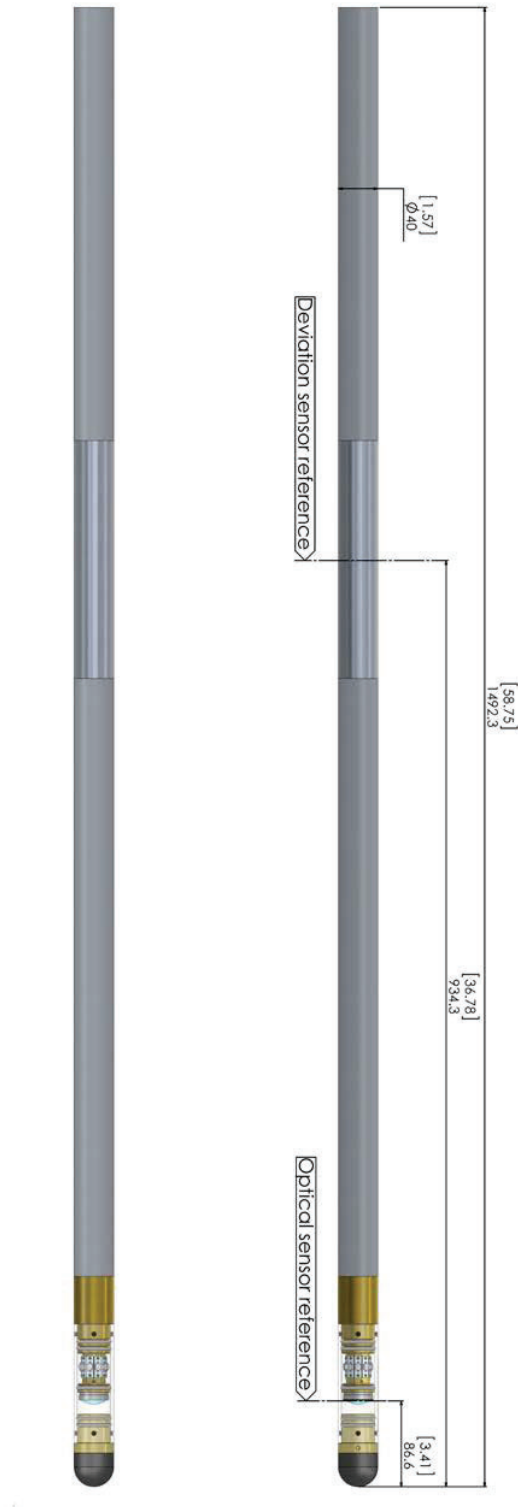


Figure 1-1 QL40 OBI-2G overview

## 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 |

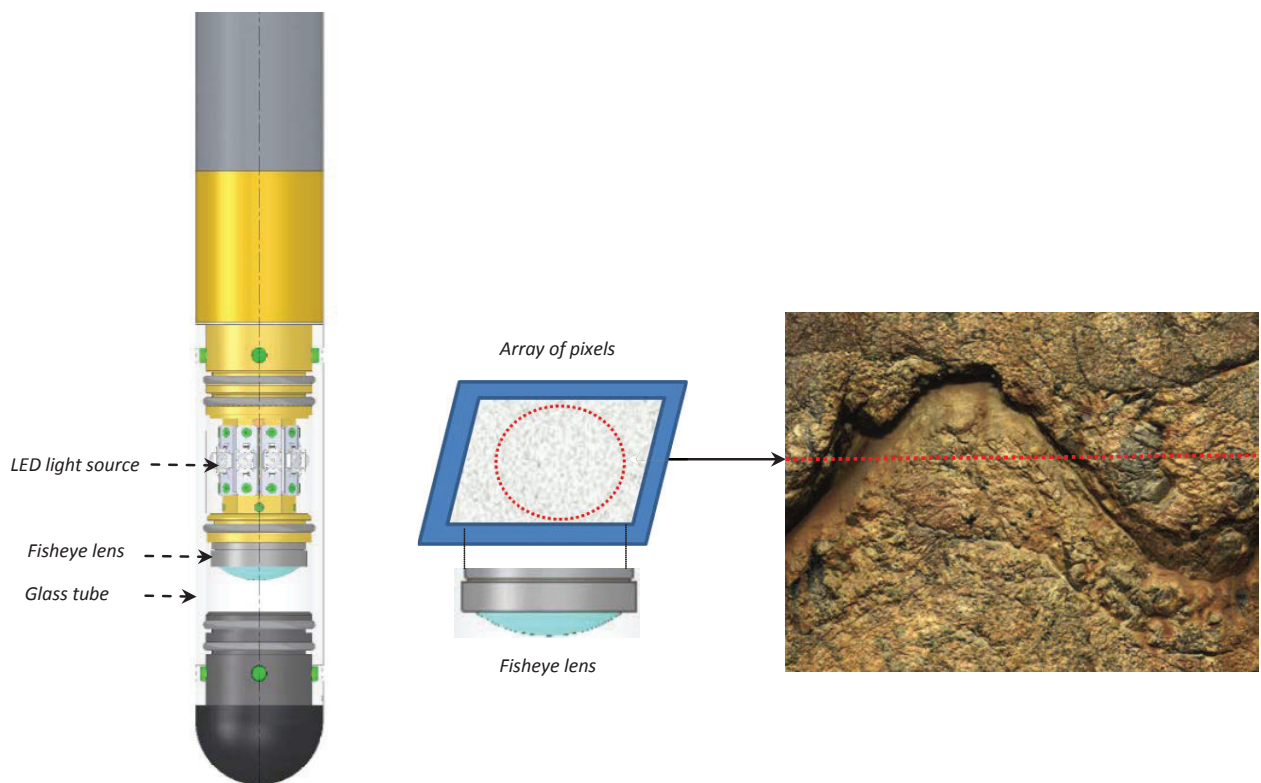
### Orientation sensor

|                   |   |
|-------------------|---|
| 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 **Quick Link** 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.

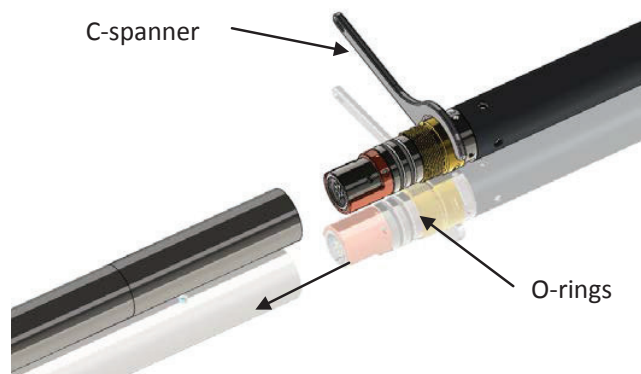
### Mid Sub

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.

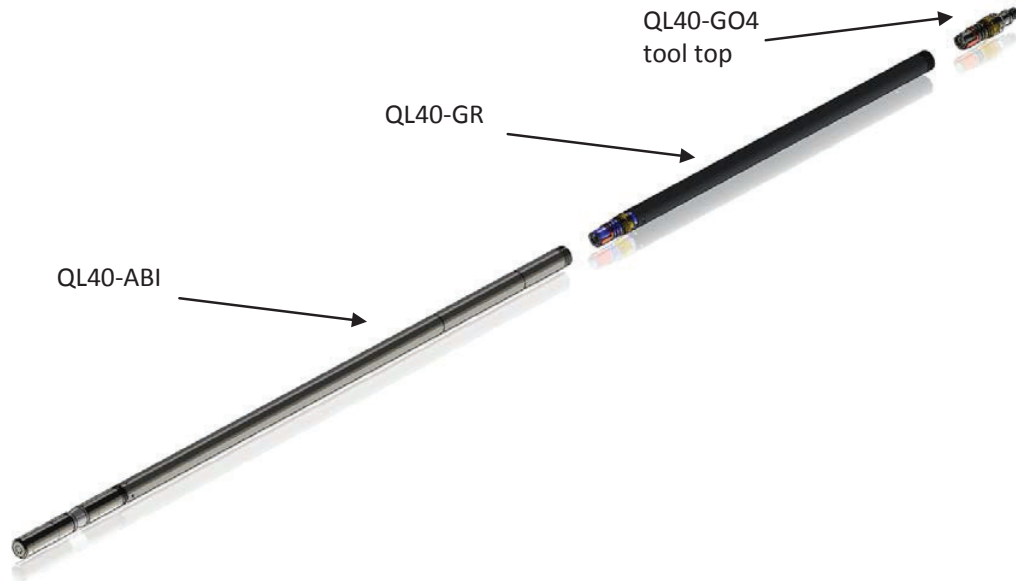
To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.



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

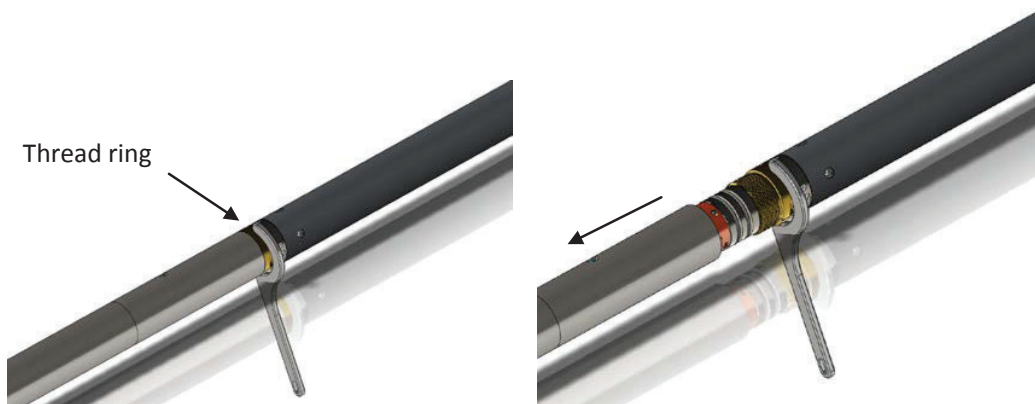


The following example of a QL40-ABI, QL40-GR and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GR sub stand-alone.



**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).

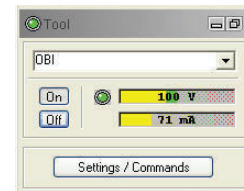


Figure 4-1 Tool panel

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).

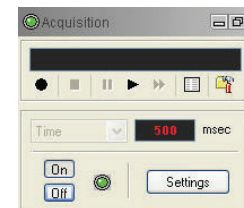


Figure 4-2 Acquisition panel □

6. □ Press the **Record** button in the **Acquisition** panel (Figure 4-2), specify a file name and start the logging.

7. □ **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%;
- □ Number of **Data** increases and number of **Errors** negligible.

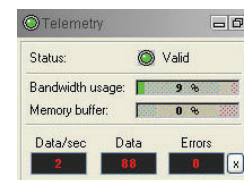


Figure 4-3 Telemetry panel

**In the OBI40Imq browser the processor "workload" and camera "frame rate" must stay below 100%**

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.

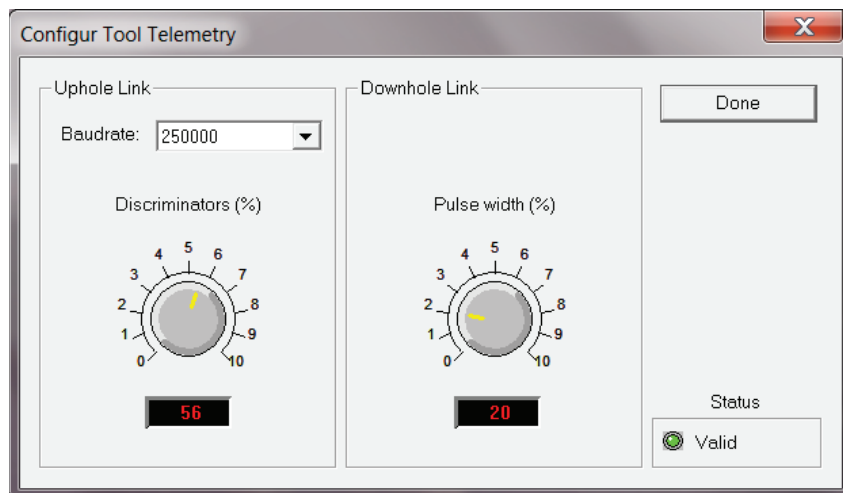


Figure 4-4 Tool communication settings

## 4.3 Tool Communication with MATRIX

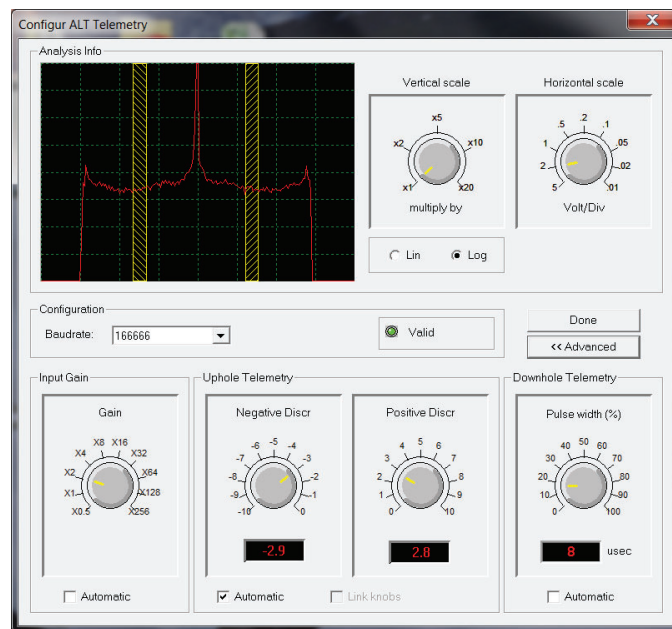
The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (Figure 4-5) providing various controls to adjust the telemetry settings and monitor its current status.

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 **linear / logarithmic** 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.

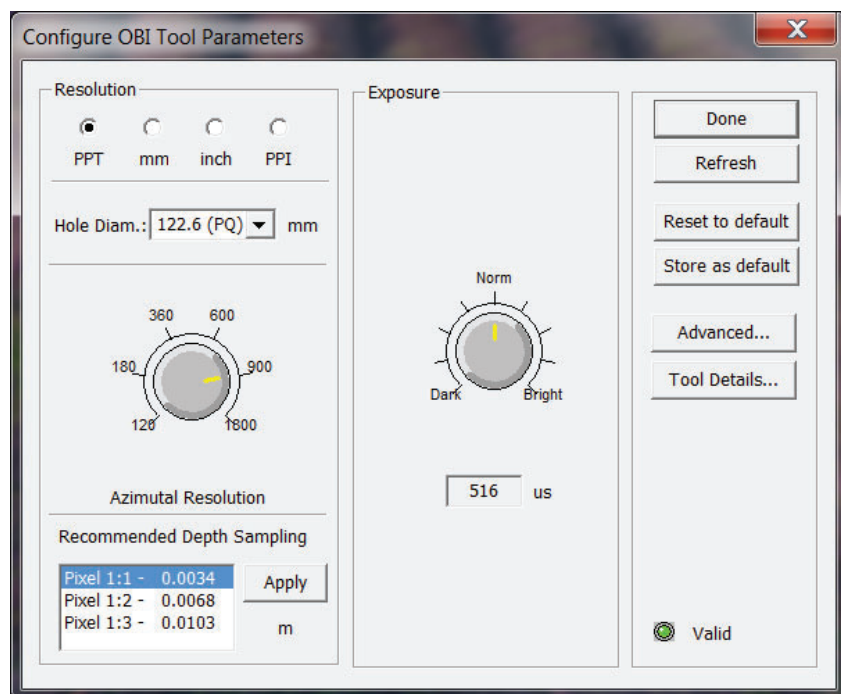


Figure 4-6 Tool parameters dialog box

### 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.*

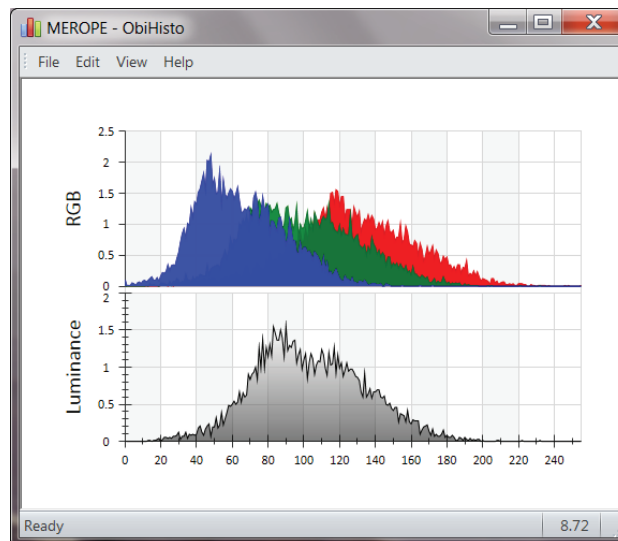
## 4.5.2 Exposure

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  $\mu\text{sec}$ .

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.

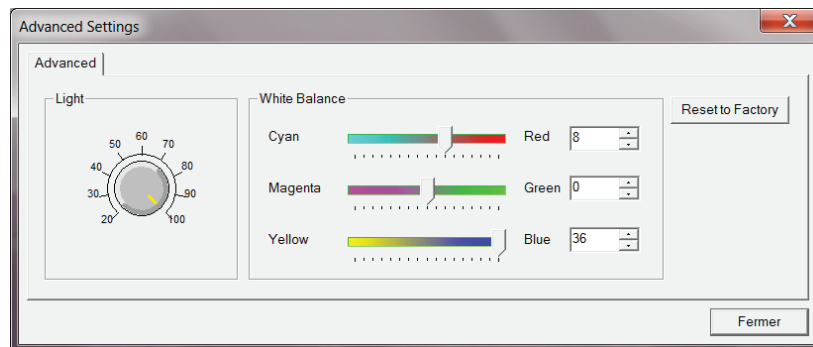


Figure 4-8 Advanced settings dialog box

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.

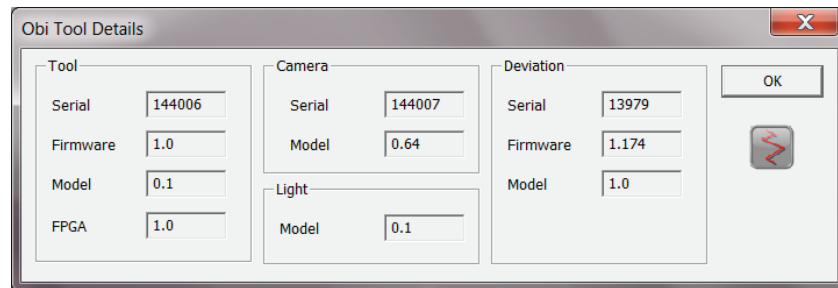
The calibration of the white balance requires specific equipment and is performed at manufacturing time. No change should be applied to the white balance settings when the tool is operated under normal conditions.

- ☐ **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

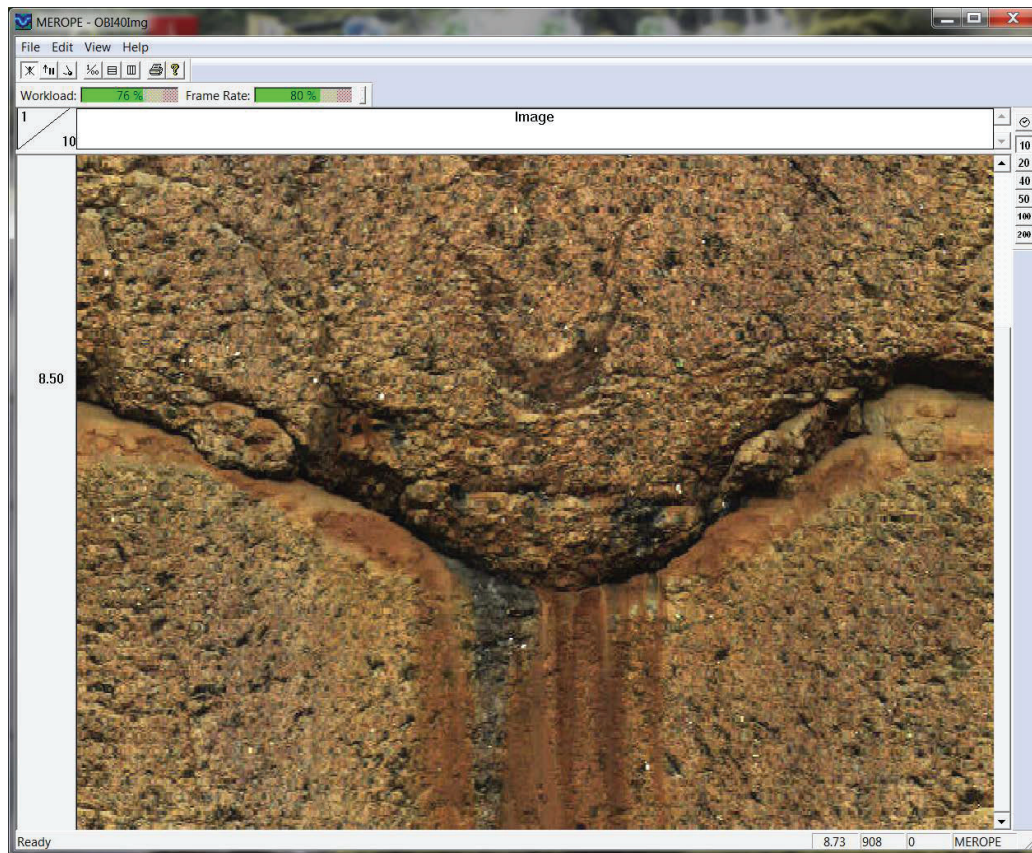
### 4.6.1 Recorded parameters

Besides the image, the following data channels are recorded by the tool.

|                   |   |
|-------------------|---|
| TCam <sup>1</sup> | 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                            |

<sup>1</sup>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.

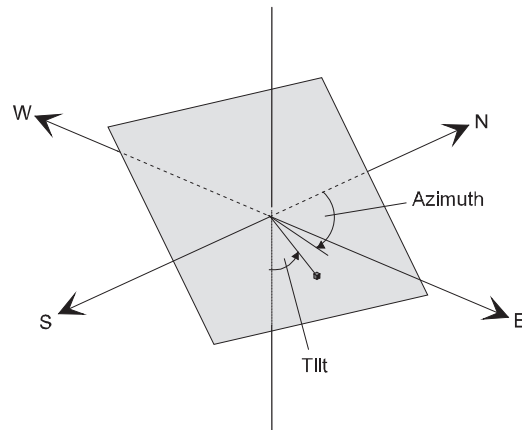


***The bar meters must be used to control the logging speed during a record. To avoid bad records it is recommended to keep the percentage values in the green range.***

#### 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



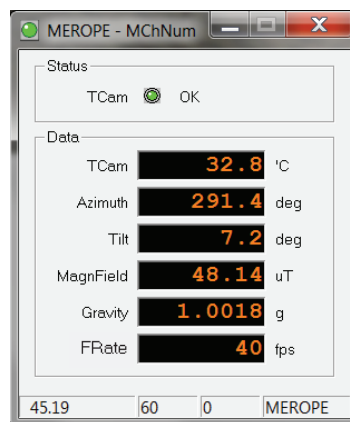
Operator defined depth scales, interval spacing and settings



Time mode display

### 4.6.2 “MChNum” Browser

Figure 4-12 shows a typical example of the numerical values displayed in the MChNum browser.



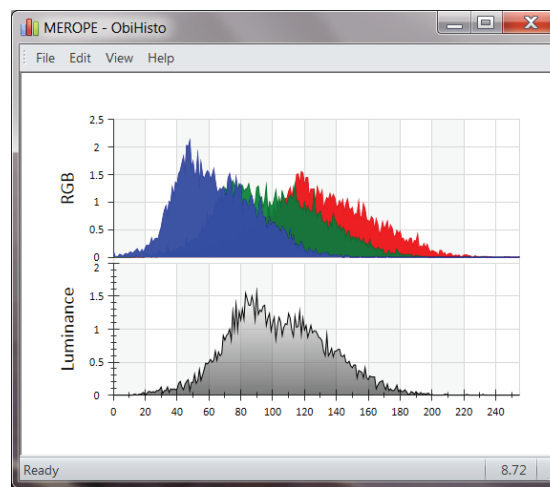
**Figure 4-12** MChNum browser

|             |   |
|-------------|---|
| TCam:       | Temperature of image sensor - °C                  |
| Azimuth:    | Azimuth from Magnetic North - deg                 |
| Tilt:       | Inclination from verticality - deg                |
| Magn.Field: | Magnetic field surrounding the borehole - $\mu$ T |
| 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.

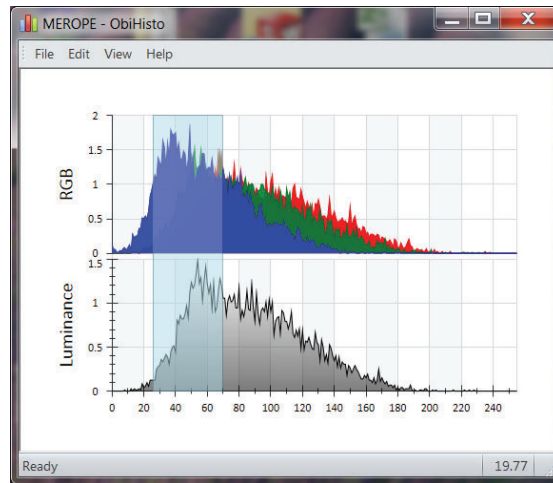
#### 4.6.3 “ObiHisto” browser

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.

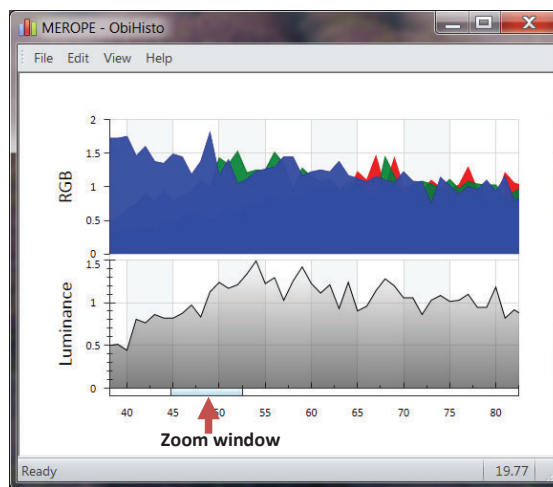


**Figure 4-13** Histogram view of the luminance and RGB colors

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.

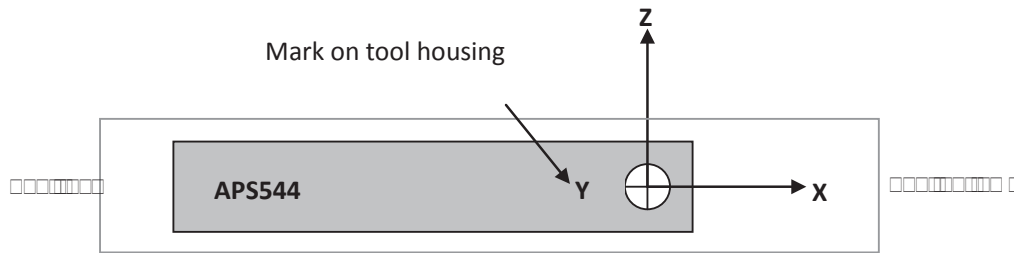
To come back to the original histogram view right click on the ObiHisto browser.

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 =  $90^\circ \pm 0.5^\circ$

Tilt =  $90^\circ \pm 0.5^\circ$

Next, roll the probe counterclockwise (looking towards the tool bottom) about its X axis in increments of  $90^\circ$  and verify that for each position the roll angle increments in succession to  $0^\circ$ ,  $270^\circ$  and  $180^\circ$  while the tilt remains  $90^\circ \pm 0.5^\circ$ .

To verify inclination at  $0^\circ$  and  $90^\circ$ , position the probe so that the X axis is pointed down ( $0^\circ$  inclination) and then horizontal ( $90^\circ$ ).

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  $0^\circ \pm 1^\circ$ . 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  $15^\circ$ , and a fixed azimuth. The data imported into WellCAD should show a deviation of the azimuth less than the limit of  $\pm 2.5^\circ$  and a deviation of the tilt less than the limit  $\pm 0.5^\circ$ .

## 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.

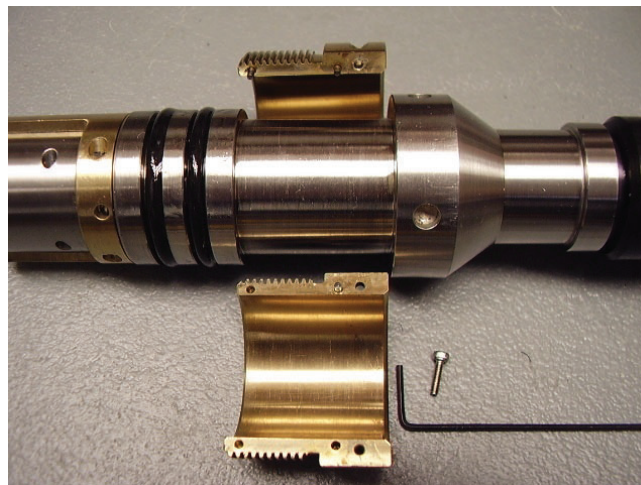
Four guide pins align the two ring halves and tend to hold them together after the screws are removed. To pry the halves apart you can use a pair of spanner wrenches inserted into the wrench holes on opposite sides of the ring mating surfaces to pull them apart slightly.

*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

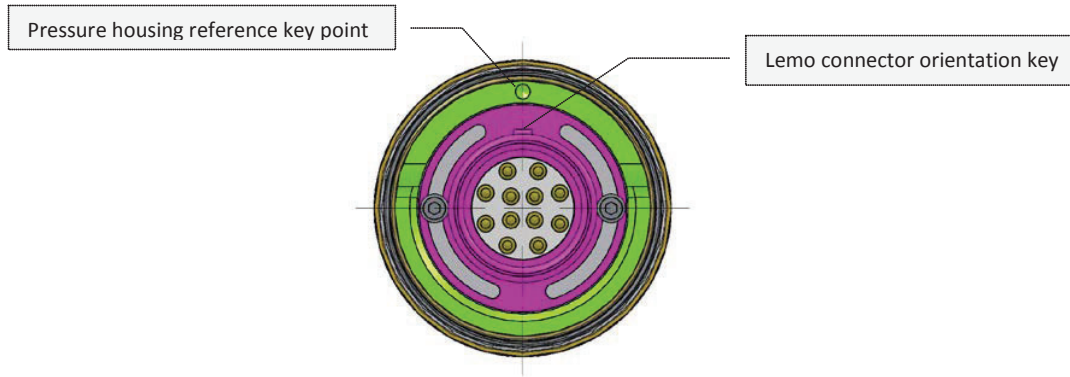
**Warning:** Removing the electronic chassis from pressure housing without prior consultation with ALT will void the tool warranty.

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

**It is strongly recommended to inspect the integrity of the glass sleeve before each run.**  
**Never immerse the tool in a borehole if any defect or crack is visible in order to avoid irreversible damage to the tool.** Replace the sleeve with a spare one if necessary.

**Always use the ALT standard screws DIN912-M2.5x3 to fix the glass sleeve on the tool.** The size and shape of the screws are specifically designed for this purpose. Spare screws are usually provided with the tool spare kit.

**Note that the use of a different screw model may damage the glass sleeve when exposed to pressure and will void the tool warranty.**

## 7 Troubleshooting

| Observation   | To Do   |
|---|---|
| <i>Tool not listed in Tool panel drop down list.</i>                              | <ul style="list-style-type: none"> <li>- Do you have a configuration file?</li> <li>- Has the configuration file been copied into the .../Tools folder (refer to logger manual about details of the directory structure)?</li> </ul>  |
| <i>Tool configuration error message when powering on the tool.</i>                | <ul style="list-style-type: none"> <li>- Check all connections.</li> <li>- 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).</li> </ul>   |
| <i>Tool panel - No current.</i>   | <ul style="list-style-type: none"> <li>- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system.</li> <li>- Verify cable head integrity.</li> <li>- Verify voltage output at the cable head (it should be 120V).</li> </ul>  |
| <i>Tool panel - Too much current (red area).</i>                                  | <p><b>! Immediately switch off the tool !</b></p> <ul style="list-style-type: none"> <li>- Possible short circuit (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity.</li> <li>- 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.</li> <li>- If the above shows no issues, use test cable (provided by ALT/MSI as an option) to verify tool functionality.</li> <li>- If the problem still occurs, please contact service centre.</li> </ul> |
| <i>Telemetry panel - status shows red.</i>  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3).</li> <li>- If problem cannot be resolved contact <a href="mailto:msi@mountsopris.com">msi@mountsopris.com</a> or <a href="mailto:alt@mountsopris.com">alt@mountsopris.com</a></li> </ul>   |
| <i>Telemetry panel - memory buffer shows 100%.</i>                                | <ul style="list-style-type: none"> <li>- 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.</li> </ul>   |
| <i>Telemetry panel – bandwidth usage shows 100%.<br/>(Overrun error message.)</i> | <ul style="list-style-type: none"> <li>- Set the baudrate to highest value allowed by your wireline configuration.</li> <li>- Reduce logging speed, decrease azimuthal resolution and/or increase vertical sample step.</li> </ul>  |
| <i>Telemetry panel - large number of errors.</i>                                  | <ul style="list-style-type: none"> <li>- Verify the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3).</li> <li>- Check bandwidth usage and telemetry error status.</li> </ul>  |

|  |   |
|--|---|
| <i>Black image – the light source stopped working.</i> | 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.<br><br>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](mailto:support@alt.lu) or [tec.support@mountsopris.com](mailto:tec.support@mountsopris.com) for further details.

### 8.2 Technical drawings

The following technical drawings are available on request:

- ☐ Wiring Diagram.

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## 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 |

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## 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 lähteivissä rei'issä ja tunnelirei'issä. Tunnelissa on mahdollista mitata jopa yläkätisiä reikiä käyttämällä apuna kairareiän sulkumekanismeja. 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.

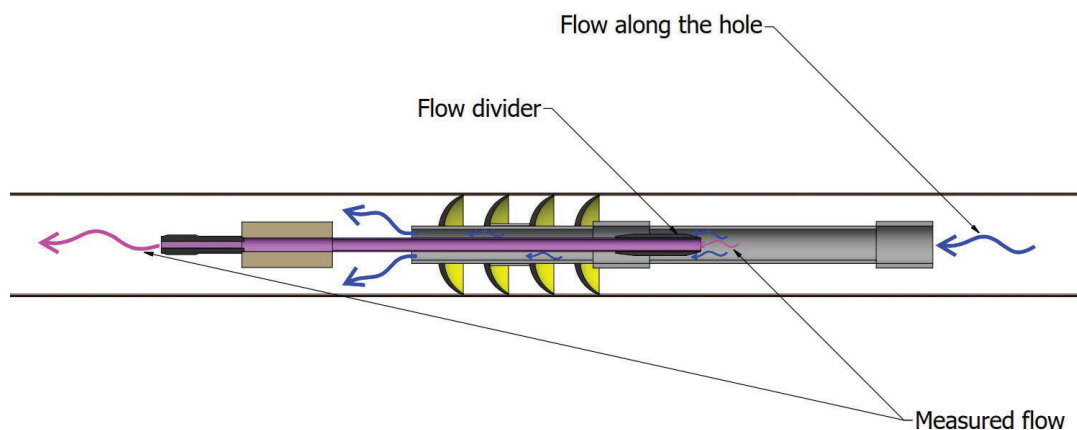
#### 2.1 Anturin kasaaminen reikäveden sähkönjohtavuuden ja reiän suuntaisen virtauksen mittaus

Reikäveden sähkönjohtavuuden (reikä-EC) mittausta varten anturi kasaetaan siten, että ajettaessa anturia kairareiässä ylös ja alaspäin vesi pääsee mahdollisimman nopeasti sähkönjohtavuus elektrodille. Reiän suuntaisen 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 kokoon-

panossa. Virtausputki joka jakaa reiän suuntaisen virtauksen virtausanturille ja ohivirtausputkeen on asetettu anturin viereen kohtaan johon se anturin sisällä tulee. Virtauksen reitti reiän suuntaisen virtauksen mittaamisen aikana on esitetty kuvassa (Kuva 2-2).



Kuva 2-1 Virtausmittari Reikä-EC-mittauskokoontyössä. Kuvassa pystyvirtausanturi ja virtausputki on otettu virtausmittarin viereen esille.



Kuva 2-2. Virtauksen reitit reiän suuntaisen virtauksen mittauksessa.

Virtausmittarin runkona toimii elektroniikkaputki (Kuva 2-3), jonka yläpäässä on yläpäätykappale ja alapäässä alapäätykappale. Yläpäätykappaleeseen on kiinnitetty kaapelipäätteen vastakappale murtosokkiin. 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 ei-

vät ole kirkkaat, niitä pitää liottaa tarvittaessa laimennetulla etikkahapol-  
la, 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 maadoitusvastusliittimen 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 alapuolel-  
la. 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 kuusiokoloruuvien reikä on kohdakkain hetulaputken kuusiokoloruuvien reiän kanssa. Kierrettä ei siis kiristetä loppuun asti. Sovitin lukitaan paikoilleen hetulaputkeen kuusiokoloruuvilla.



Kuva 2-6. Hetulaputki, hetulaholkki ja sovitin.

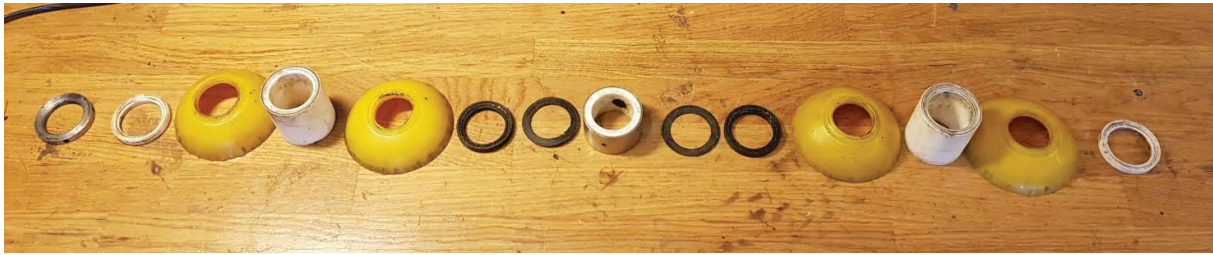


Kuva 2-7. Hetula putki ja sovitin kiinnitettynä virtausanturin suojaan.

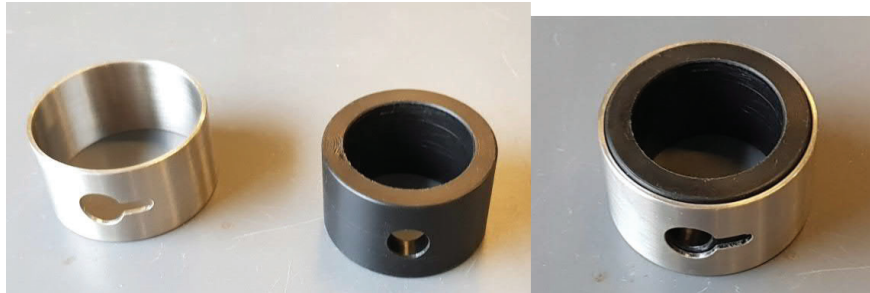
Hetulaputken kiinnityksen jälkeen hetulaputkeen laitetaan hetulat hetulaholkkeineen ja maadoitusvastuselektrodin rengas. Tässä vaiheessa pitää tarkistaa hetuloiden kunto. Hetuloiden tulee olla ehjät ja elastiset. Rikkinäiset ja kovettuneet hetulat pitää vaihtaa ehjiin.

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 epätaustainen reuna tulee hetulaa vasten. Hetuloiden väliin laitetaan aina paksumpi (Kuva 2-10) hetulaholkki ja ohuet hetulaholkit tulevat hetuloiden ulkopuolelle.



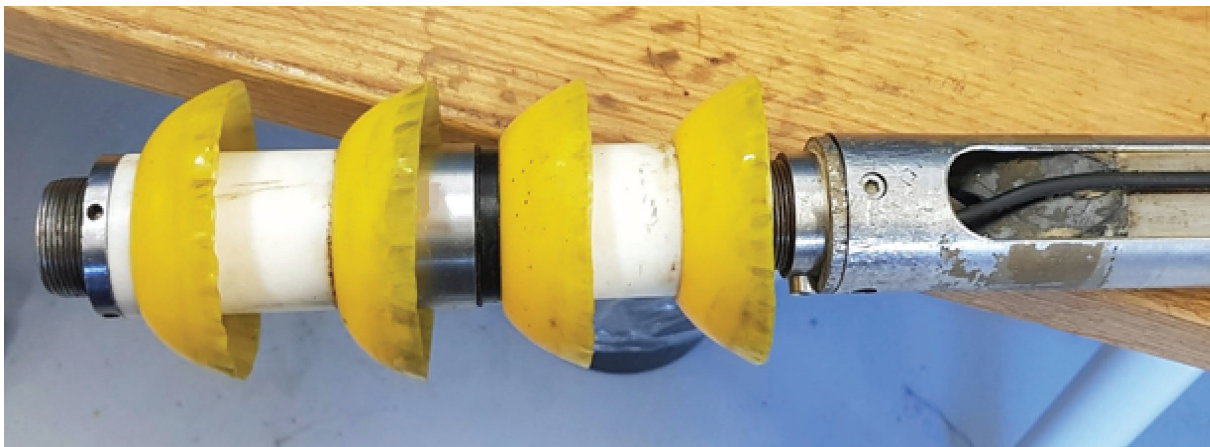


Kuva 2-8. Hetulaputkeen asennettavat osat oikeassa järjestyksessä.



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.

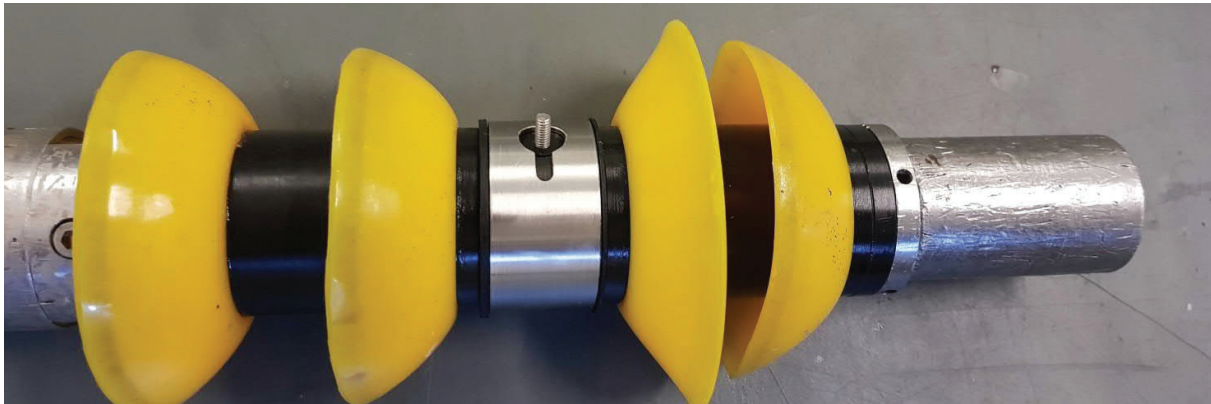


Kuva 2-13. Maadoitusvastuselektrodin johdon pujottaminen.

Johtimen pää, jossa on kierretappi, asennetaan maadoitusvastuselektrodissa olevaan reikään Kuva 2-14 mukaisella tavalla. Maadoitusvastus-

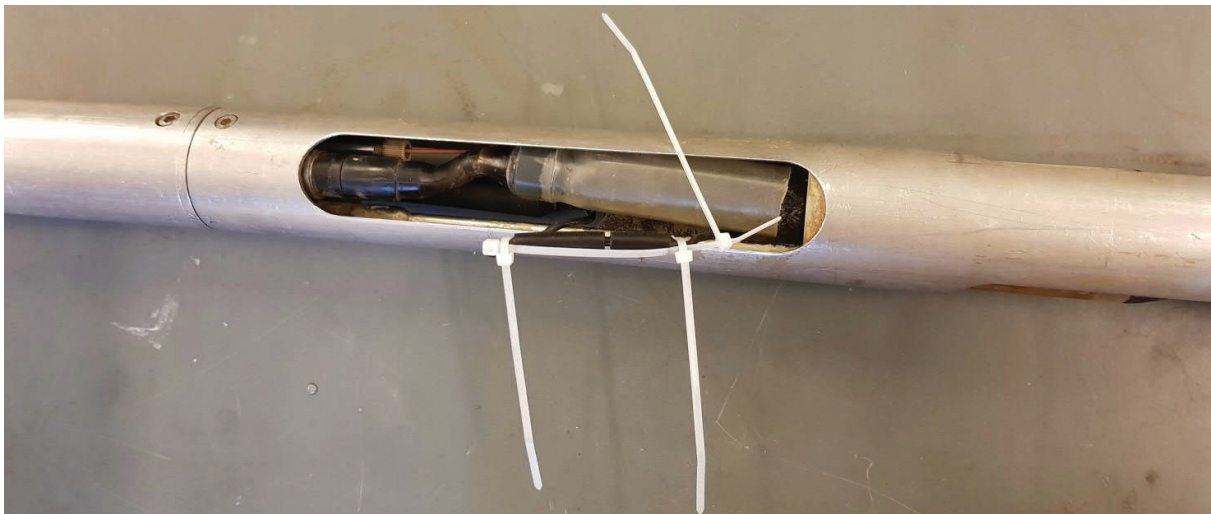


elektrodia teräsrengasta käännetään niin, että kierretappi menee elektrodin kapeampaan uraan. Kierretappiin laitetaan mutteri, jolla johdin kiristetään paikalleen maadoitusvastuselektrodiin. Mutteri kannattaa asentaa kierretappiin jo ennen kuin johdin asetetaan paikalleen reikään. Tällä estetään johtimen pään pyöräminen 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 mitaanko reikävettä vai mittavälistä tulevaa vettä.

Reikä-EC:n ja reiän suuntaisen virtauksen mittausta varten hetuloiden ki-  
ristämisen jälkeen laitetaan pystyvirtausohjain ja virtausputki paikoil-  
leen, Kuva 2-19. Virtausputki ja pystyvirtausohjain (Kuva 2-17) liitetään  
toisiinsa kierteellä, Kuva 2-18. Ennen virtausputken ja pystyvirtausoh-  
jaimen liittämistä toisiinsa, tulee kierteeseen laittaa ohut kerros Moly-  
kote 111 compound -voiteluainetta. Sitten virtausputki ja pystyvirtausoh-  
jain työnnetään hetulaputken ja kiilassa olevan reiän läpi paikalleen vir-  
tausanturin virtauskanavaan.

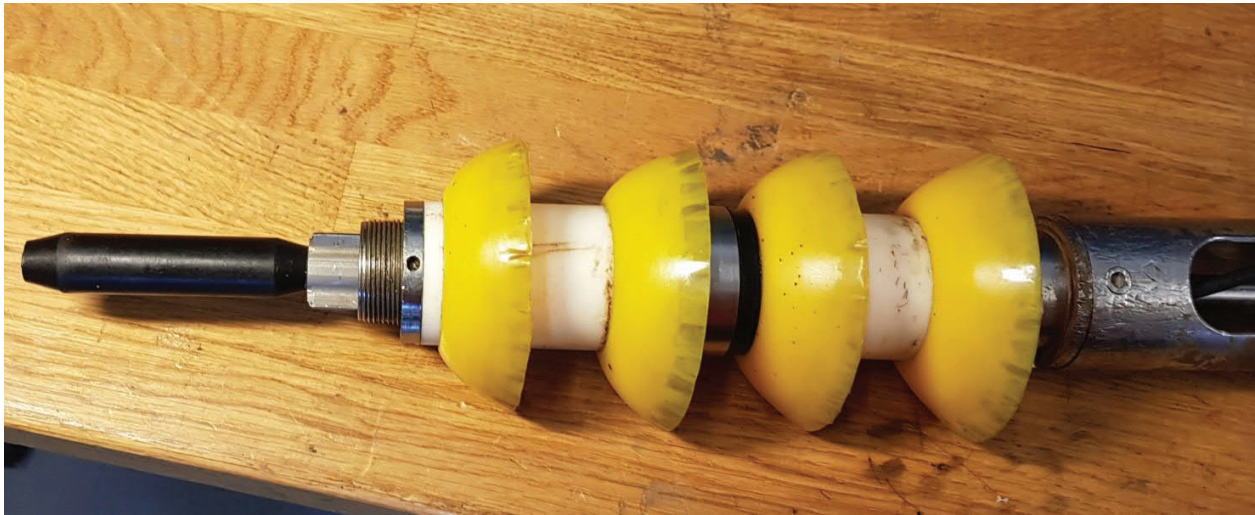


Kuva 2-17. Pystyvirtausohjain (vasemmalla) ja virtausputki (oikealla).



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 liittinosat.

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 abso-luuttipaineanturin 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 karstas-ta. Puhdistaminen tehdään kevyellä vesihionnalla vesihiontapaperilla. Asennuksen jälkeen pitää varmistua siitä, että EC elektrodi ei pääse tu-lemaan ulos anturin rungon sisältä kiinnittämällä se nippusiteellä tai tei-pillä.





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.



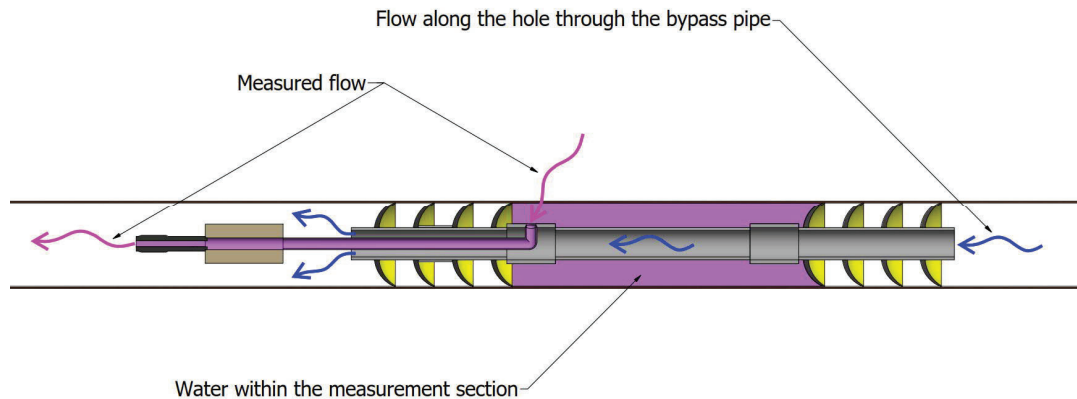
Kuva 2-28. Avoin painolenkki.

## 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.

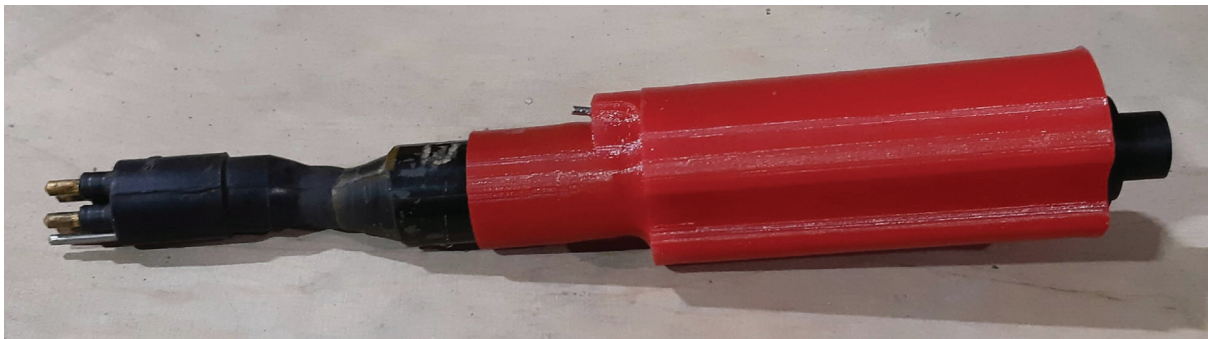


Kuva 2-30. Rakovirtauksen ja reiän suuntaisen virtauksen reitit virtausmittauksen aikana.

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-elektrodin 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 mittausta 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 kaapelipääteen kiinnittämistä Virtauseromittariin tai dummy-luotaimen pitää tarkastaa, että kaapelipääteen O-renkaat ovat kunnossa ja varmistettava etteivät ne leikkaudu asennuksessa. Vesitiiviyyden varmistamiseksi laiteaan 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).





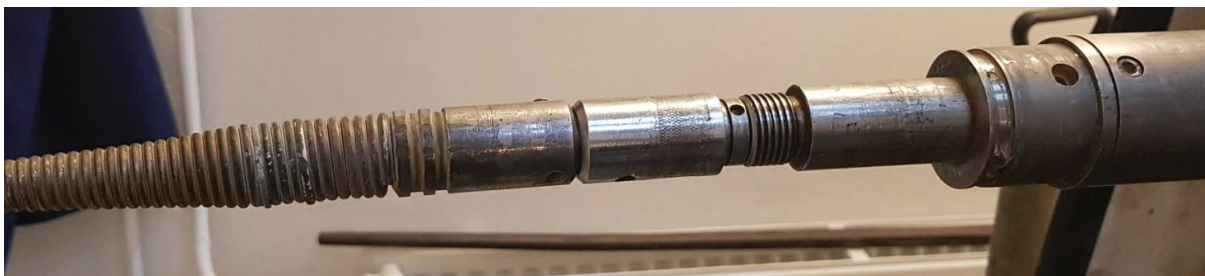
Kuva 3-2. Kaapelipäätteen vastakappale virtauseromittarin yläpäässä. Hahlo näkyy sisällä alareunassa.

Ennen kaapelipäätteen kiinnittämistä kaapelipääte tulee pujottaa irrallaan olevan Virtauseromittarin kivikupin läpi niin, että kivikupissa olevat kiertet 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 kiertelille.



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 ki-vikuppi paikalleen ja kiinnitetään se kahdella kuusiokoloruuvilla (Kuva 3-7).



Kuva 3-5. Kaapelipääteen kiinnitysholkin kiristäminen lukkopihtieillä.



Kuva 3-6. Kaapelipääteen 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 kiinnitetään virtauseromittarissa kiinni olevaan painolenkkiin. Ennen virtauseromittarin nostoa ketjutaljan varaan tulee yläpään kivikupin kiertäisiin 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 tipumaan reikään noston aikana. Pehmeuste 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 vinssilä 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 kaapeliinsovitussosat (Kuva 4-6) kiinni.



Kuva 4-6. Jatkoputkien pihdit ja kaapeliinsovitussosat.

Kaapeliinsovitussosat kiinnitetään jatkoputkien pihtiin kuusiokoloruuveilla. Lisäksi tarvitaan vielä taljaankiinnitysosa (Kuva 4-7). Jatkoputkien pihdit kaapeliinsovitussosineen kiristetään vaijerin ympärille ja pujotetaan taljaankiinnitysosa paikalleen, niin että vaijeri kulkee sen urassa ja pihdit ovat Kuva 4-7 näkyvän lenkin sisällä. Taljaankiinnitysosa kiin-

nitetään ketjutaljan koukkuun ja nostetaan virtauseromittaria ketjutaljalla (Kuva 4-8), niin että saadaan irrotettua kivikupista pidike ja L-rauta. Sit-  
ten ajetaan vinssillä kaapelia sisään sen verran, että saadaan ylimääräi-  
nen kaapeli sisään. Tämän jälkeen lasketaan ketjutaljalla virtauseromit-  
taria reikään, niin että anturi jää roikkumaan kaapelin varaan. Kun vir-  
tauseromittari on kaapelin varassa, poistetaan taljaankiinnitysosa ja pih-  
dit 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 nähdessä reiän takapuolella. Jos kairareikä lähtee esimerkiksi betonilaatasta, niin betonilaataan voi porata reiän, johon voi ankkuroida koukun varmistusliinan/-ketjun kiinnitystä varten.

Kun virtauseromittari on saatu kairareikään, niin että kaikki pihdit, L-rauta ja kivi kuppiin asennettava pidike on irrotettu, lasketaan virtauseromittari reikään syvyydelle, josta mittaus halutaan aloittaa. Matkalla aloitusyvyteen 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. Tahtipyörä tukijalkojen varassa.

## 5 Mittauksen alkuvalmistelut

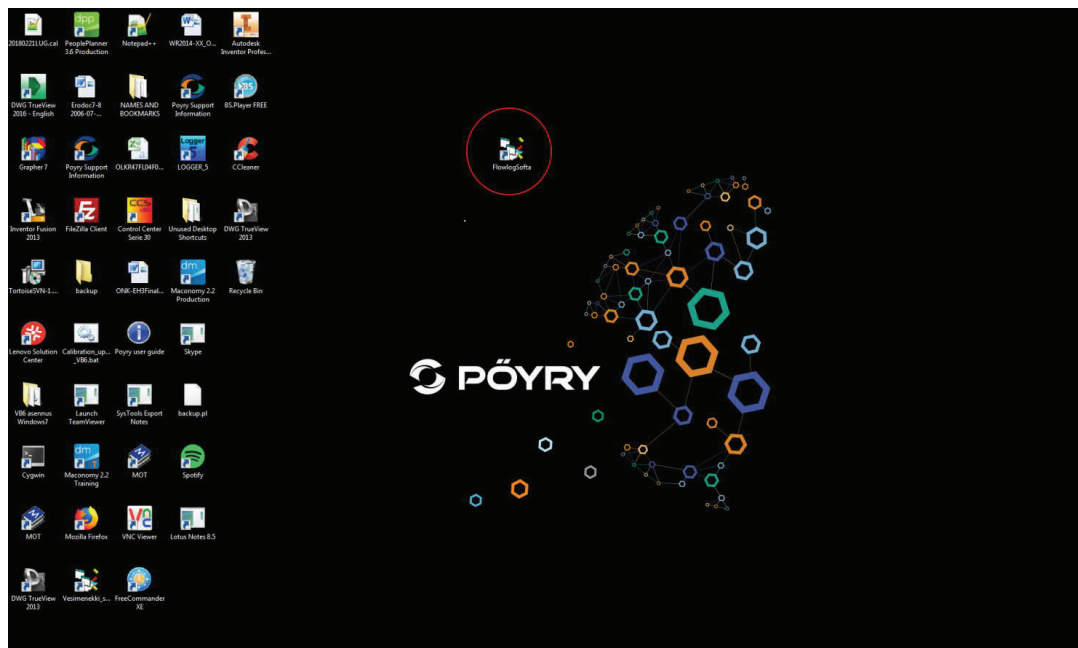
Tässä luvussa esitellään PFL-ohjelmiston ja vinssin käyttö mukaan lukien mittauksen aikana tehtävät tarpeelliset käytännön toimenpiteet. Kappaleessa esitetyt tiedostot ja kansiot ovat nimetty sen mukaan, että mittaukset tehtäisiin Olkiluodossa reiällä OL-KR41. Tällöin on helpompi ymmärtää mistä tiedostojen 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.

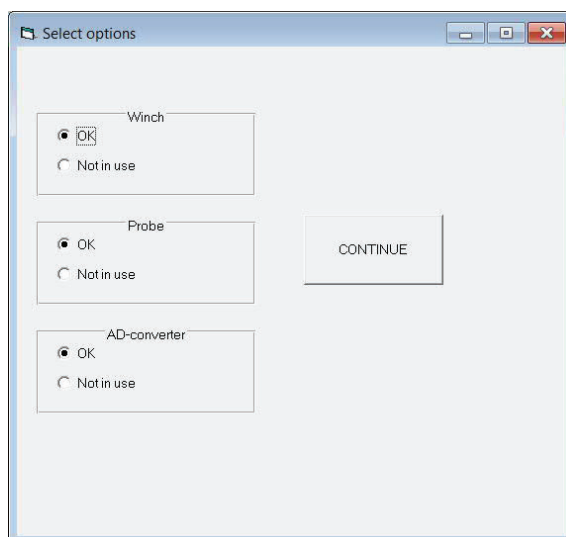
## 5.1 PFL-ohjelmiston käynnistys ja mittausvalmistelut

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.

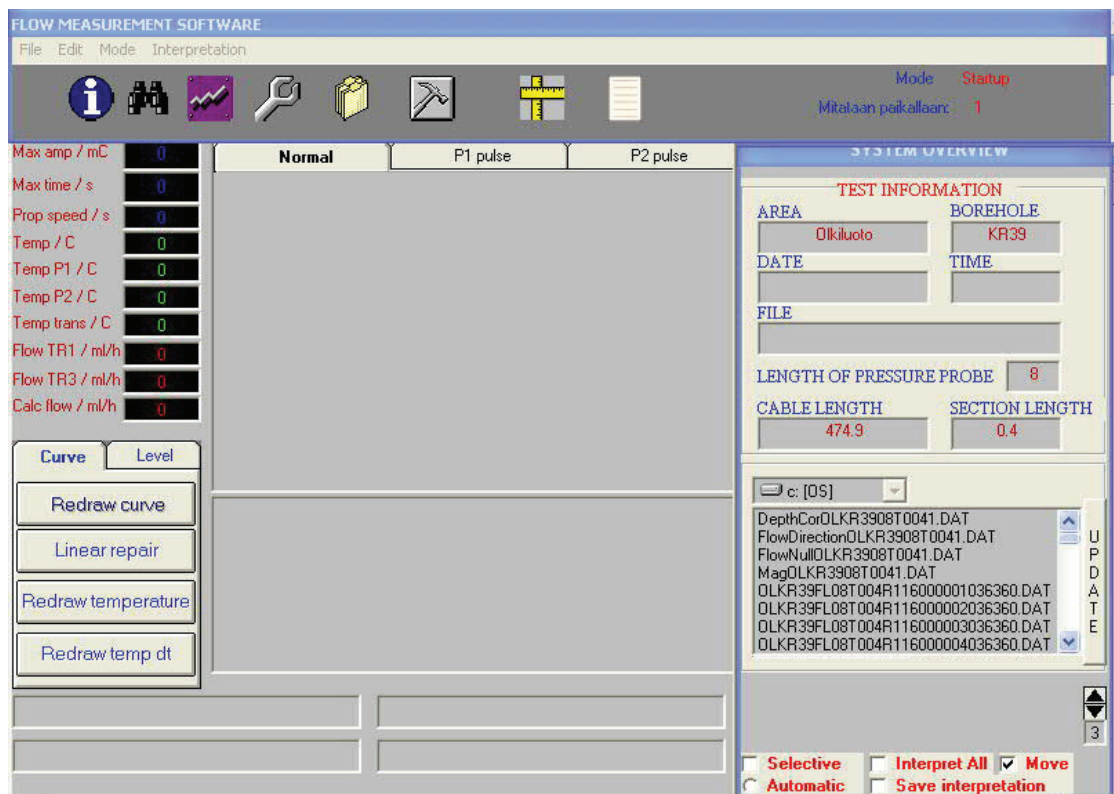
PFL-mittausohjelmisto toimii Microsoft Visual Basic 6.0 ohjelmankehitysympäristön alla. Mittausohjelman polku on C:\FlowLog\FlowLogSofta\FlowlogSofta.Vbp. Kun PFL-Mittausohjelmisto on käynnistetty, painetaan F5-näppäintä tai Start-nappia ohjelman yläpalkista. Tällöin näytölle tulee Kuva 5-2 mukainen 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 resurssien-hallinnassa. 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 mittauksen aloituspäivän mukaan. Esimerkiksi jos mittaukset aloitettiin 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 A**OLKR41****005m****T1**, jossa:

**A** = mittauksen kirjain alkuarvoissa  
 (A: reikä-EC-mittaus ilman pumppausta  
 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 kansiota. 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).

Measurement and analysing details

**Location**

Area: Olkiluoto  
Drillhole: KR41  
Drillhole name to files: KR41 ####  
Inclination: 69.9 °  
Zground: 4.11 m

**Geometry**

Depth: 125.75 m  
Section length: 0.5 m  
Section Diameter: 76 mm  
Pressure sensor: 4 m

**TAPE Check**

☐ Set counter to nearest 10 meter  
Abs. pressure measured  
☒ Section  
Flow measurement heat pulse  
☐ Only Power 1

**Path and Calibration**

Working directory: c:\FlowLog\Olkiluoto\Holes40-49\  
Calibration file Sensor: 17051105.cal  
Calibration file Trailer: 170727TR02.cal Clear  
Cable calibration file: 170727CC02.cal  
Calibration file PrBox: Clear  
Fracture depth (F):  
Year to file name: 2018  
Order no.: 2110878

**Depth corrections**

☐ Use depth correction file  
☐ Use tape correction file  
Rubber disk to 0-mark: 13.04 m  
Cable length casing: 0.35 m  
Cable length trailer: 4.13 m  
Calculate Depth correction  
Depth correction: m  
Corrected depth: m Calc winch depth

**Run data**

Operator Initials: PP ##  
New Test Number: 1  
Measurement limit for EC: 0 ml/h  
Repeat number: 1 #  
Measurement direction: ☐ Up ☒ Down  
Measure Conductance of bedrock: ☒  
Type of measurement: A  
Pumped Drillhole

**POTTI ONKALO**

☒ None ☐ PVA  
☐ PP ☐ PH  
☐ TR ☐ KR

**PFLWS**

☐ PFLWS 1  
☒ PFLWS 2

**Final disposal area**

☐ CTPH ☐ CT  
☐ DTPH ☐ CTC  
☐ DPH ☐ DT  
☐ DH

**Measurement times**

With Section: 20 s  
Between Sections: 10 s  
Measurement/s: 100  
Waiting time between Transverse measurements: 0 min  
Use custom measurement step (m): ☐ 0.1

**Pumping measurement**

**Box**

☒ None  
☐ Box 1  
☐ Box 2  
☐ Box 3  
☐ Box 4  
☐ Box 5

**Tubing**

☐ 1, small  
☒ 2, medium  
☐ 3, large

**Calibration**

First meas. date:   
First meas. time:   
Current standby time:   
Total standby time:   
Total time for P1:   
Total time for P2:   
Calibration Filename:   
SAVE  
CLOSE

Kuva 5-4. Alkuarvoikkuna.

Alkuarvoikkunassa asetetaan mittauksen alkuarvot kuntoon, kuten muun muassa reiän tiedot, anturin kalibrointitiedot, aloitussyvyys ja reikä-paineanturin syvyys. Tarkemmat selitykset alkuarvoikkunan tiedoista on esitetty Taulukko 5-1.

Taulukko 5-1 Alkuarvonäytön valinnat ja niiden selitykset.

| Kenttä/Painike | Selitys |
|----------------|---------|
| Location       |         |
| Dr             | M       |

[illegible]



[illegible]

|       |  |
|-------|--|
| SAVE  |  |
| CLOSE |  |

Alkuarvoikkunan avauduttua PFL-Mittausohjelmistoon **TÄYTY 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 kaade-tiedot. Reikä tiedot pitää pyytää tilaajalta ennen mittausta. Reikä tiedoista tärkeimmät ovat reiän nimi, reiän kaade ja reiän suun korkeustaso merennästä.

Seuraavassa kentässä ”**Path and Calibration**” valitaan mittauskansion lisäksi virtauseromittarille ja mittauskärrylle (Trailerille) oikeat (viimeisimmät) kalibrointitiedot. Lisäksi asetetaan mittauksen 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), mittausuunta (Measurement direction) ja mittauksen kirjain (Type of measurement)

”**POTTI ONKALO**” -kenttään laitetaan ”None”. Nämä on käytössä pelkästään ONKALO mittauksissa.

”**Geometry**” -kenttään tulee mittauksen aloitus syvyys (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. Pidemmällä 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 kalibroitiedoston. 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 sähkö. 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 Virtauseromit-tari 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 potentiometrillä.

(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 valintaviipu ”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 lopetusvyvyys sekä varmistetaan virtauseromittarin oikea syvyys aloitushetkellä.

Kuva 5-8. Winch-ikkuna. Näkyvissä olevat painikkeet riippuvat valitusta mittauksesta.

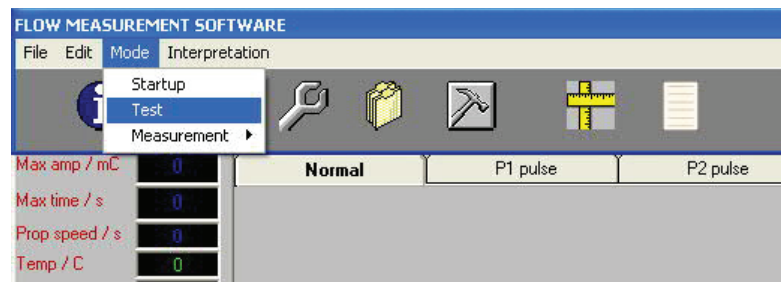
|                            |   |
|----------------------------|---|
| ”Winch” -ikkunan toiminnot |   |
| Tension                    | Näyttää kaapelin jännityksen (kg).          |
| Low                        | Näyttää kaapelin jännityksen alarajan (kg). |



|                |  |
|----------------|--|
| 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 kohdesyvyys. 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).  |

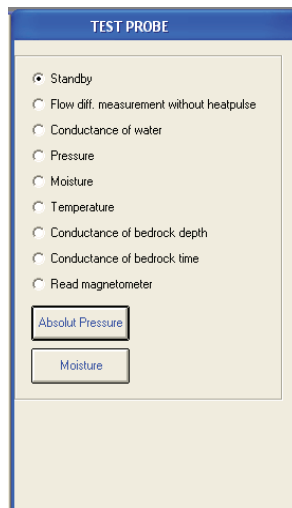
#### 5.4 Virtauseromittarin ja vesipinta-anturin testaus

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.

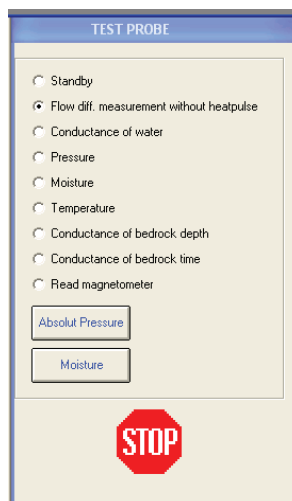


Kuva 5-9. Test mode -valinta.

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.





|  |  |  |  |
|--|--|--|--|
|  |  |  |  |
|--|--|--|--|

## 5.5

## Testattavat signaalit

”Test Probe” -ikkunasta valitaan testattavat signaalit, jotka selostetaan seuraavassa.

Flow diff. measurement without heatpulse:

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 helppointa testata puhaltamalla virtausanturin sisään anturin ollessa ilmassa, jolloin lukemien tulisi muuttua hyvin voimakkaasti.

Conductance of water:

Mitataan veden sähkönjohtavuutta nelipiste-elektrodilla, jolloin sekä elektrodiin syötettävä virta ( $U_{in}$ ) ja mittauselektrodien välinen jännite ( $U_x$ ) mitataan. Elektrodin testaaminen tapahtuu ainoastaan sähkönjohtavuudeltaan tunnetussa nesteessä. Ilmassa elektrodin toimivuutta ei voi luotettavasti testata.

Pressure:

Reikäveden pinnan mittaamiseen tarkoitetut paineanturit ( $p_1$  tai  $p_2$ ) ovat 4–20 mA:n virtalähtelimellä 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 vesipinnan korkeus (m) vesipinta-anturin päällä. Lopuksi verrataan vesipintamittarilla mitatun ja ”RawData display” -ikkunassa olevan vesipinnan arvoja. Vesipinta-anturin näyttämä arvo tulee olla  $\pm 10$  cm vesipintamittarilla mitatusta arvosta.

| RAWDATA DISPLAY      |   |      |        |
|----------------------|---|------|--------|
| Pressure measurement |   |      |        |
|                      | V | Data | Change |
| p1                   | 0 | 0    | m      |
| p2                   | 0 | 0    |        |
| Air pressure         | 0 | 0    | kPa    |
| P abs                |   | 0    | kPa    |
| Optical sensor       |   |      |        |
| Optical              |   |      |        |
| Pumping              |   |      |        |
| Pumping              |   |      |        |
| Flowsensor           |   |      |        |
| Upper therm          |   |      | C      |
| Lower therm          |   |      | C      |
| Middle therm.        |   |      | C      |
| Meas therm.          |   |      | mK     |
| Conductance          |   |      |        |
| Bedrock              |   |      | ohm    |
| Water Ux             |   |      | ohm    |
| Water Uin            |   |      | ohm    |
| Winch motor          |   |      |        |
| Temperature          |   |      | C      |

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. Elektronikkakortin 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 aloitus-syvyys 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 kilopascalina.

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.

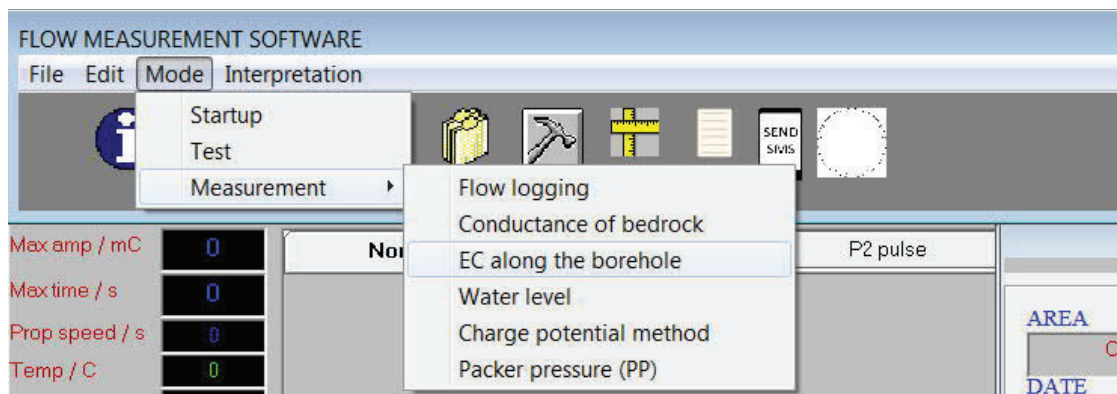
”No moisture in the tool !” elektroniikkaputkessa ei ole kosteutta.

## 6 Mittaaminen PFL-ohjelmistolla

Seuraavassa on esitetty mittauskohtaiset ohjeet mittauksen suorittamiseen. Alkuarvojen asettaminen on ohjeistettu kappaleessa 5 joten tässä vaiheessa oletetaan alkuarvojen olevan oikein.

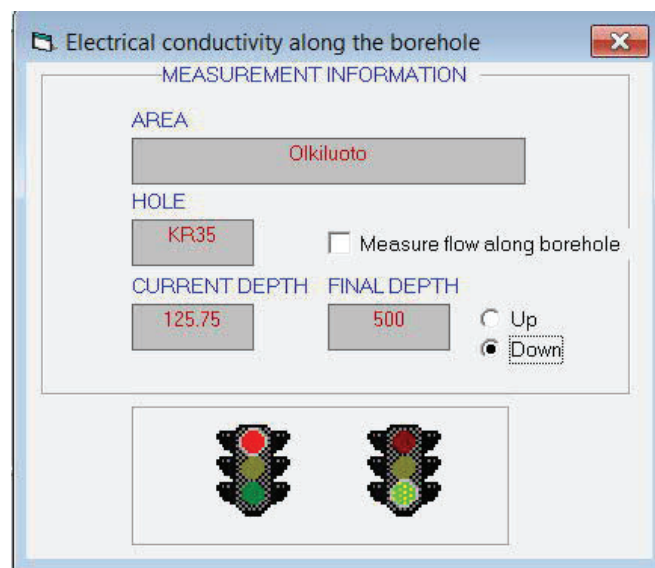
### 6.1 Reikä EC-mittaus ja reiän suuntaisen virtauksen mittaus (A ja D mittaukset)

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 lopetusvyvyys 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 automaattilla 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 ko-

pioinnin jälkeen mittausta jatketaan asettamalla "Automatic" täppä ja klikkaamalla "Start New measurement".

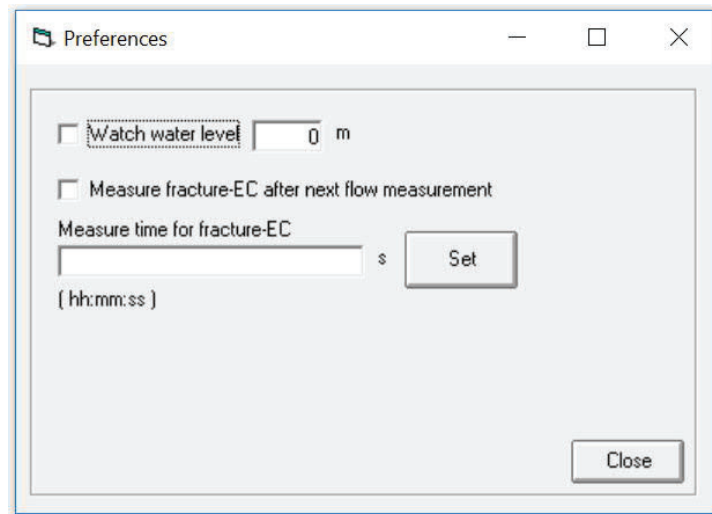
### 6.3 Rakoveden sähkönjohtavuusmittaus

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 syvyysiksi eikä todellista syvyyttä joten syvyyskorjaus tulee ottaa huomioon.

| StartLength | StopLength | MeasurelimitToCondWater |
|-------------|------------|-------------------------|
| 0           | 150        | 10000                   |
| 150         | 500        | 1000                    |
| 500         | 1000       | 500                     |

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 Pumpkauksen 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 tehty 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 ava- tessa Grapher pyytää uutta datatiedostoa, koska vanhaa ei enää löydy. Jos näin käy, niin Grapherin kysymykseen ei saa missään nimessä vasta- ta ”No”, koska silloin koko käyrä poistuu kuvasta. Pahimmassa tapauk- sessa kuvapohjasta voi tulla lähes käyttökelvoton. Tästä työtavasta saa- tava etu on se, että Grapher-kuvaan tehtävien muutoksien määrä pysty- tään 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 jo- kaiselle mittaukselle, kun niiden tulkinta aloitetaan. Kaikki tulkitut tie- dostot tulevat tähän samaan kansioon, josta ne kopioidaan Maastotulkin- nan FlowLogging-kansioon.

Ennen tulosten käsittelyä mittauskansioista tulee löytyä myös elevation- tiedosto jossa on kairareiän taipumatieto (Z-koordinaatti kairareiän pi- tuuden suhteen). Tyhjä elevation-tiedosto tehdään valikosta "Interpretati- on → 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.

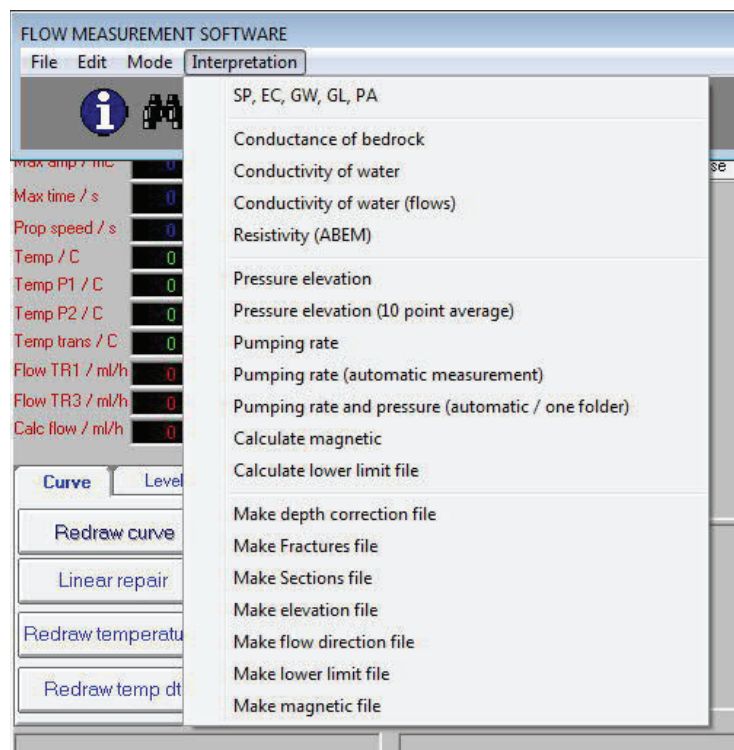
Tulkinnoissa ensimmäinen tehtävä on syvyyskorjauksen kirjaaminen sy- vyyskorjaus tiedostoon. Tiedoston pohja tehdään valitsemalla "Interpre- tation → Make depth correction file" Reikä-EC mittauksen syvyyskor-

jaus 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 kuvatus 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 mittausta 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.

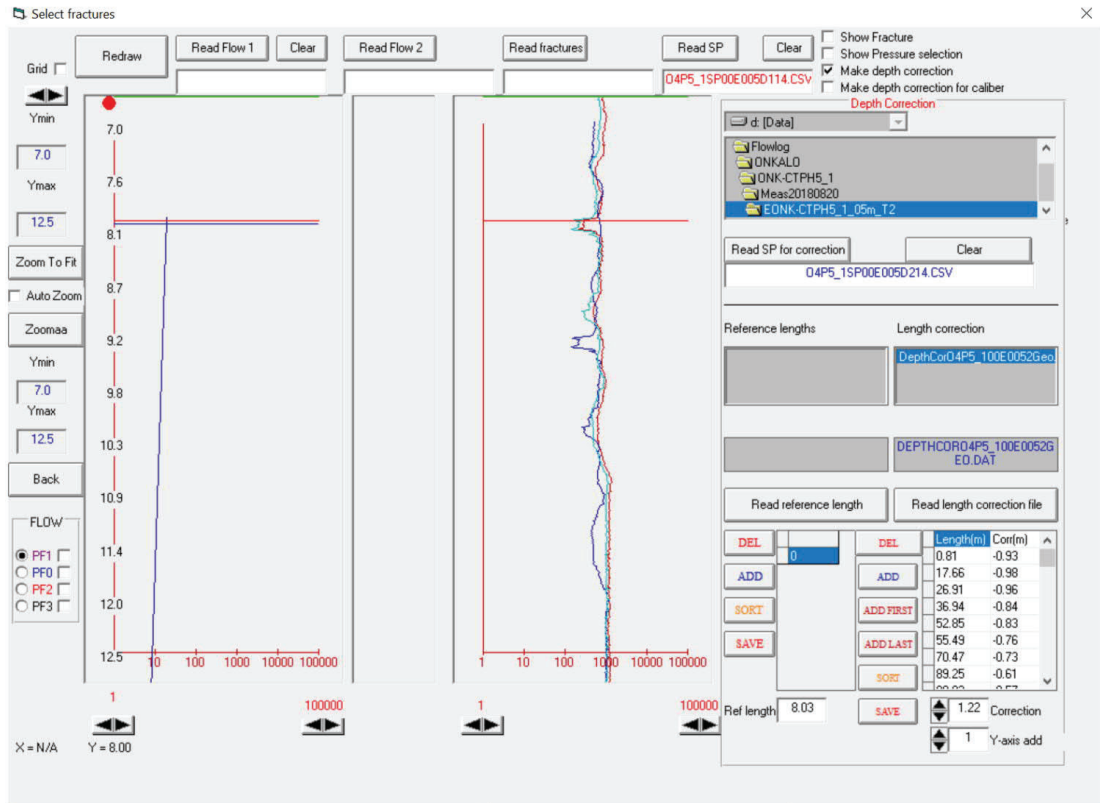
Käytettäessä pelkästään vinssin matkamittarin lukemaa syvyydestiedon määrittämiseen alkuarvoissa tulee olla määritettynä "Use tape correction file". Tätä pitää käyttää jos mittauksen aikana kaapelin syvyysmerkkejä on käytetty vinssin matkapyörän lukeman kohdistukseen. Jos syvyysmerkit on kohdistettu 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 kohdistaa toisiinsa. Mittauskampanjan ensimmäinen mittaus jossa on mitattu SPR, voidaan kohdistaa geofysiikan dataan tai ennalta tunnetuihin kairareidän 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 anomaliaita 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 virtauskuviin.

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.

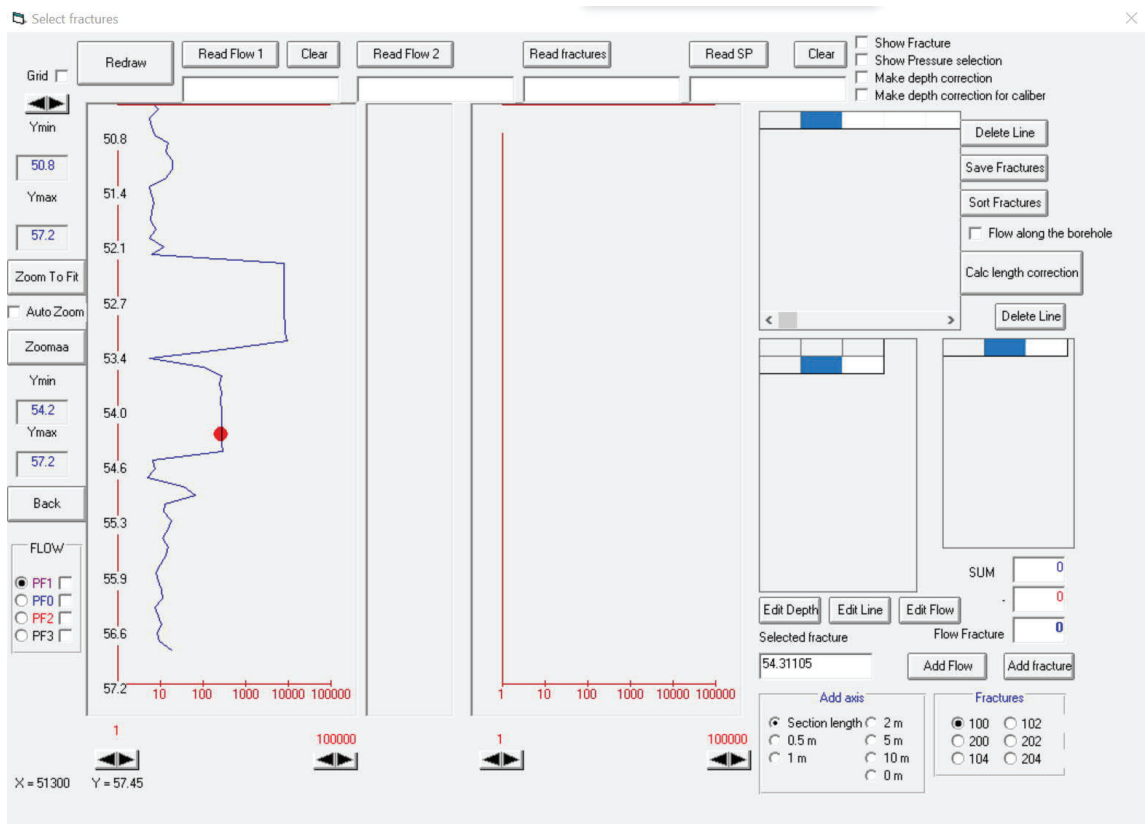
Virtaussuunnista tehdään suuntatiedosto **Interpretation**-valikon **Make flow direction file** (FlowDirection.... .DAT), johon merkitään korjattu syvyys, jossa suunta vaihtuu sekä virtauksen suunta (P=Positive eli virtaus kalliosta reikään, N=Negative eli virtaus reiästä kallioon). Suunnan muutos pyritään 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

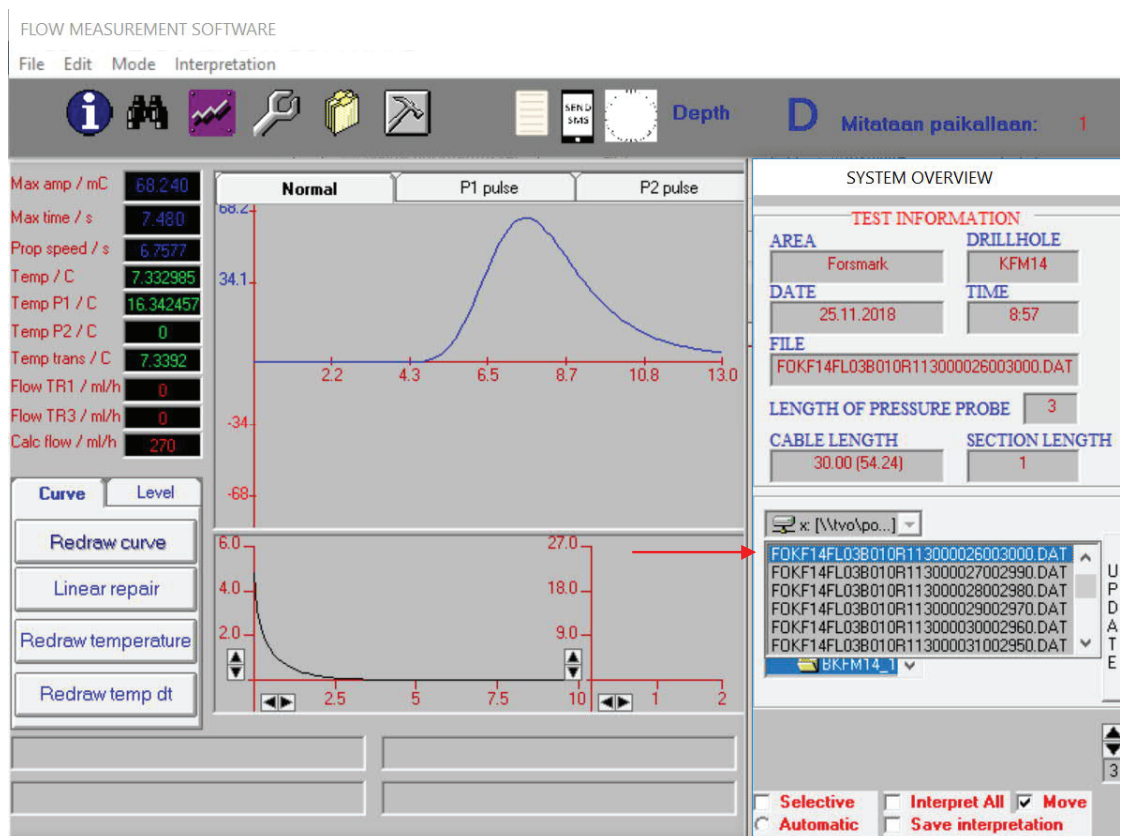
55,N

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 virtaus-suunta 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 tuloksiin.

OLKR46EC02G005T105.CSV  
OLKR46EC02G005U105.CSV  
OLKR46EC02G005W105.CSV

Näiden datojen perusteella tehdään tulokuvat joiden perusteella voidaan arvioida mittauksen edustavuutta. Mittaus tehdään osana automaattimitausta joten käytännössä tuloksia tarkastellaan jälkepäin 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 mitausten 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 pitäisi, 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)

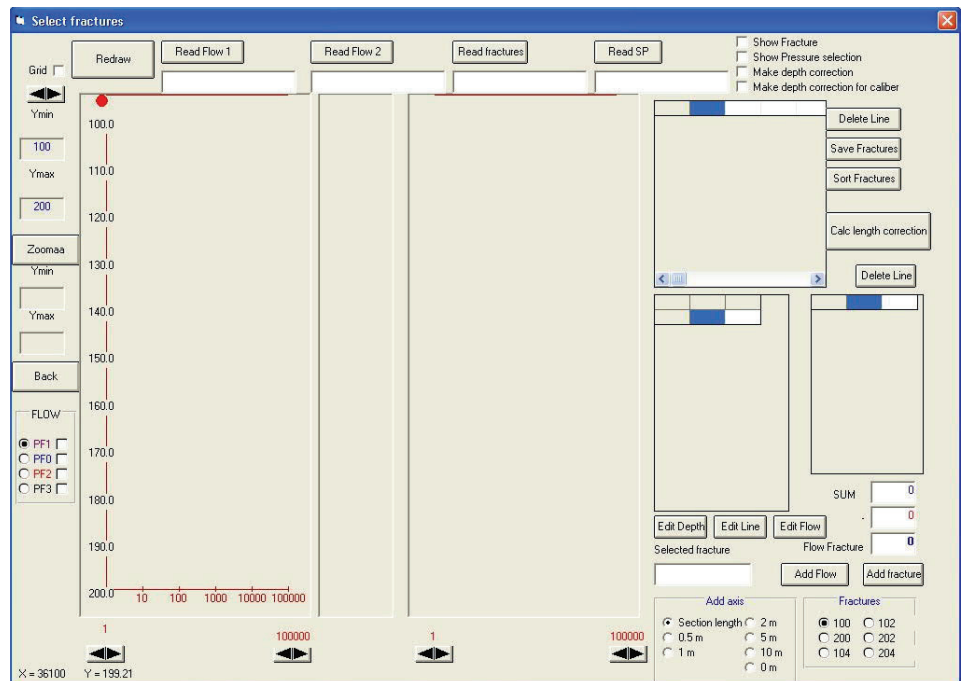
**Read Fractures:** KR46Fractures.csv

**Read SP:** OLKR46SP02B020D107.CSV (B-mittauksesta)

Kohtaan Flow1 valittiin nyt tiedosto, jolle rakotulkinta halutaan tehdä.

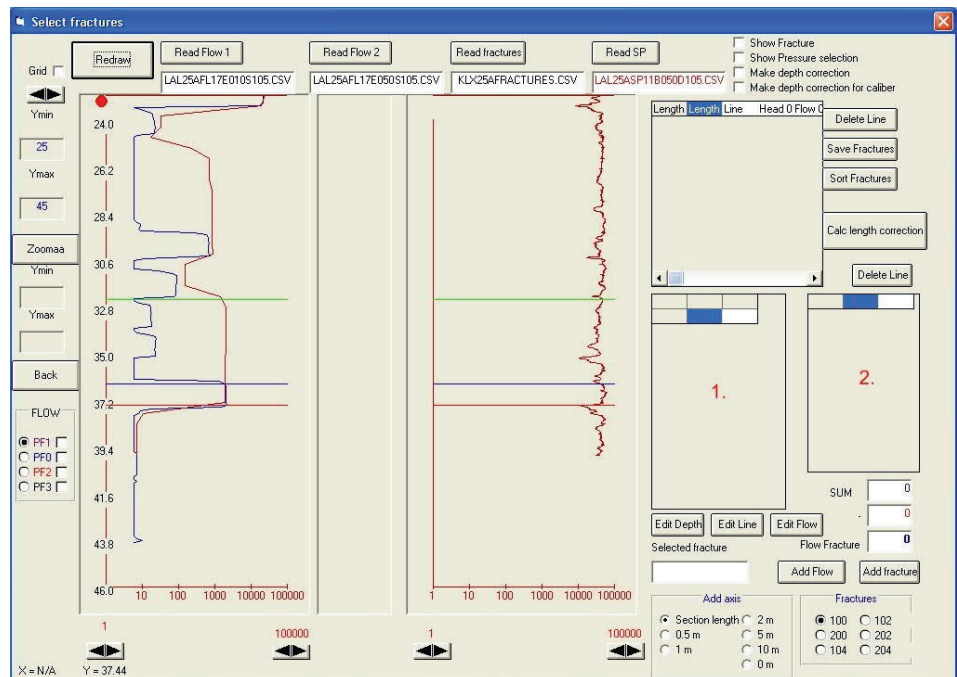
Tämän jälkeen voi painaa Redraw-nappia, niin käyrät tulevat näkyviin. Virtauskäyräkuvan päällä voi painaa hiiren oikeaa ja vasenta nappia valitakseen ”zoomausalueen”, jota haluaa tarkastella tarkemmin. Tämän jälkeen pitää vielä painaa Zoomaa-nappia, jotta zoomaus ”astuisi voimaan.” Alueen voi myös rajata 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.



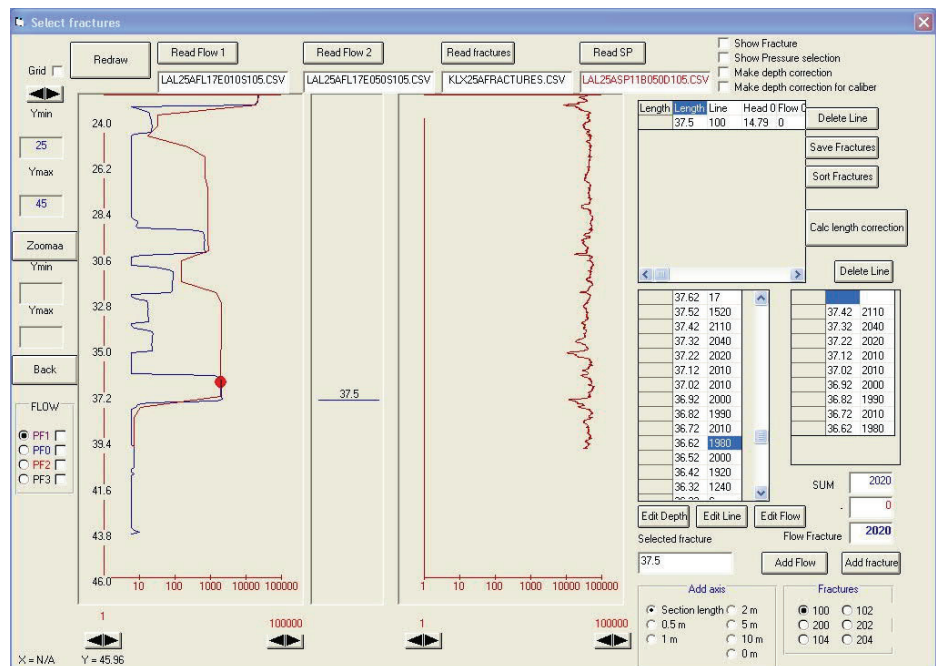
Kuva 7-7. Rakotulkinta-ikkuna.

Alkutoimien jälkeen voidaan aloittaa itse rakopaikkojen haku. Rakopai-  
kan voi hakea hiirellä SP-käyrän kohdalta. Kuva 7-8 punainen vaakavii-  
va osoittaa raolle valitun paikan. Sininen ja vihreä viiva ovat mittaussek-  
torien 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 vir-  
tausta, 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. Näis-  
tä 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 sekto-  
rin välein toisistaan. Tässä tapauksessa se ei ole tarpeellista, joten vä-  
hennetään luku nolla.



Kuva 7-8. Rakopaikan valinta.

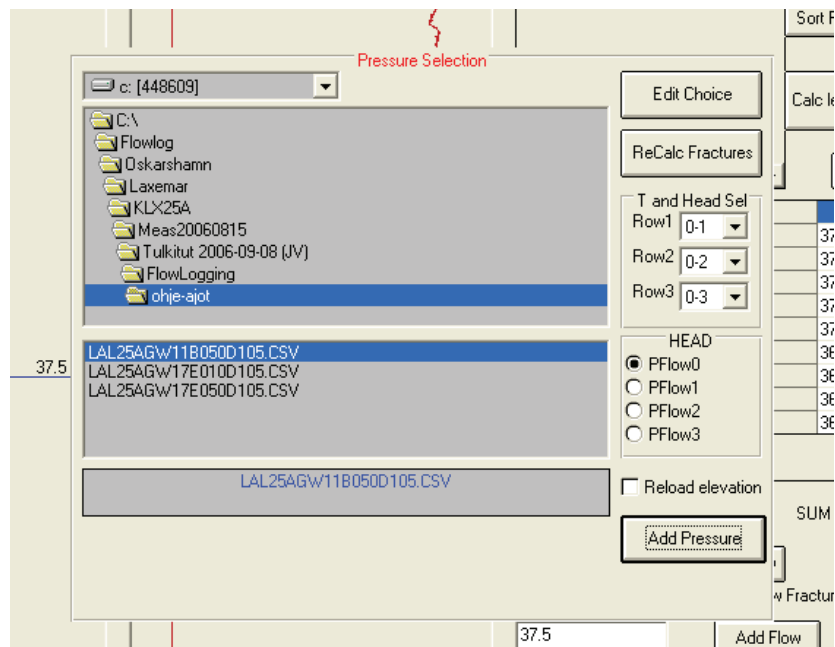
Kun virtaus on saatu määritettyä, se pitää lisätä rakotiedostoon. Tämä tehdään painamalla **Add fracture**-nappia. Lopputulos näkyy kuvassa 3-4.



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.



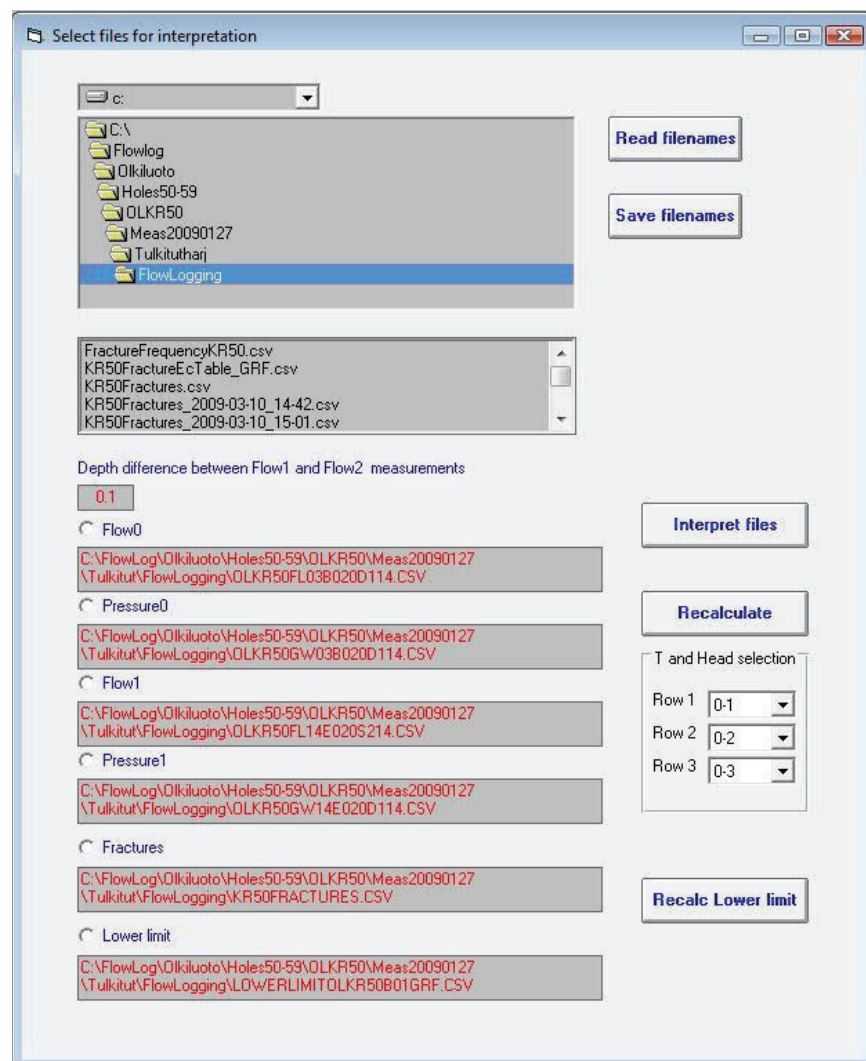
Kuva 7-10. Pressure selection-ikkuna. Ikkuna avautuu rakotulkintaikkunan päälle.

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. OLKR50FL03B020**D**114.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 sektoritulkinnassa 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 jouuu 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

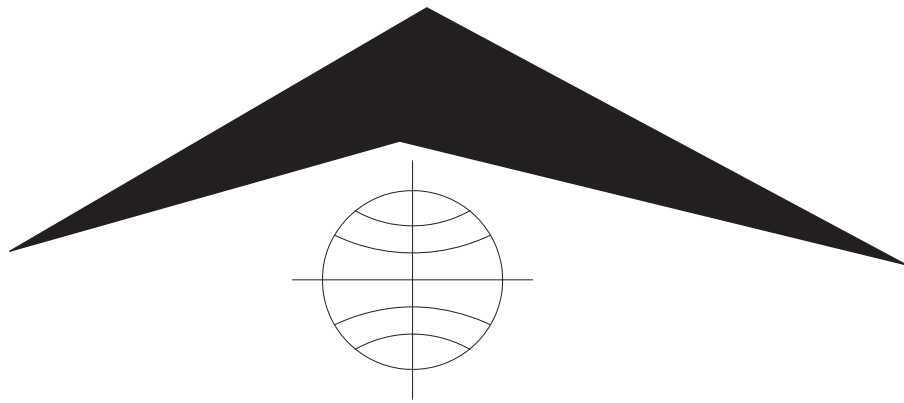
Rako-EC tulkinnassa toimistolla tulee käyttää valmista fractures-tiedostoa (**Conductivity of water (flows)**) –tulkinnasta valitaan fractures-



---

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.**

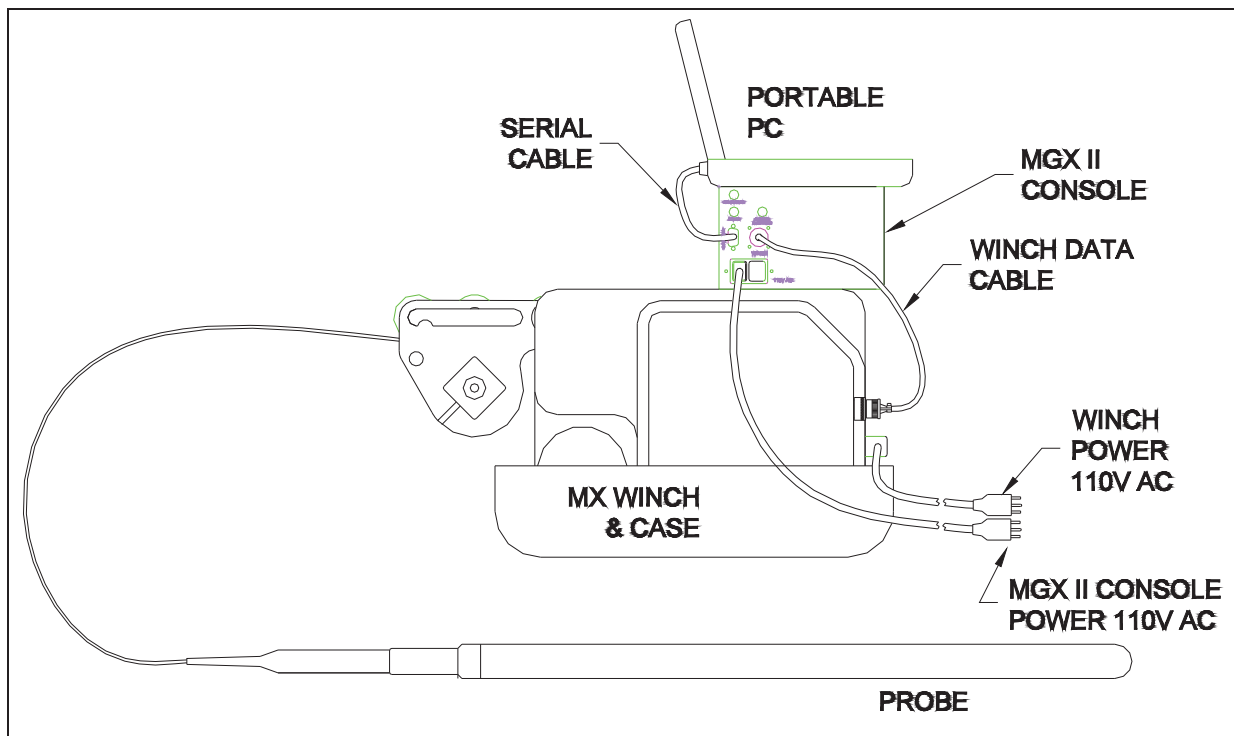


Figure 1

## 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.

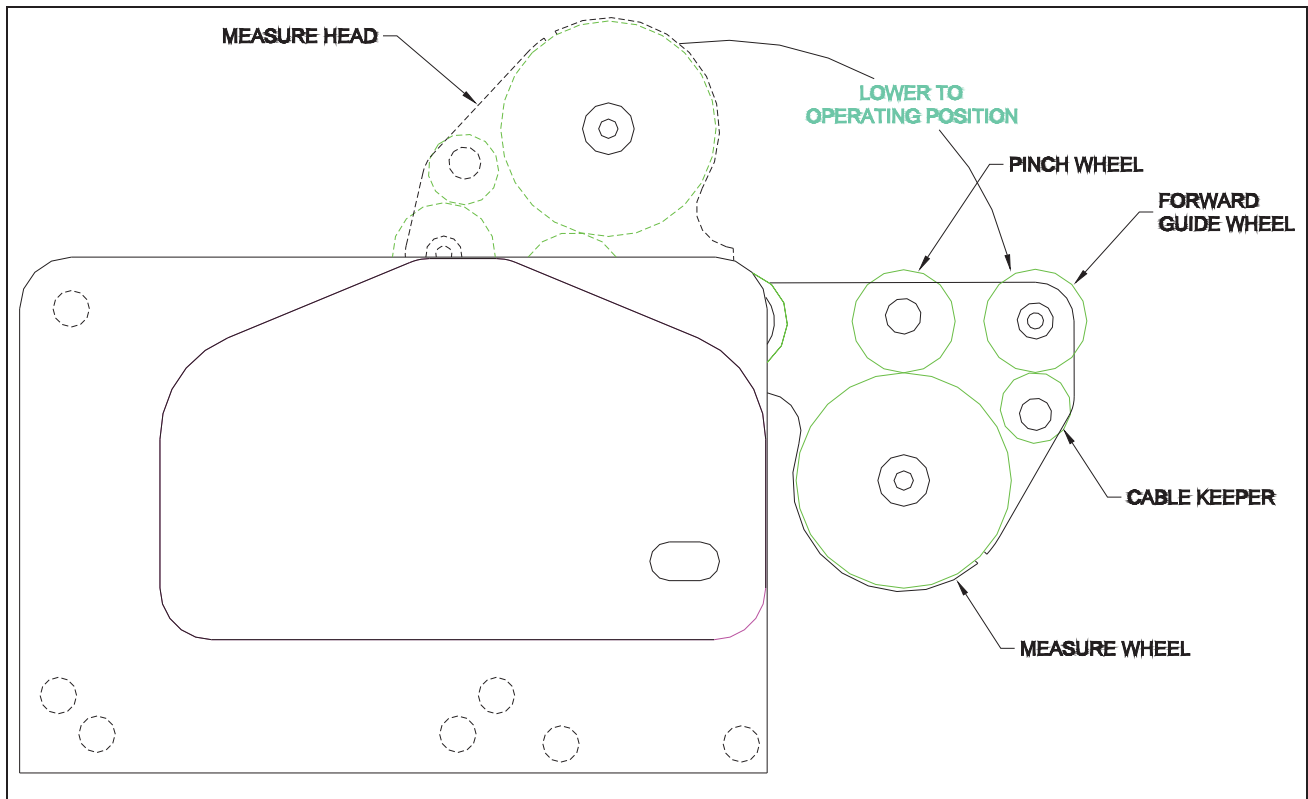
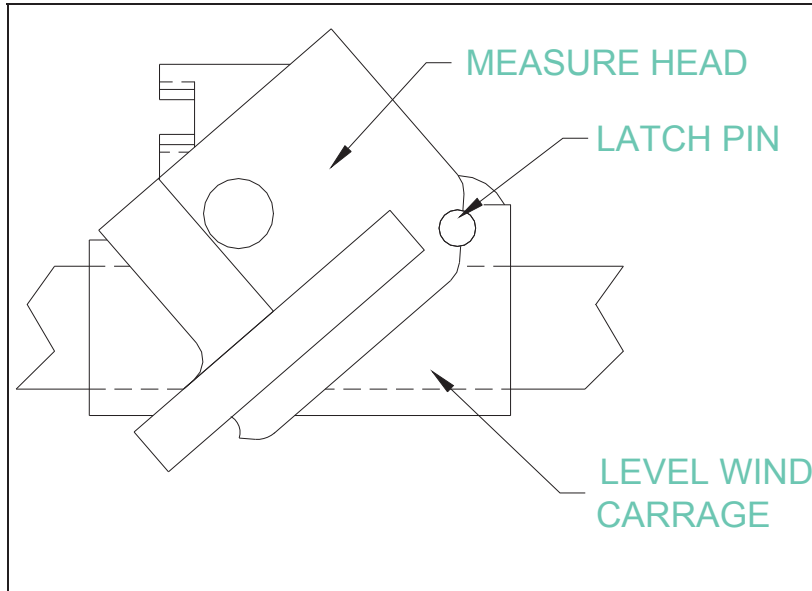


Figure 2

3. Release the MEASURE HEAD by pushing the LATCH PIN down.

**Figure 3**



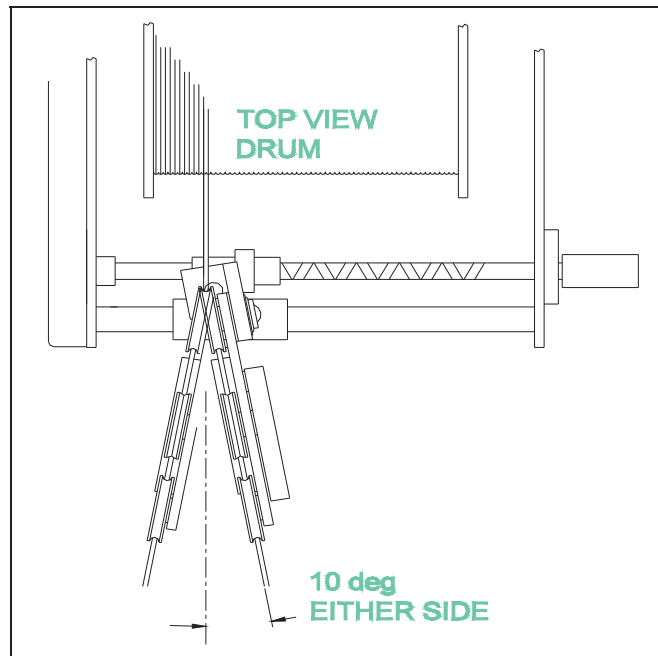
4. Set the winch so the cable path will be within the limits of the measure head.

These limits are:

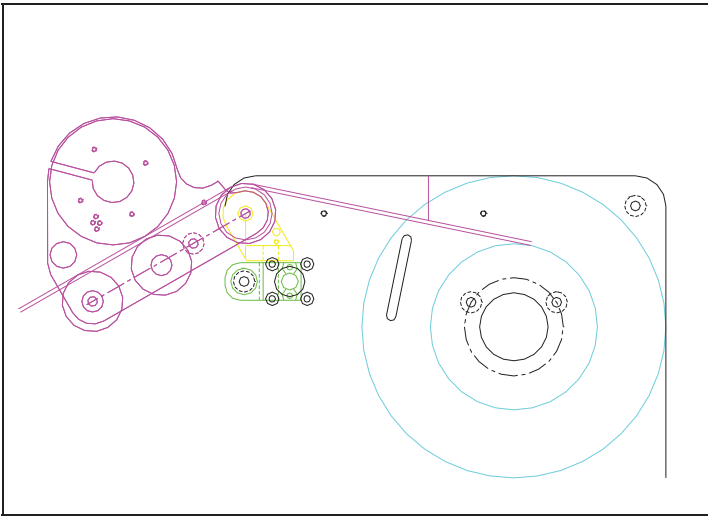
45° up  
5° down  
10° left, right

See figures 3 & 4

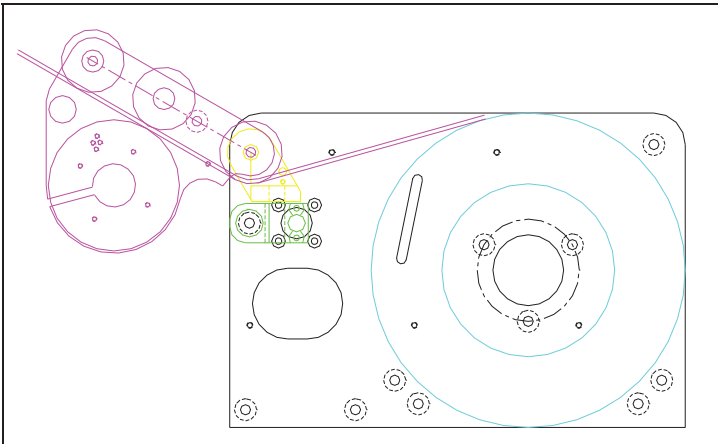
**IF THE CABLE PATH MUST LOG MORE THAN 5 DEGREES BELOW HORIZONTAL THE MEASURE HEAD SHOULD BE REMOVED AND TURNED UP SIDE DOWN. THE CABLE PATH WILL NOW GO OVER THE TOP OF THE REAR GUIDE WHEEL. See Figure 5 & 6**



**Figure 4**



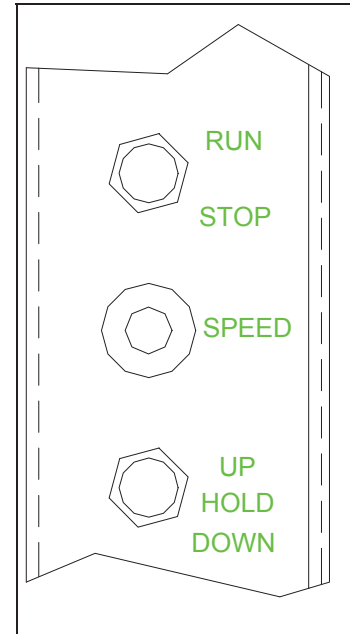
**Figure 6 - When logging more than 5° down**



**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!!**



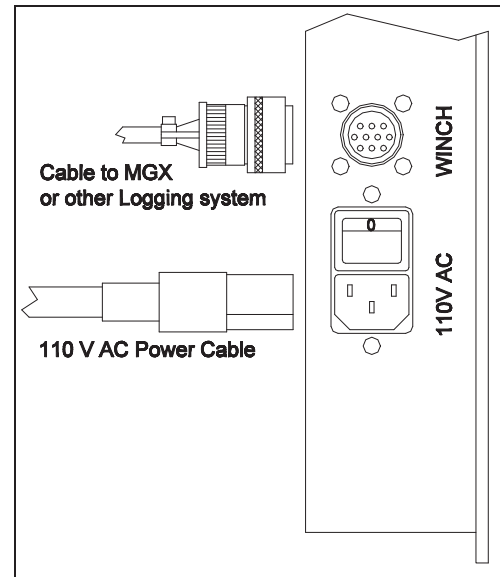
**Figure 7**

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.

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.



**Figure 8**

**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 BOTH 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 emergency brake 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 power is applied 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 does not function if the winch is not connected to an external depth encoder supply (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 by 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.

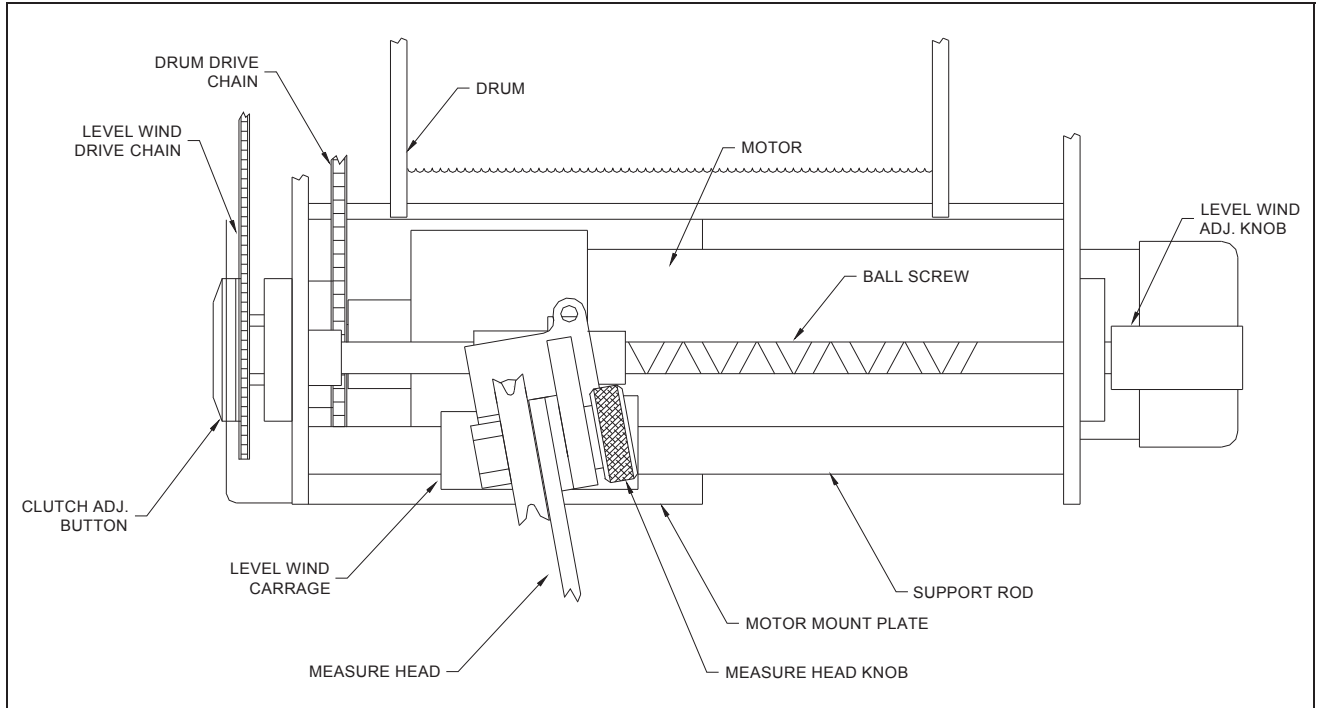


Figure 9

### 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 FOLLOWING 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.

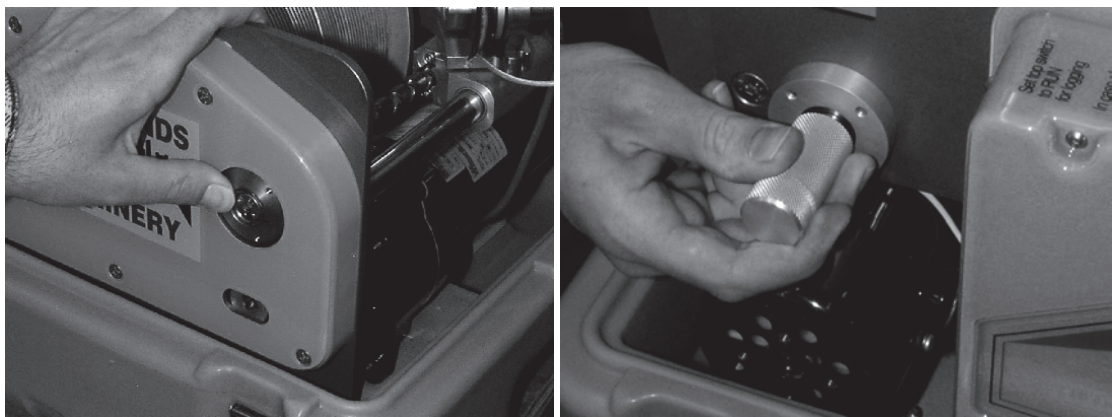


Figure 10

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-spoiled 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.

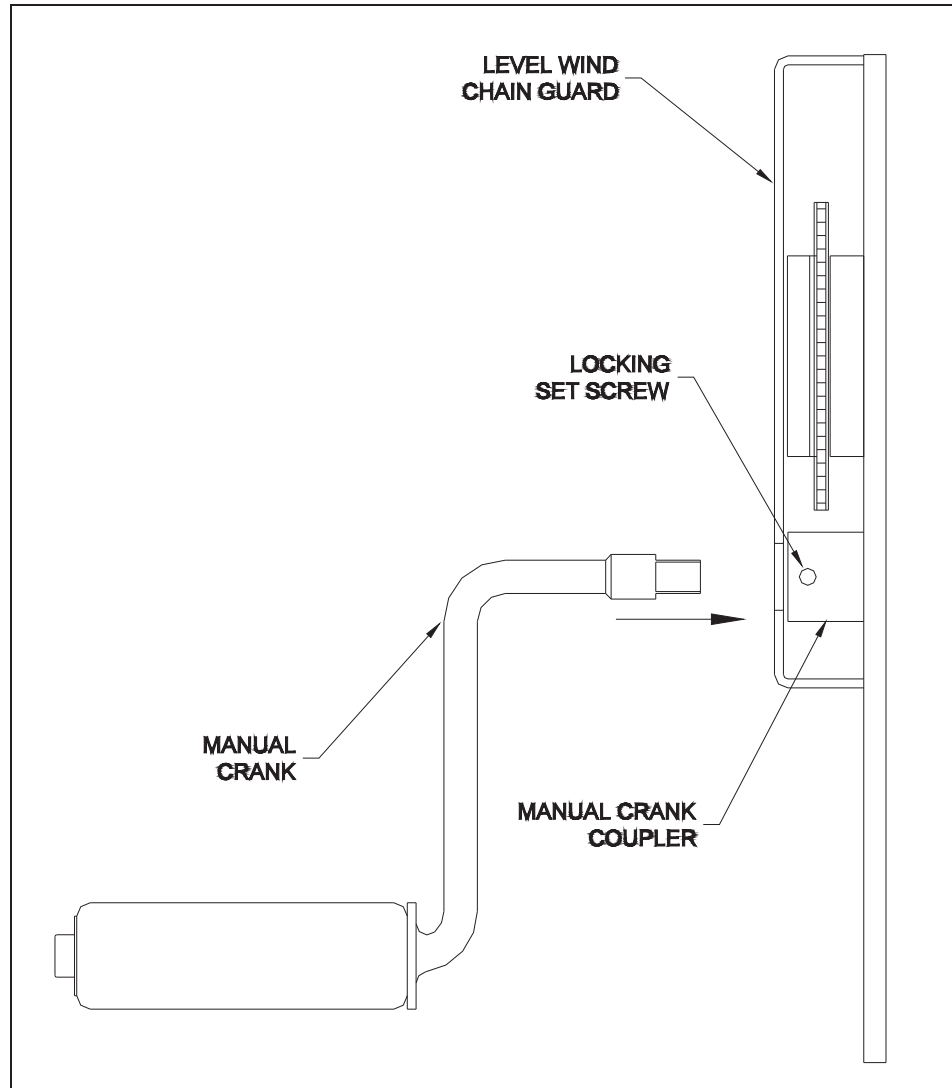


Figure11

## 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

|                                  |   |
|----------------------------------|---|
| <b>Motor:</b>                    | 1/4 hp, SCR type  |
| <b>Controller:</b>               | 4 quadrant, with current limit                          |
| <b>Speed:</b>                    | 0 to 85 ft/min  |
| <b>Load:</b>                     | 100 lbs   |
| <b>Cable Capacity:</b>           | 2624ft (800M) 1/10 in<br>1640ft (500m) 1/8 in           |
| <b>Shipping Weight:</b>          | 125 lbs   |
| <b>Winch Size:</b>               | 16 wide x 20.5 long x 12 high                           |
| <b>Case Size:</b>                | 17 wide x 17 long x 18 high in the case                 |
| <b>Cable off-axis tolerance:</b> | 10° left, 10° right, 12° down, 45° up<br>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 |



# Logger

## Software Application Guide



Version 13.0

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v20.04.02

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# 1 General Information

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## 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).

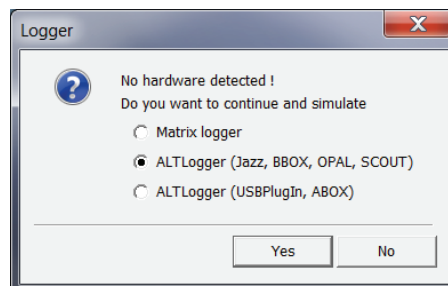


Figure 1.1 – Select hardware to simulate

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.

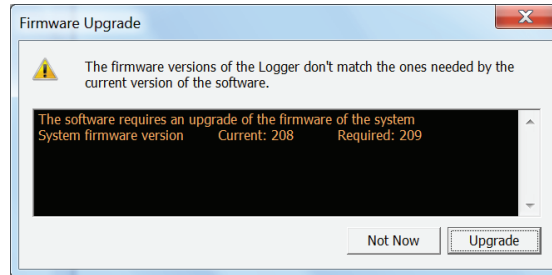
- **Start** the Logger software.
- From the Tool panel drop down list **select the tool** (loads tool configuration).
- Click the top right icon in Depth panel and **zero the tool**. The tool top / cable head joint should be levelled with the ground or other depth reference datum.
- In the Tool panel 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.



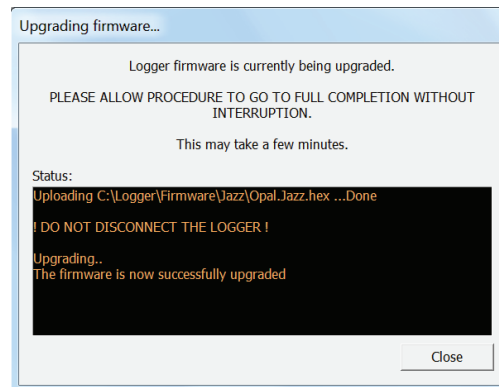
*Figure 2.1 – Firmware upgrade*

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.*

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.

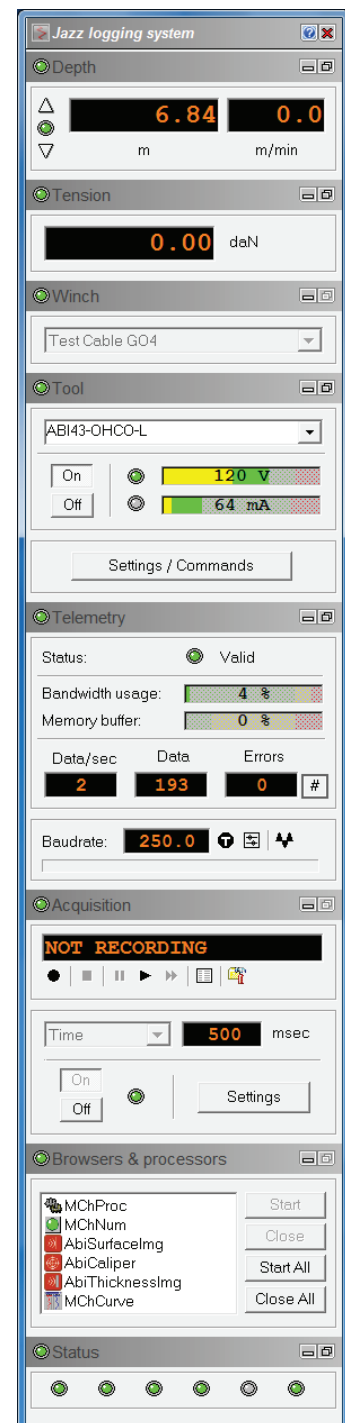


Figure 3.1

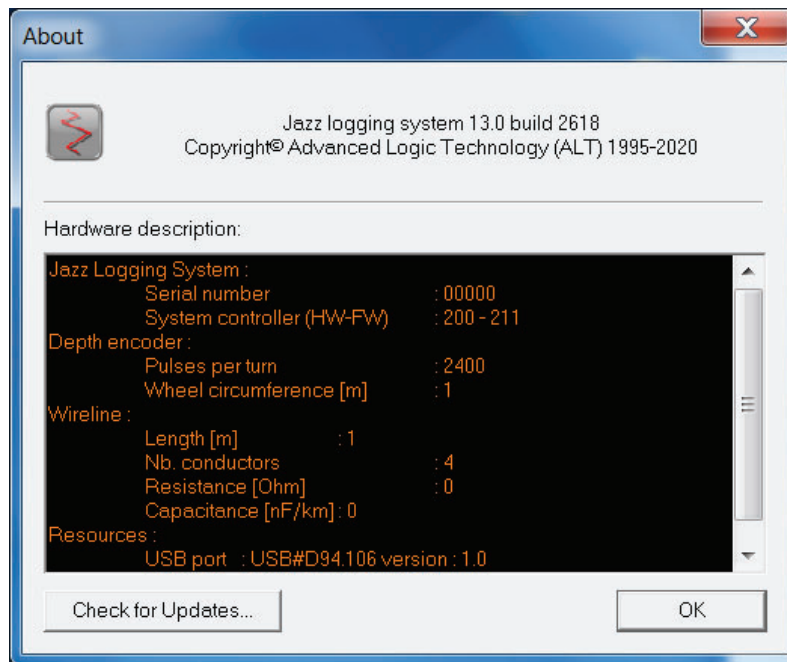


Figure 3.2 – About dialog unit

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)

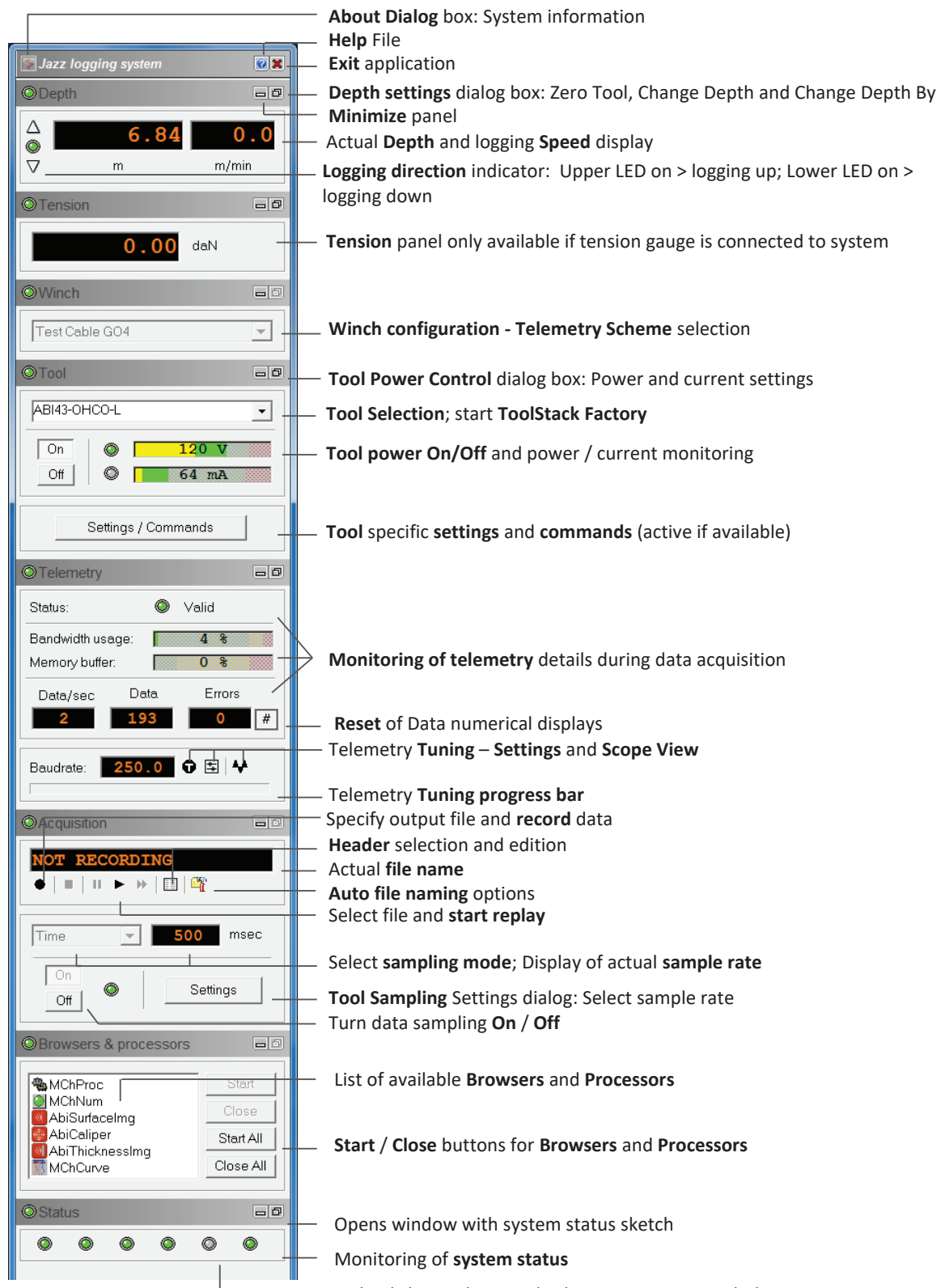
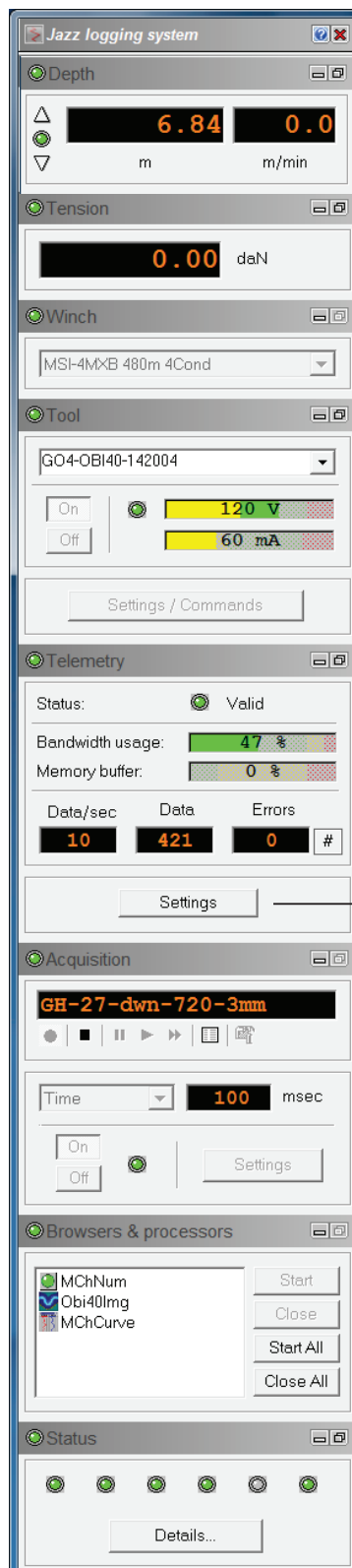


Figure 3.4 – Dashboard – ALT Modem

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)

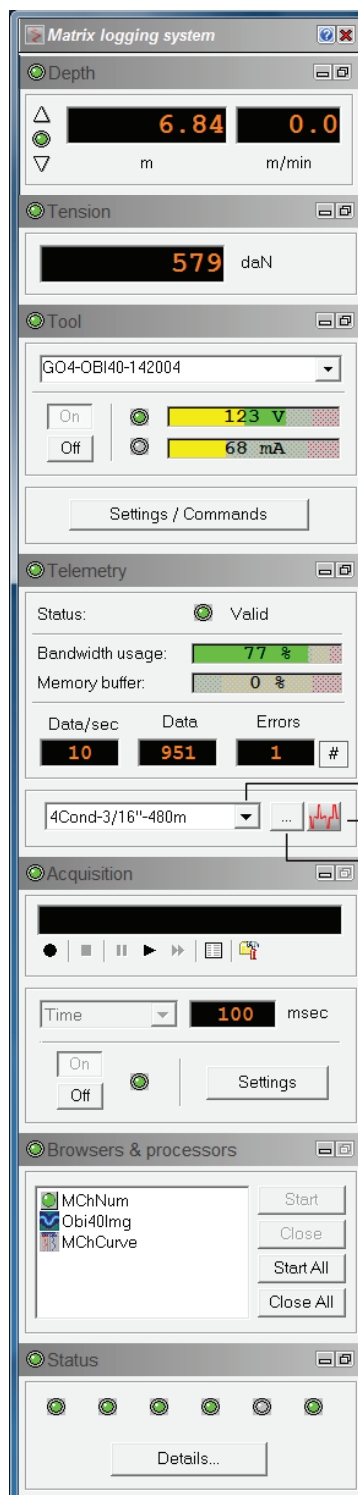


The dashboard options and general features are presented in page 9.

For this dashboard display click on **“Settings”** button in the Telemetry Panel to access to the telemetry settings dialog.

Figure 3.5 – Dashboard – ALT Shallow

### 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.

Winch **Telemetry Scheme** selection

Wireline **Scope View**

**Telemetry Settings**

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.

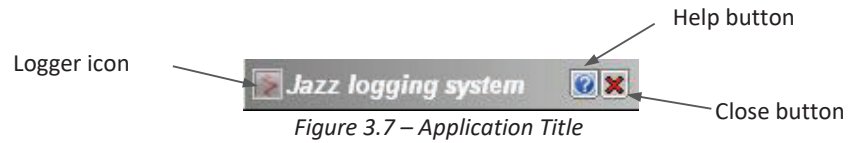


Figure 3.7 – Application Title

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.

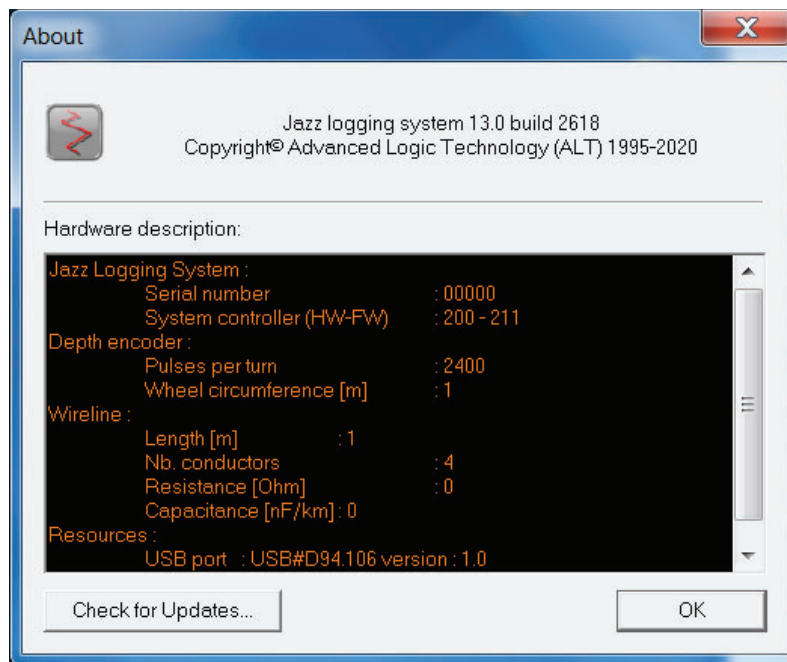


Figure 3.8 – System software and hardware description

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

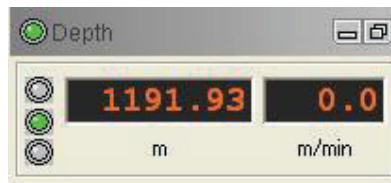


Figure 3.9 – Depth Panel

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).

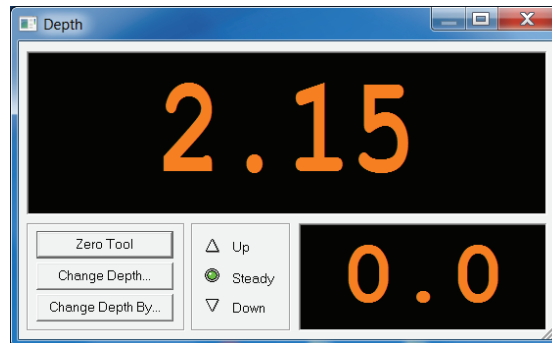


Figure 3.11 – Depth Settings

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

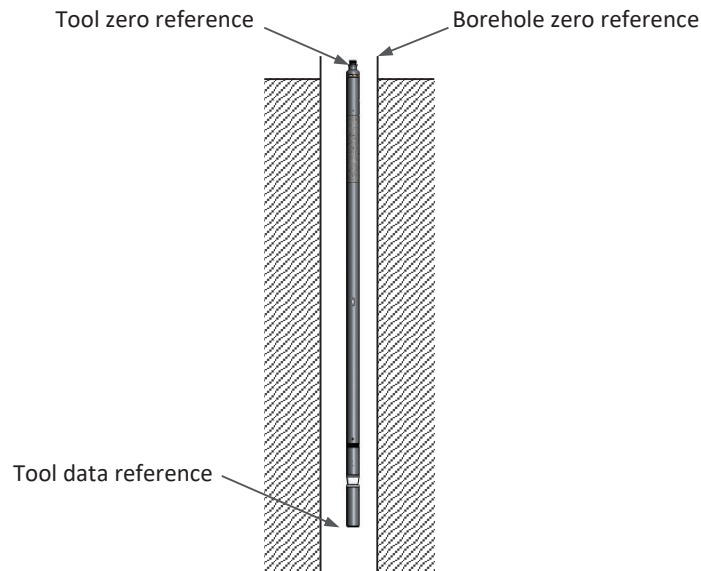


Figure 3.12 – Tool zero references

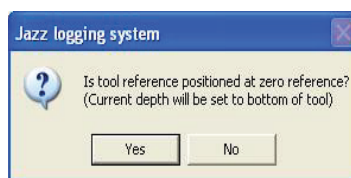


Figure 3.13 – Tool zero confirmation

**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.

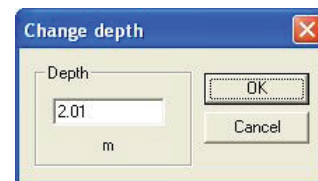


Figure 3.14 – Tool zero confirmation

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.

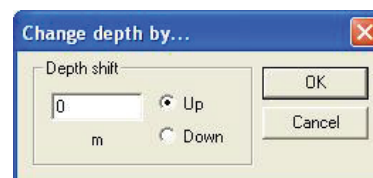


Figure 3.15 – Tool zero confirmation

### 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*.

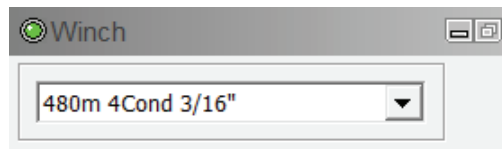


Figure 3.17 – Winch Panel

### 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.

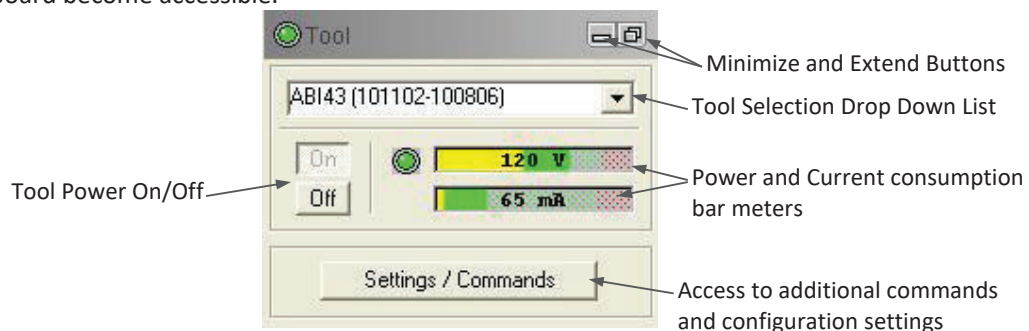


Figure 3.18 – Tool Panel

### 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.

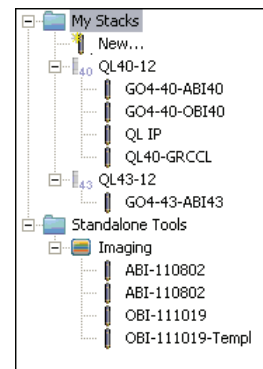


Figure 3.19 – Tool selection drop down list

### 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.

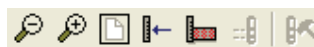


Figure 3.21 – ToolStack display controls

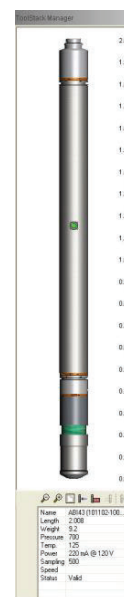


Figure 3.20 – ToolStack Manager

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).

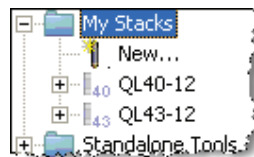


Figure 3.22 – Select **New** to start ToolStack Factory

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**.

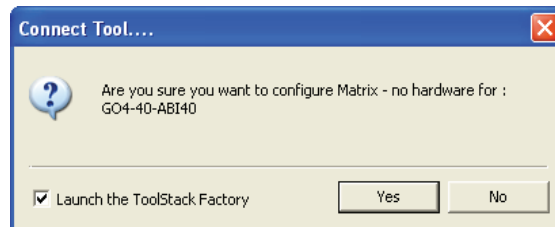


Figure 3.23 – Tick the option unit to start ToolStack Factory

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).

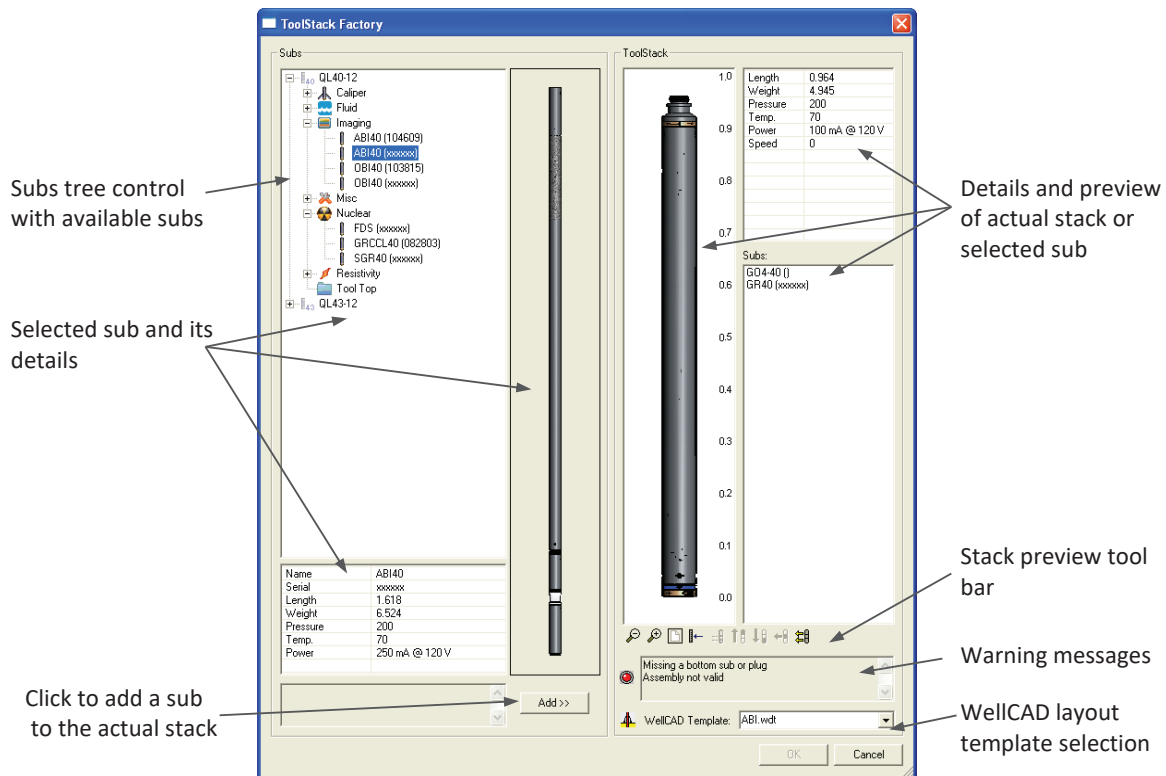


Figure 3.24 – ToolStack Factory

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 Televiwer (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.

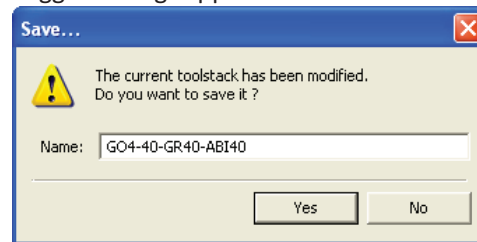


Figure 3.25 – Tool Stack confirmation

### 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

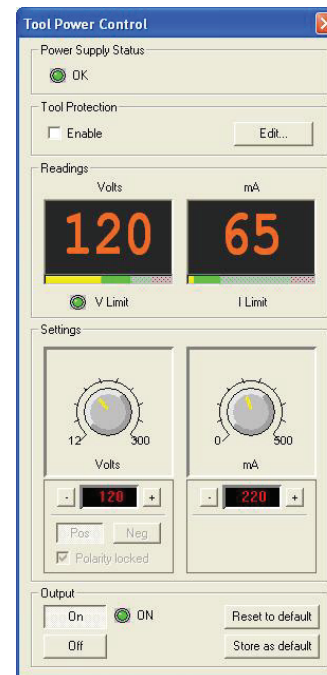


Figure 3.26 – Tool Power Control

user input. As an orientation the nominal (NOM) values as suggested for this type of tool are displayed next to the edit unites.

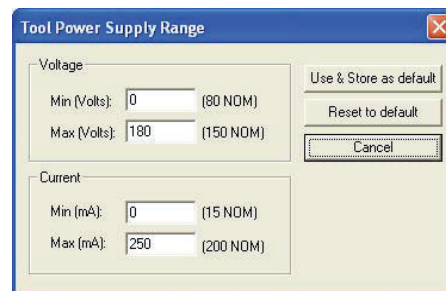


Figure 3.27 – Tool Power Supply Range

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:

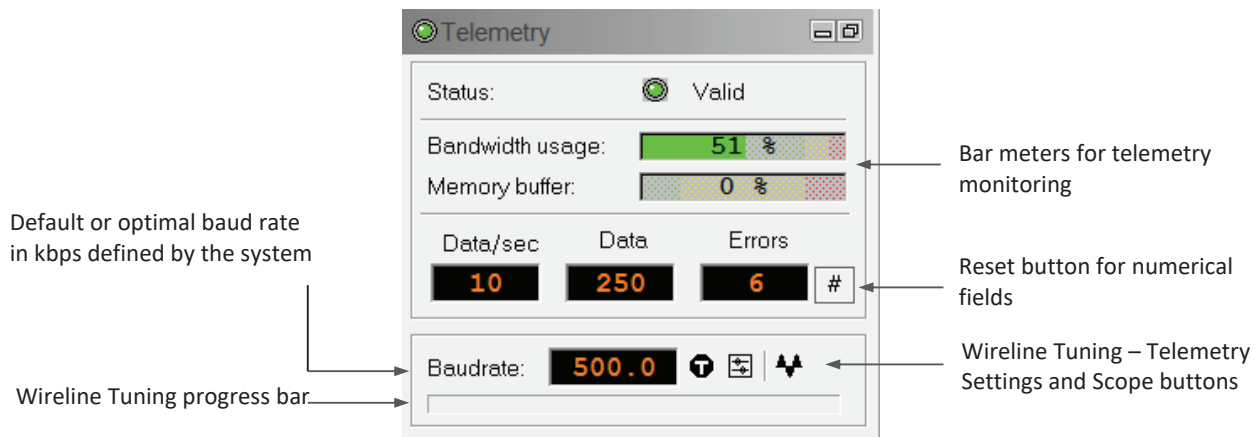


Figure 3.28 – Telemetry Panel – ALT Modem (OPAL – SCOUT PRO- SCOUT)

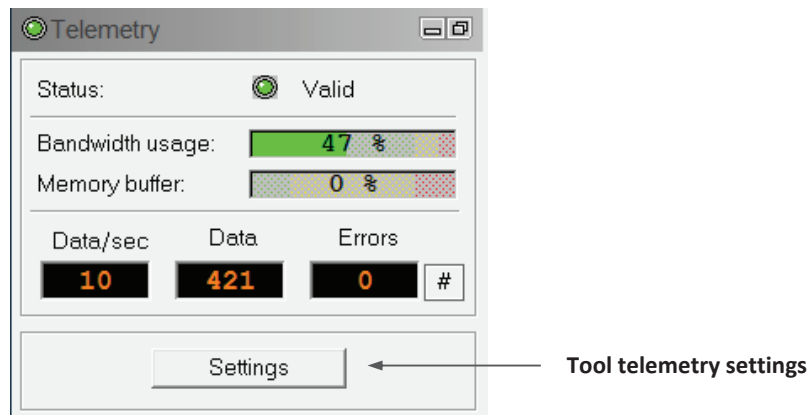


Figure 3.29 – Telemetry Panel – ALT Shallow (BBOX - ALTLOGGER)

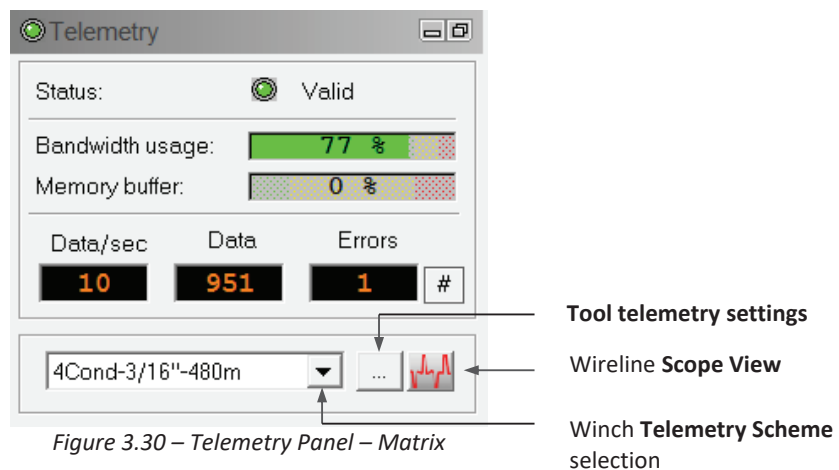


Figure 3.30 – Telemetry Panel – Matrix

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.

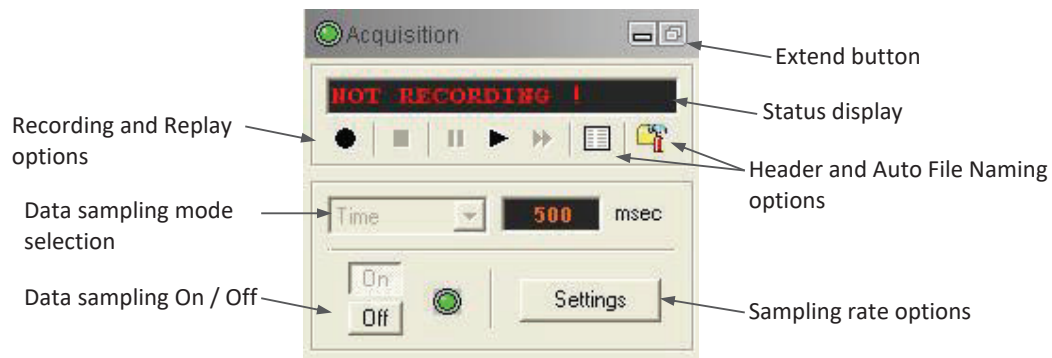



Figure 3.31 – Acquisition panel

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).

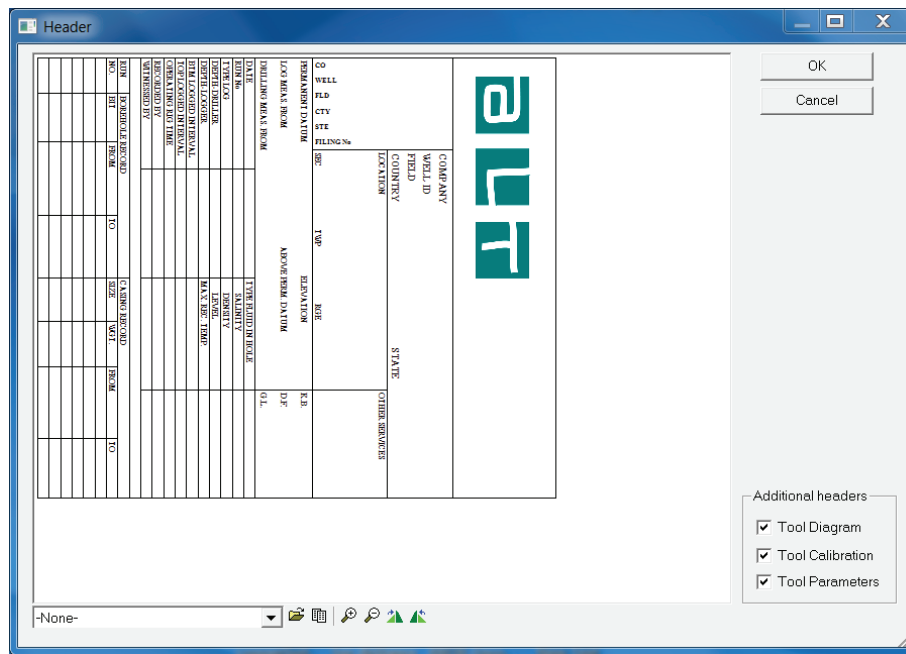


Figure 3.32 – Header dialogue unit

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.

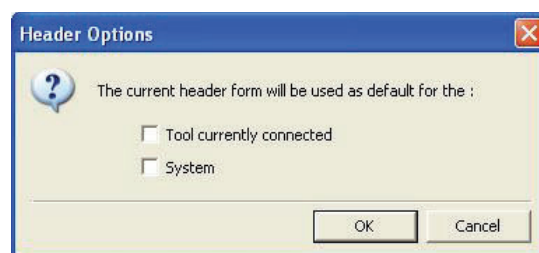


Figure 3.34– Header options dialogue

**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.

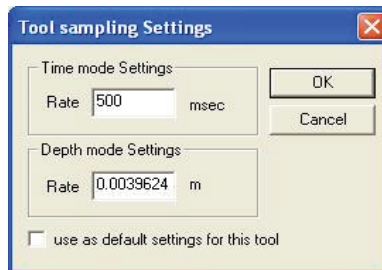


Figure 3.35– Tool sampling options for standalone tools

For tool stacks using multiple subs (e.g. ABI with GR) the dialogue unit in Figure 3.36 opens.

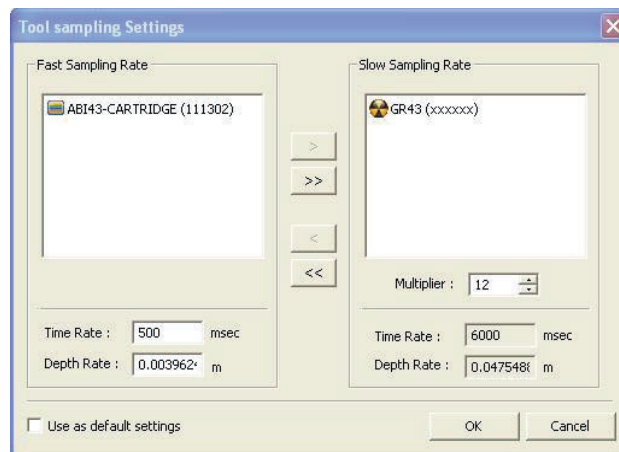


Figure 3.36– Tool sampling options for multi sub tools

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 1/200<sup>th</sup> 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).

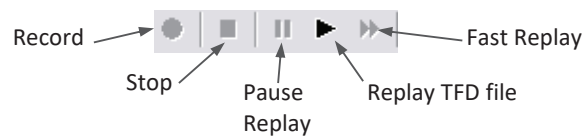



Figure 3.37 – Record and replay options

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.

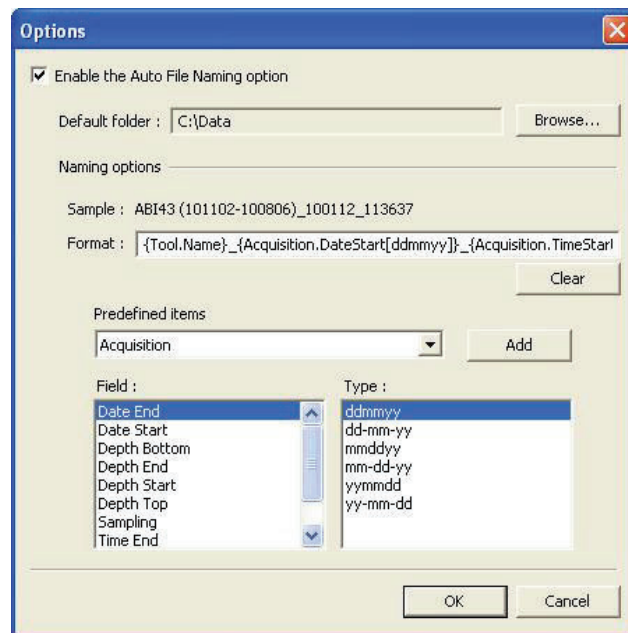


Figure 3.38 – Auto File Naming options

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.

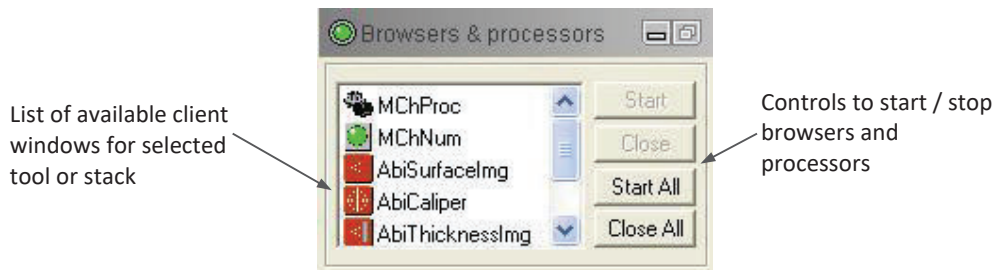


Figure 3.39 – Browsers & processors panel

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).

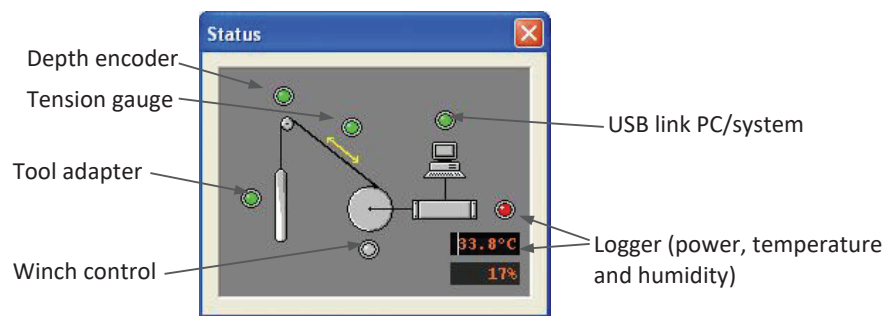


Figure 3.40 – Extended Status panel

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 **Multi Channel 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.

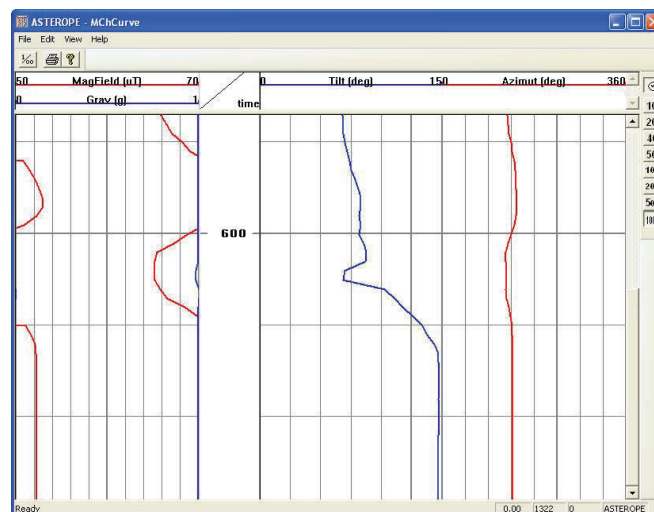


Figure 4.1 – MChCurve browser window

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).

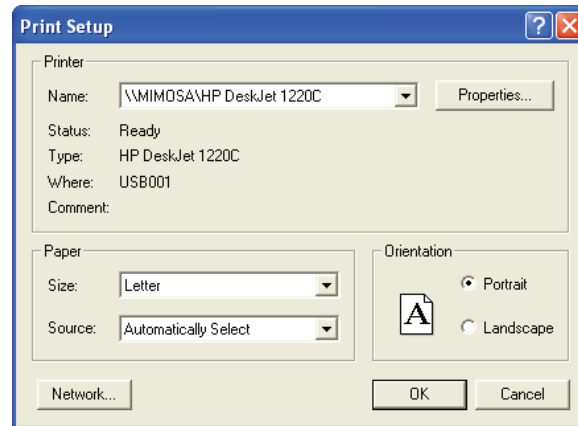


Figure 4.2 – Print Setup dialog unit

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.

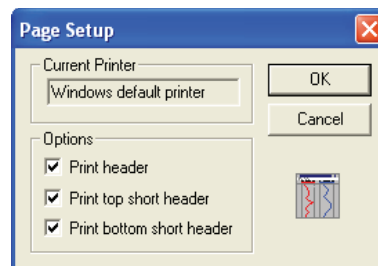


Figure 4.3 – Page Setup dialog unit

**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.

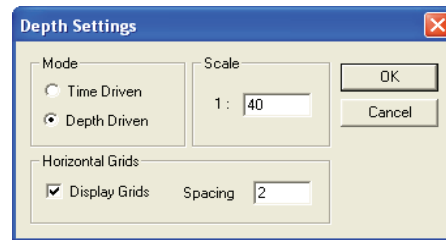


Figure 4.4 – Depth Settings dialog unit

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.

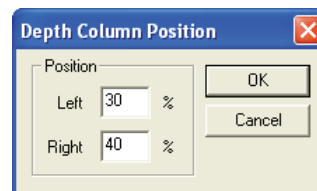


Figure 4.5 – Depth Column Position dialog unit

**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.

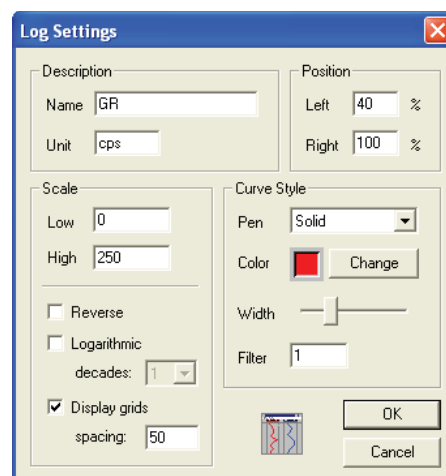


Figure 4.6 –Log Settings dialog unit

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.

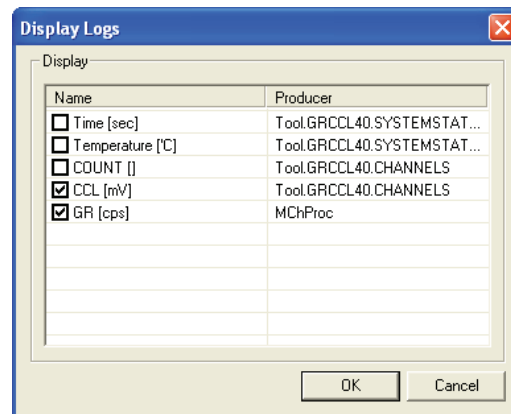


Figure 4.7 – Displayed logs selection

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 **Multi Channel Numeric 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.

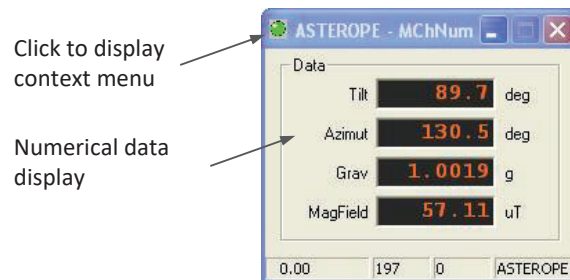


Figure 4.8 – MChNum browser window

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).

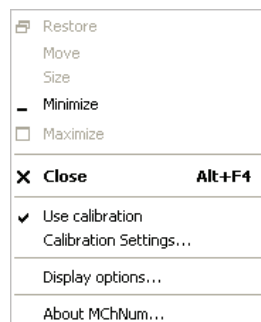


Figure 4.9 – MChNum browser context menu

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.

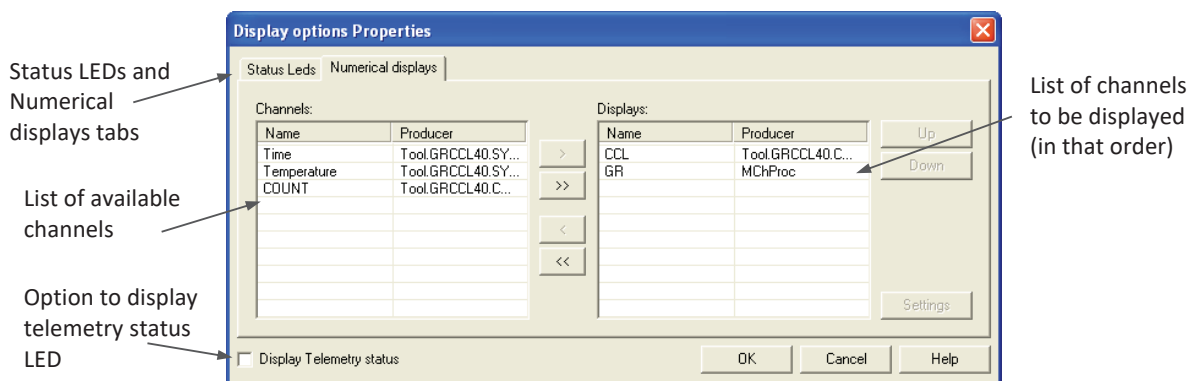


Figure 4.10 – MChNum browser context menu

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.

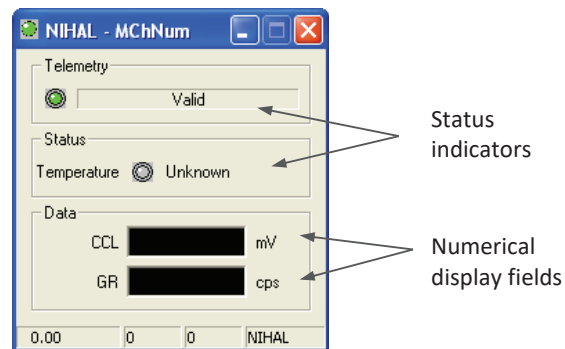


Figure 4.11 – MChNum browser with status LEDs and numerical display fields

### 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.

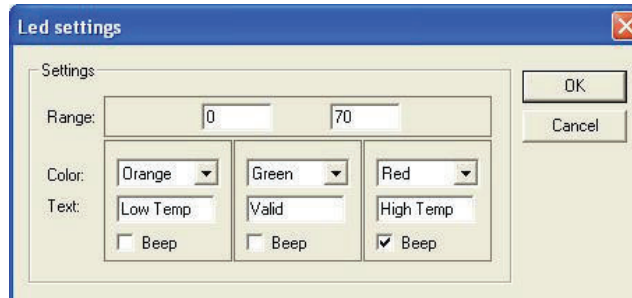


Figure 4.10 – MChNum browser context menu

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 note 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.

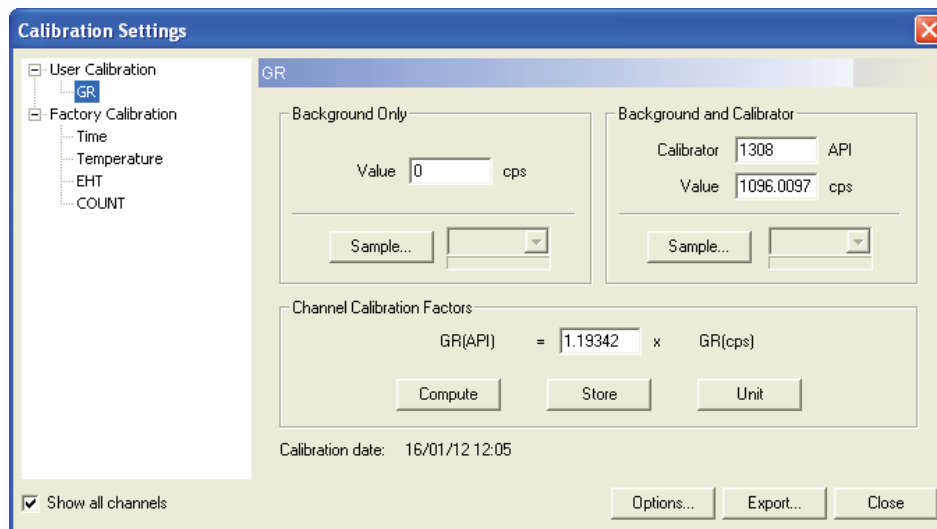


Figure 4.11 – Calibration Settings dialog unit for the QL40 GAM tool

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.

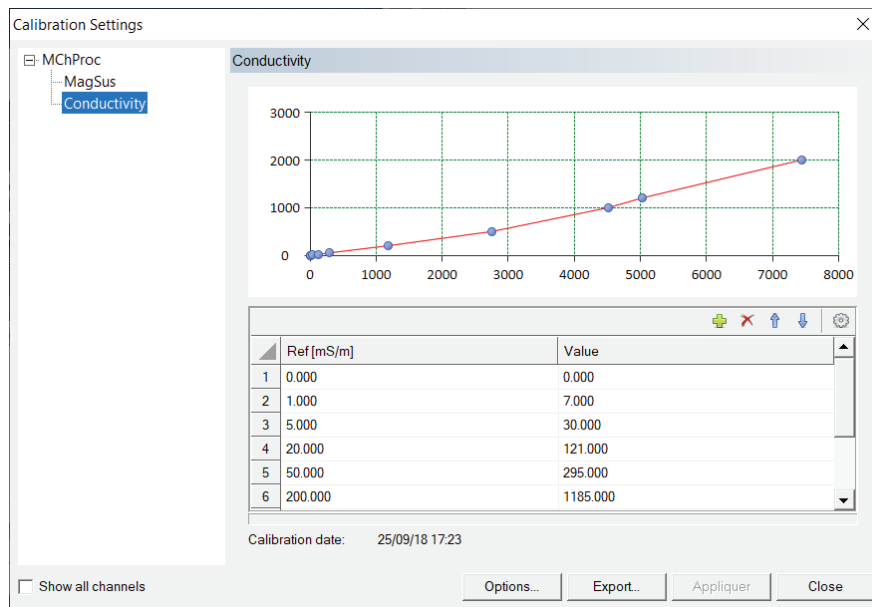


Figure 4.12 – Multi-point calibration example

### 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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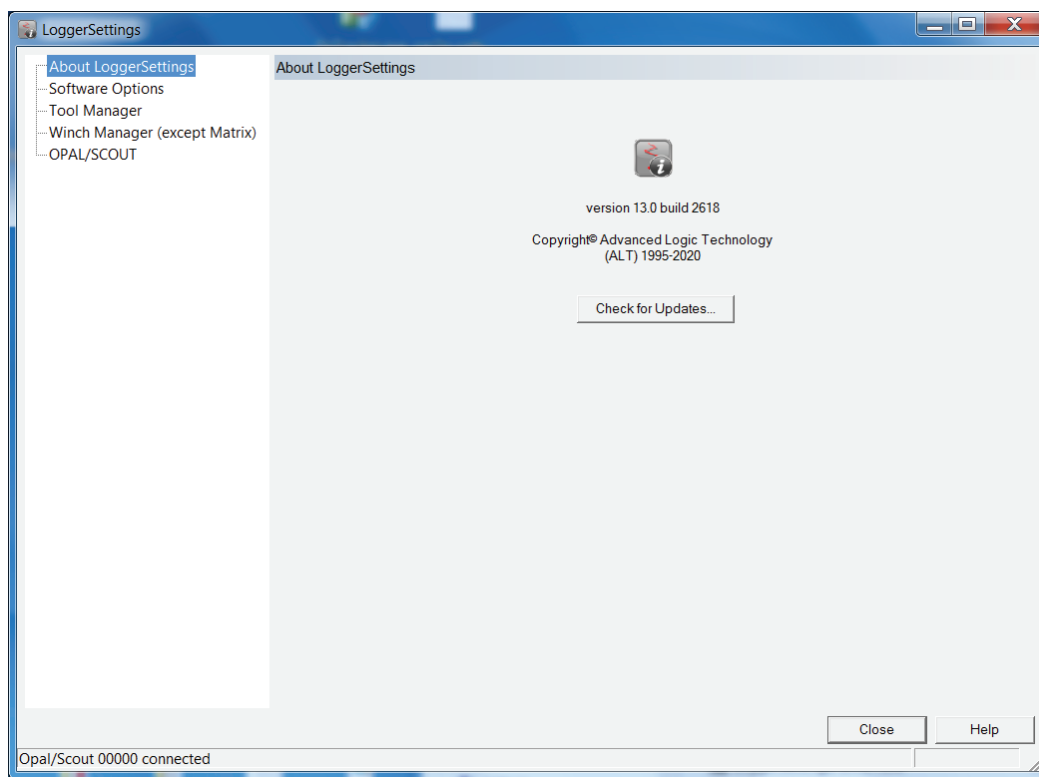
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## 1 General Information

**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** - Application user interface

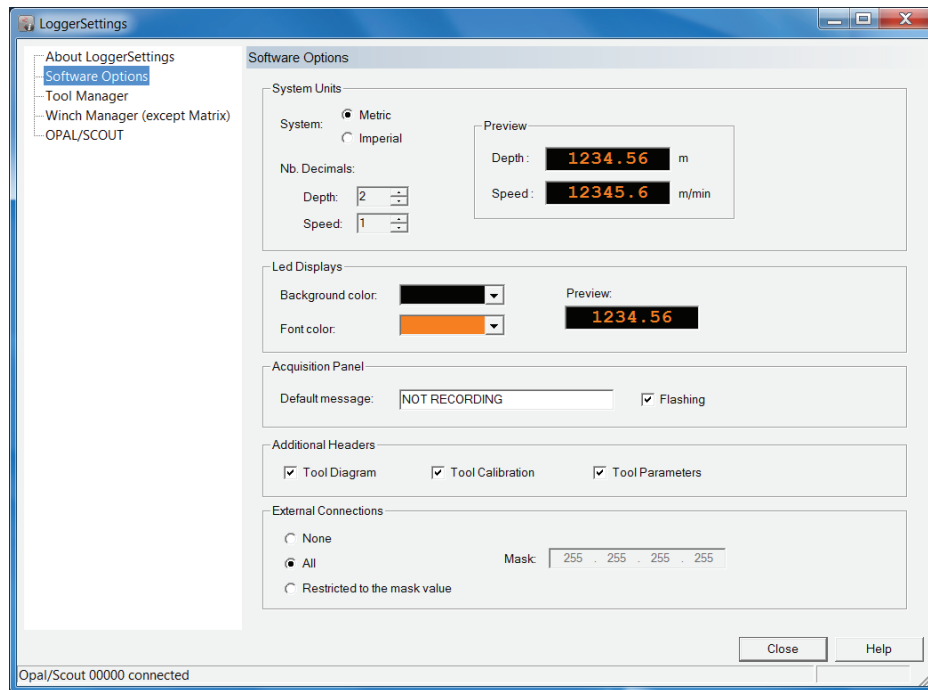
When starting the application the “About LoggerSettings” page showing the application version and build number will be displayed (Figure 1-1).

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** – Software Options

### **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

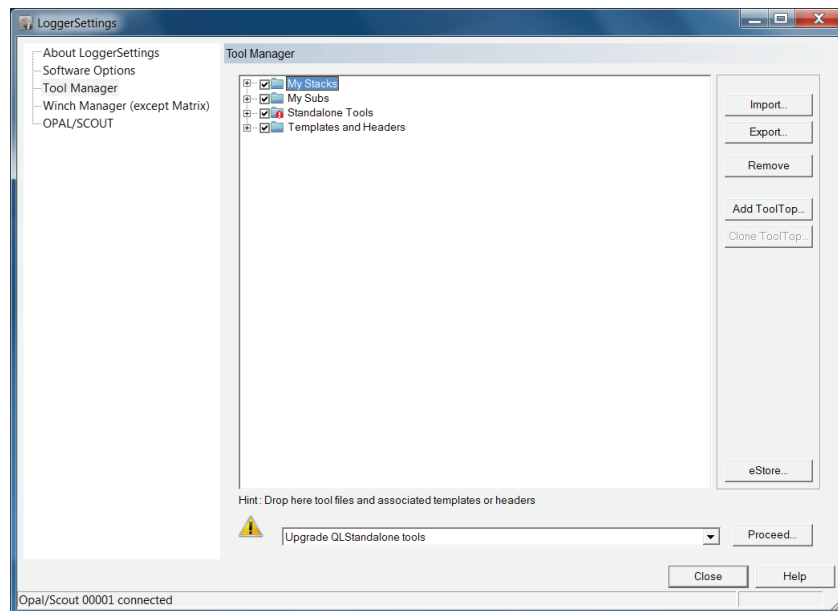
**External Connections:**

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** Tool Manager Page

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.

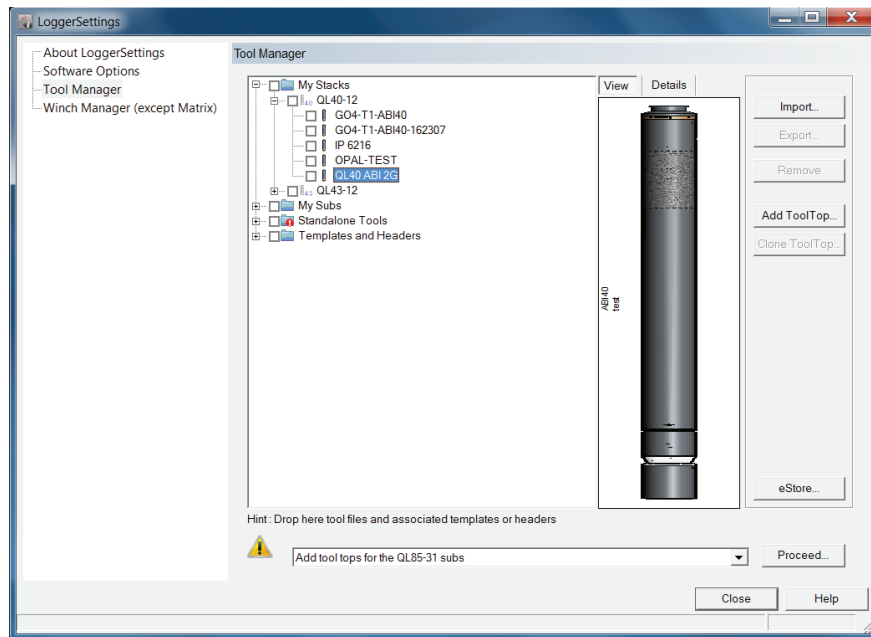
***Standalone Tools:***

Listed are all standalone tools (i.e. non stackable tools).

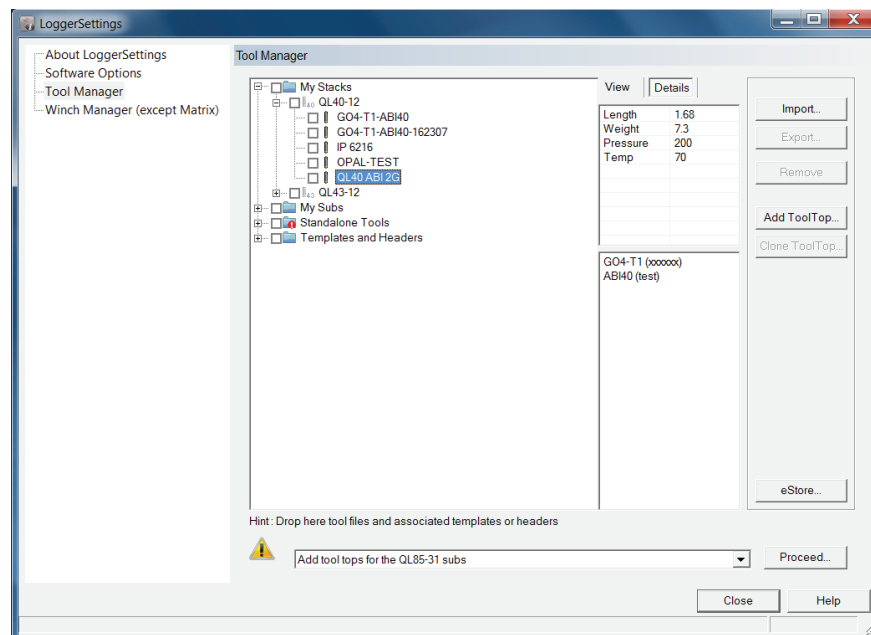
**Templates and Headers:**

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** Tool Stack preview



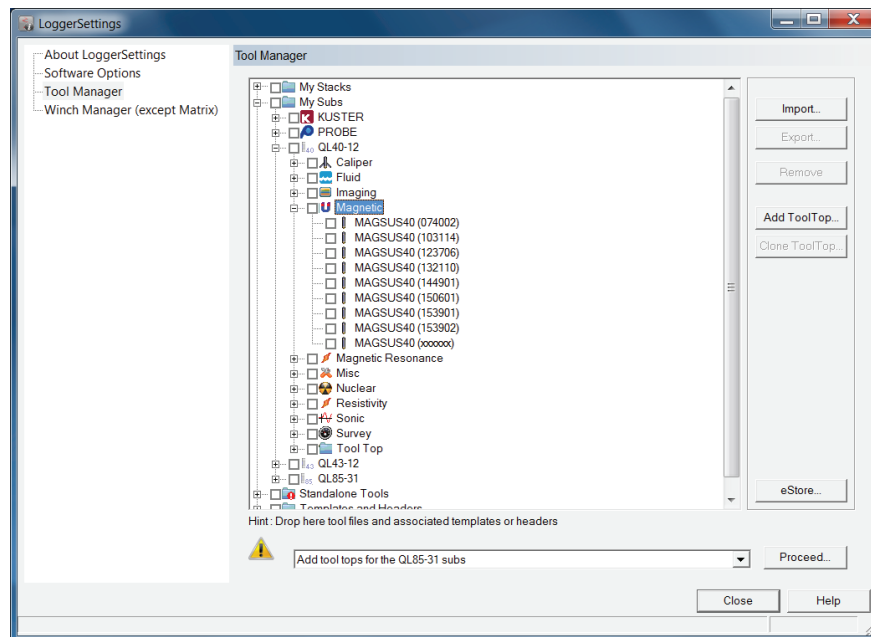
**Figure 3-3** Tool Stack details

### 3.1 Importing and installing files

The tool configuration files supplied with the logging equipment can be installed in different ways:

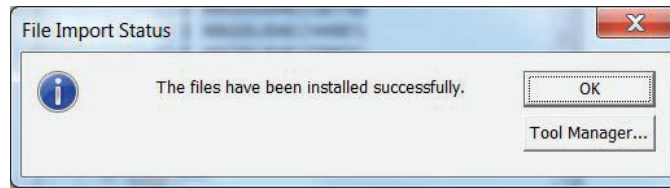
- **Drag and drop the configuration files** on “**LoggerSettings**” icon visible on your computer’s desktop.  
Note that multiple tool configuration files can be installed all at once when they are grouped into a single folder. **Drag and drop the folder** containing the files on Logger Settings icon.
- 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).

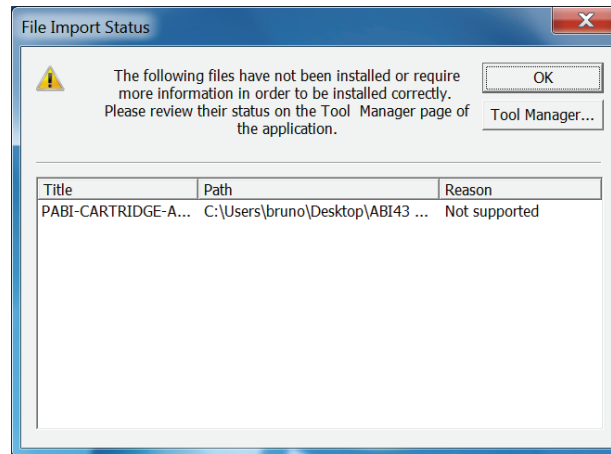


**Figure 3-4** Tool Manager Import option

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** Successful installation message



**Figure 3-6** File installation failure message

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.

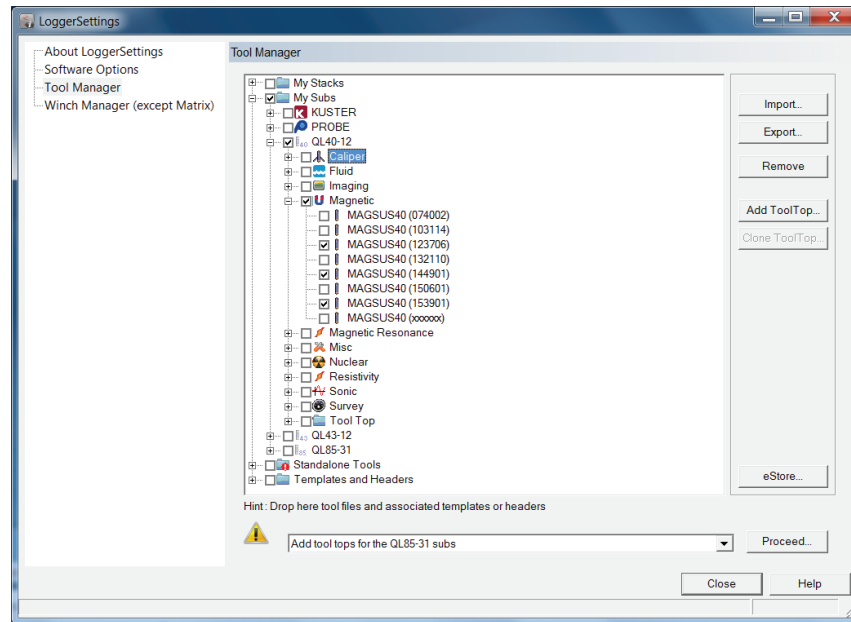


Figure 3-7 Select tools for export

### 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:

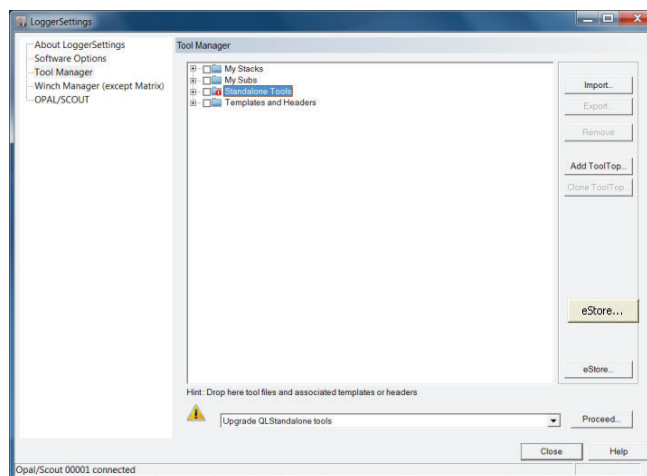


Figure 3-8 – Invalid configuration indicator

In this example QLStandalone tool configuration files are invalid and must be corrected. Click on **“Proceed”** for the next step.

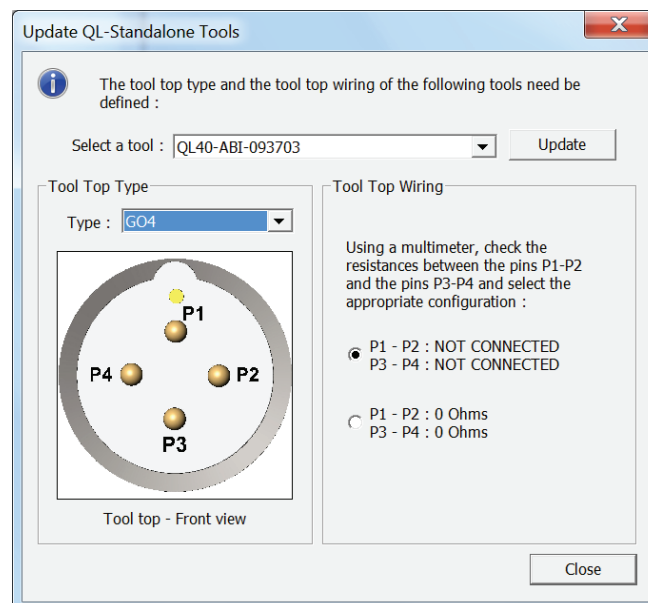
From the **“Update QL-Standalone Tools”** dialog box (Figure 3-9), select from the drop down list the tool configuration file to update and then chose the tool top type to allocate to this specific tool. User must confirm the wiring of the tool top mounted physically on the tool as detailed in the tool 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.

---

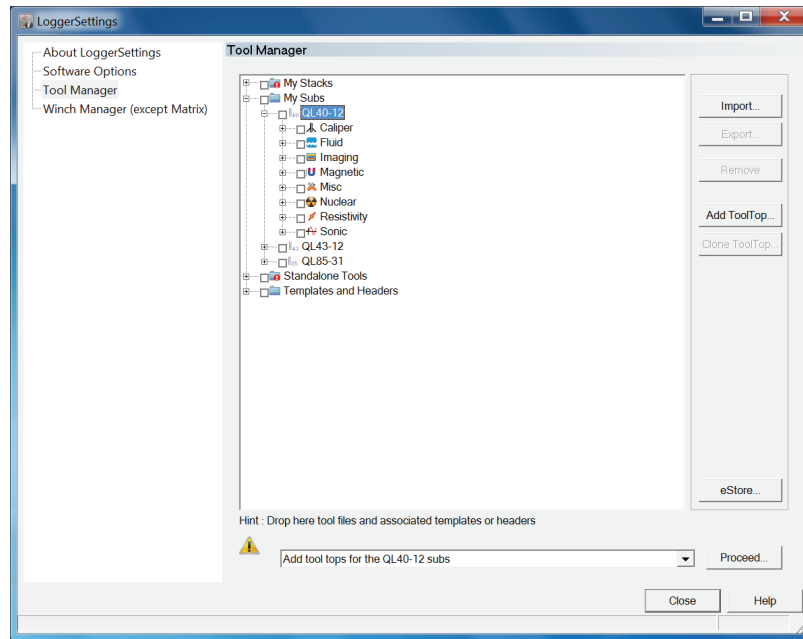
**Note:** The acquisition system configures the power/coms and auxiliary lines based on the tool top wiring defined by the User. Improper settings may damage the tool or degrade the tool telemetry performance. Contact ALT in case of any doubt or question.

---



**Figure 3-9** Updating a QL-Standalone tool configuration file

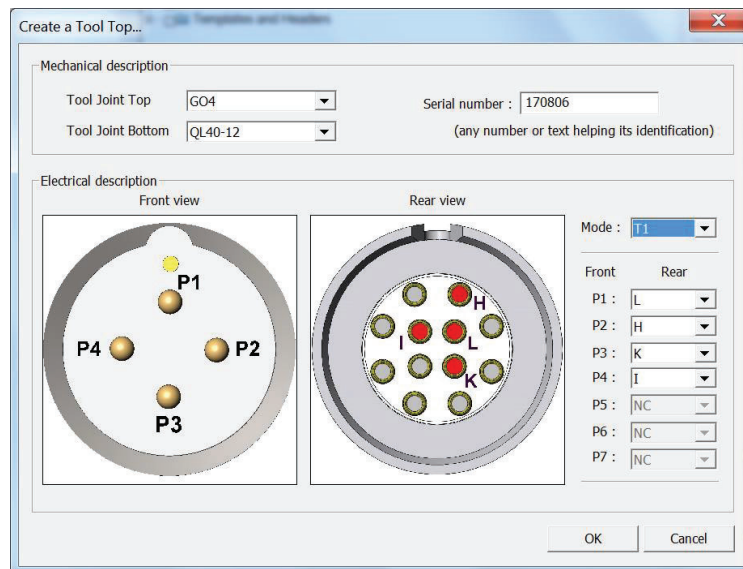
When no tool tops are defined for a family of QL-tools (Figure 3-10), the user will need to create the required tool top configurations. This can be done by selecting either **“Add Tool Tops for QLxx-xx Subs”- Proceed** or by clicking on the **“Add Tool Top”** button:



**Figure 3-10** Add Tool Tops

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<sup>1</sup>
- click on **OK** to confirm your settings and to create the new tool top

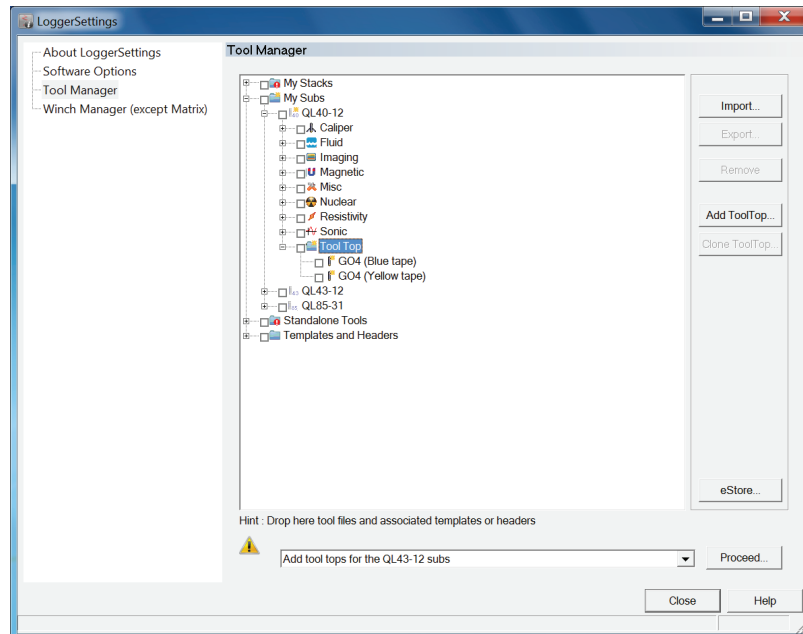


**Figure 3-11** Create a QL40-12-GO4 Tool Top – T1 wiring mode

The newly created tool tops are now displayed in a **“Tool Top”** folder (Figure 3-12) and are highlighted with a yellow icon.

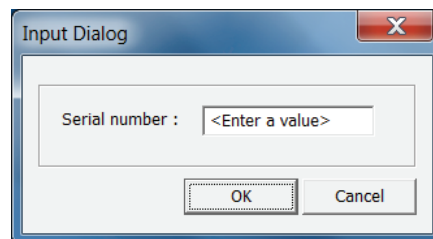
<sup>1</sup> Contact ALT for any non-standard wiring





**Figure 3-12** Tool top folder listing the new tool tops created

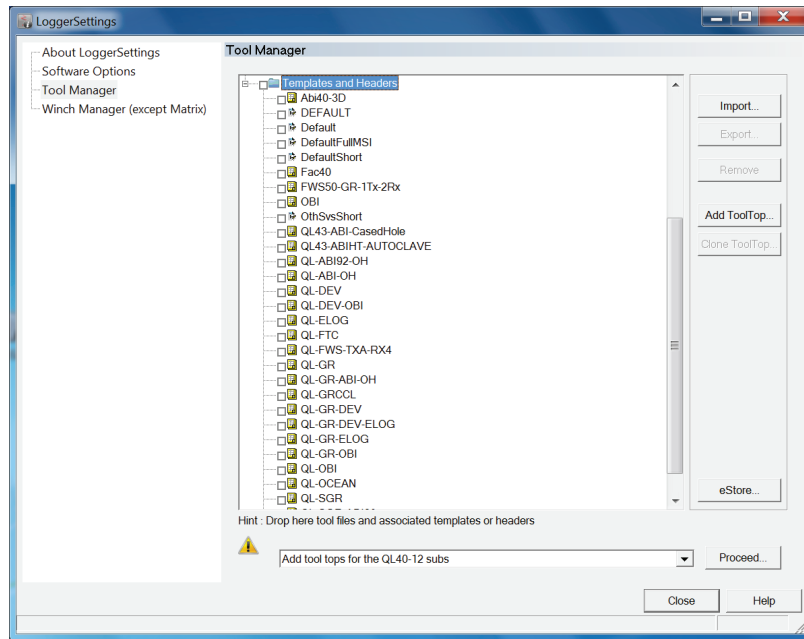
The **“Clone Tool Top”** button can be used to duplicate an existing tool top configuration. User will be asked to assign a reference number or a description for the duplicated tool top (Figure 3-13).



**Figure 3-13** Assigning a reference number to a clone tool top

### 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** Templates and headers

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.

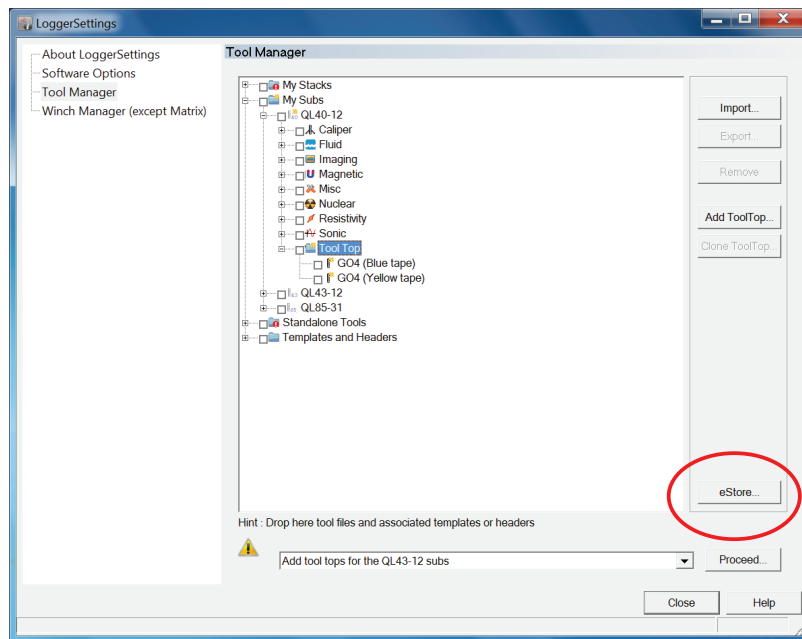
In order to edit a header design or layout template simply double left click on the corresponding icon in the tree control to start HeadCAD or WellCAD.

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”

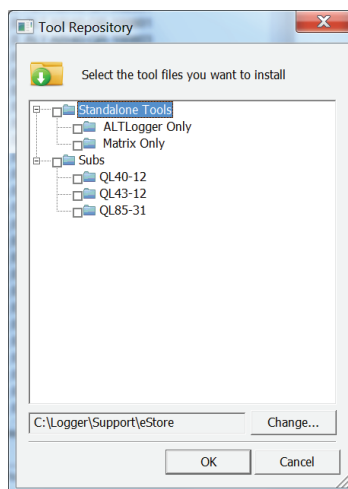
The main purpose of the LoggerSettings and the Tool Manager in particular is to support the user in organizing and manage his logging tool configurations. To avoid an overflow of the Tool Manager window with old or unused configuration files an external tool repository is available to remove elements 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** Click on the **eStore** button to access the external storage

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).

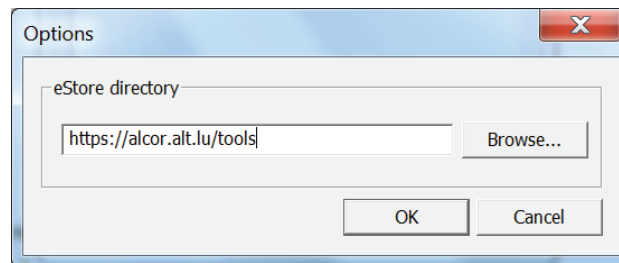


**Figure 3-16** eStore content – select and click OK to add it to the current Tool Manager stock

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.

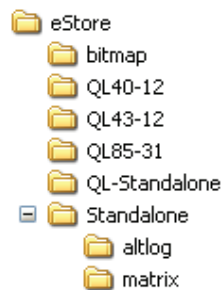
Should you wish to access another external tool repository click the **Change** button and enter a local or network path into the corresponding dialog box (Figure 3-17).



**Figure 3-17** Enter the location of an alternative eStore

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)

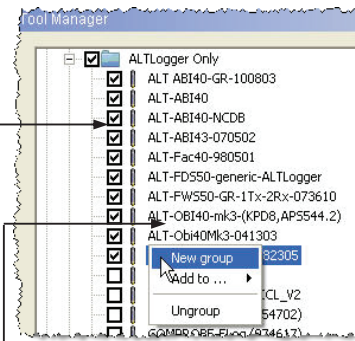


Figure 3-18 create a new group



Figure 3-19 Name the new group

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)

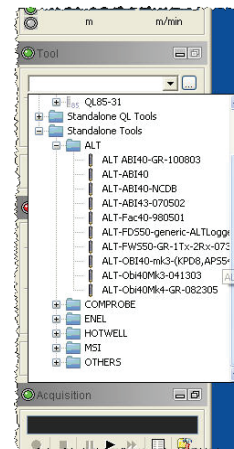


Figure 3-20 Dashboard tool panel

## 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).

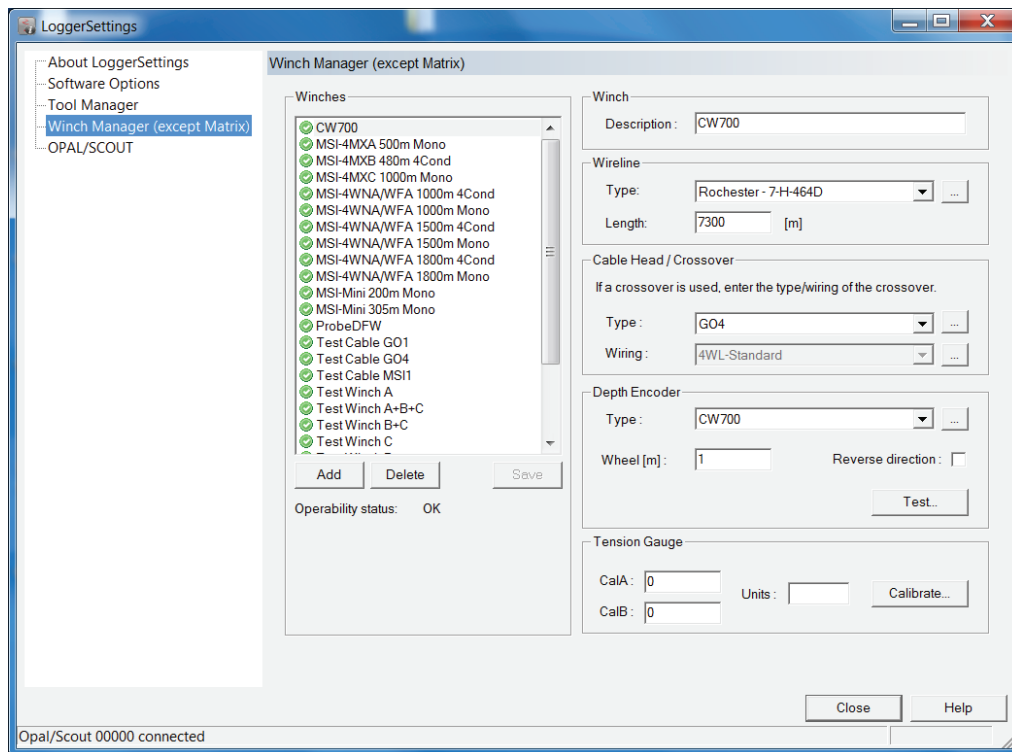


Figure 4-1 Winch Manager page


To create a new winch configuration, click on **“Add”** button and fill the edit boxes on the right side of the page:

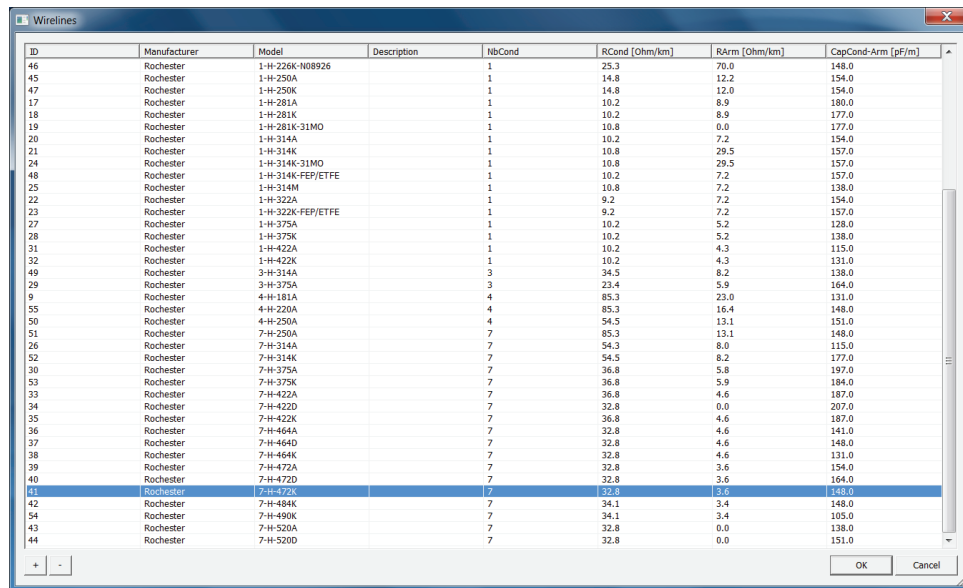
#### Winch:

- 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.



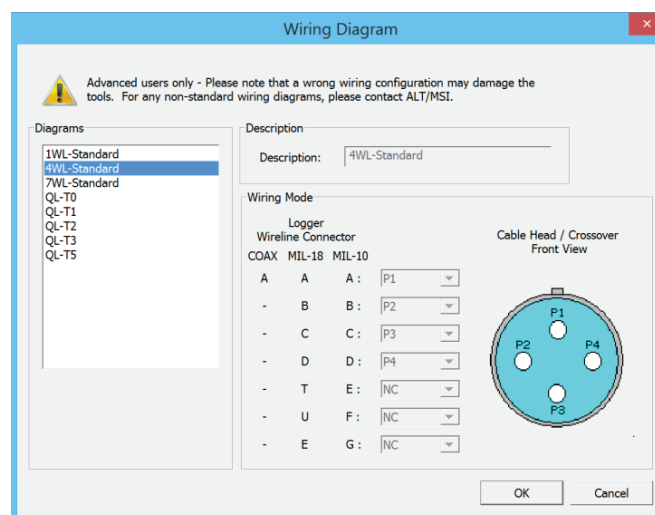
| ID | Manufacturer | Model             | Description | NbCond | RCond (Ohm/km) | RArm (Ohm/km) | CapCond-Arm (pF/m) |
|----|--------------|-------------------|-------------|--------|----------------|---------------|--------------------|
| 46 | Rochester    | 1-H-226K-N08926   |             | 1      | 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           | 187.0              |
| 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              |

Figure 4-2 Wirelines table

**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.



**Wiring Diagram**

Advanced users only - Please note that a wrong wiring configuration may damage the tools. For any non-standard wiring diagrams, please contact ALT/MSI.

**Diagrams**

- 1WL-Standard
- 4WL-Standard**
- 7WL-Standard
- QL-T0
- QL-T1
- QL-T2
- QL-T3
- QL-T5

**Description**

Description: 4WL-Standard

**Wiring Mode**

Logger Wireline Connector

COAX MIL-18 MIL-10

A A A : P1

- B B : P2

- C C : P3

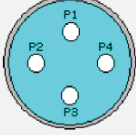
- D D : P4

- T E : NC

- U F : NC

- E G : NC


**Cable Head / Crossover Front View**

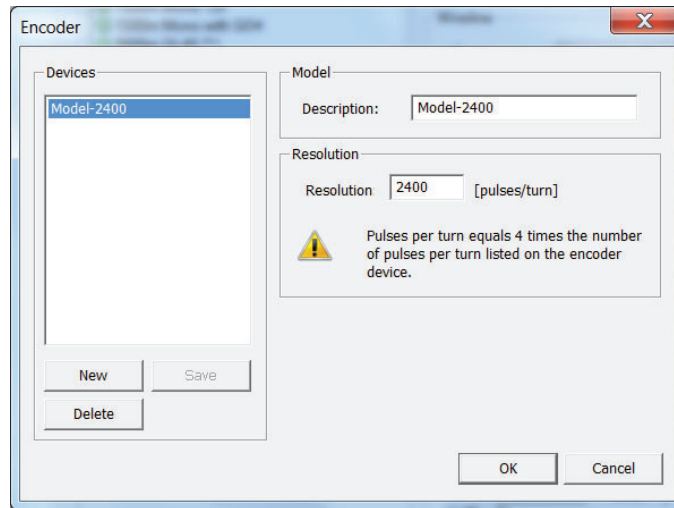


OK Cancel

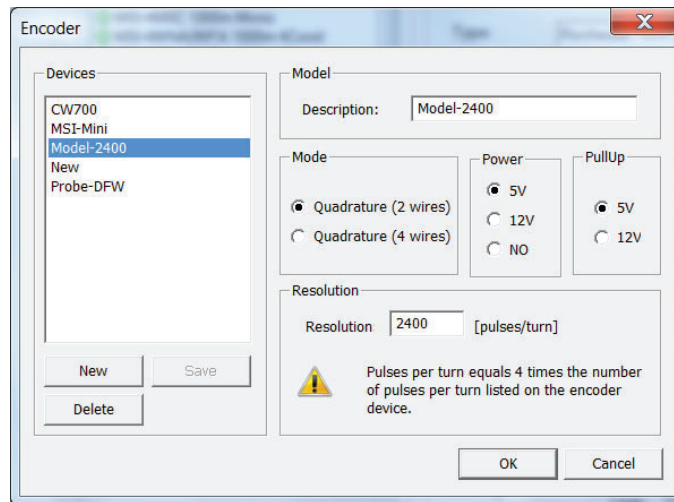
Figure 4-3 Defining the cable head wiring

### 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** Adding a new encoder device for OPAL-SCOUT-BBOX-ALTLogger



**Figure 4-5** Adding a new encoder device and settings for SCOUT PRO

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.



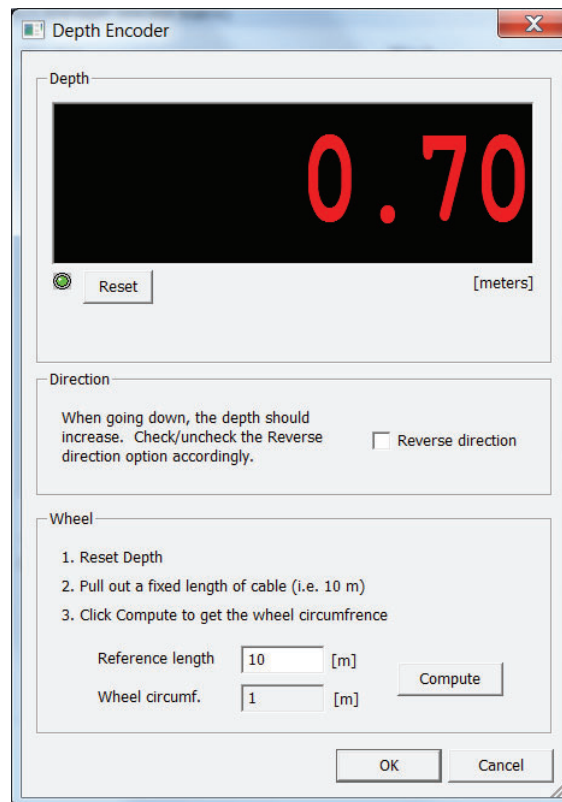
For SCOUT PRO The depth encoder settings are defined through LoggerSettings application and must be configured to suit the depth encoder specifications.

|               | Description  |
|---------------|--|
| <b>Mode</b>   | Depth encoder wiring mode:<br><i>Quadrature (2 wires): two channel output encoder A , B</i><br><i>Quadrature (4 wires): four channel output encoder A , B and inverted A- , B-</i> |
| <b>Power</b>  | Power Voltage selection: 5 or 12V<br><i>To Disable Power – select NO</i>   |
| <b>PullUP</b> | 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

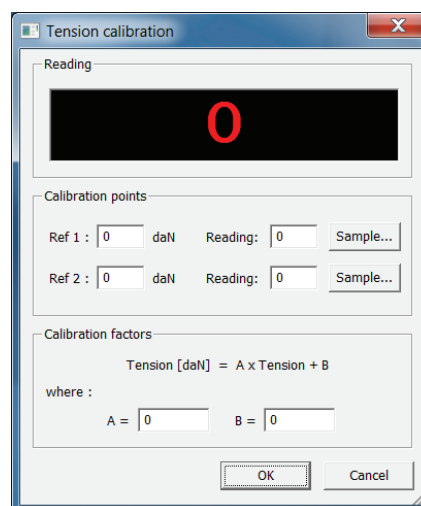


**Figure 4-6** Checking the depth settings

### 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)

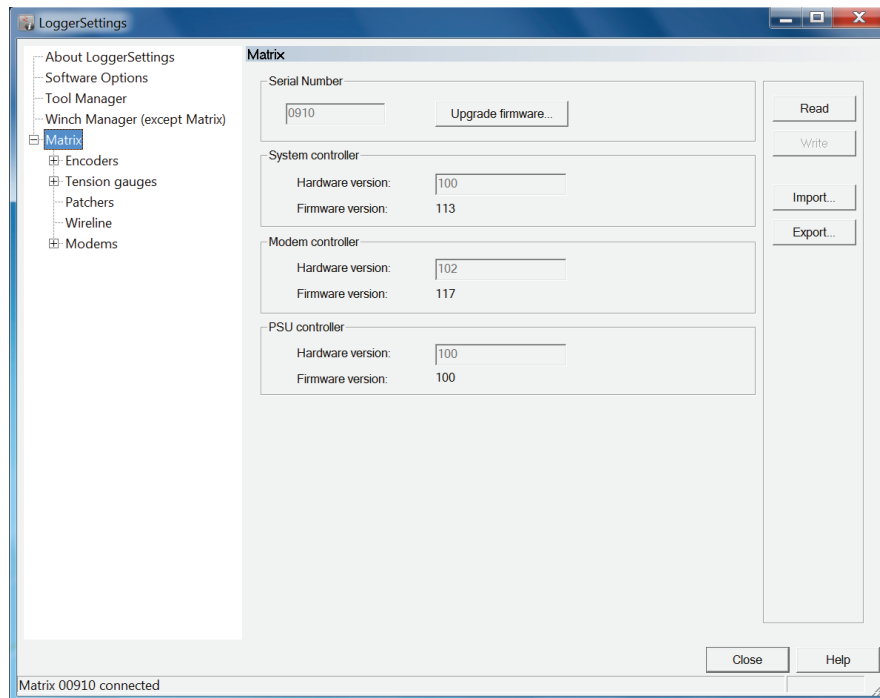


**Figure 4-7** Tension calibration page

- 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** Matrix System Information

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.

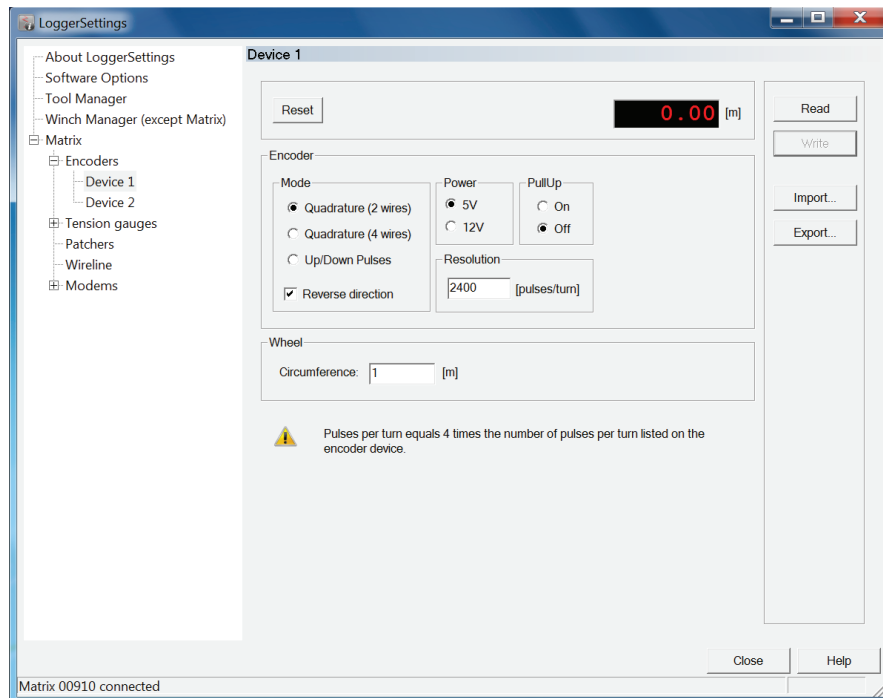


Figure 4-9 Depth encoder settings

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.*

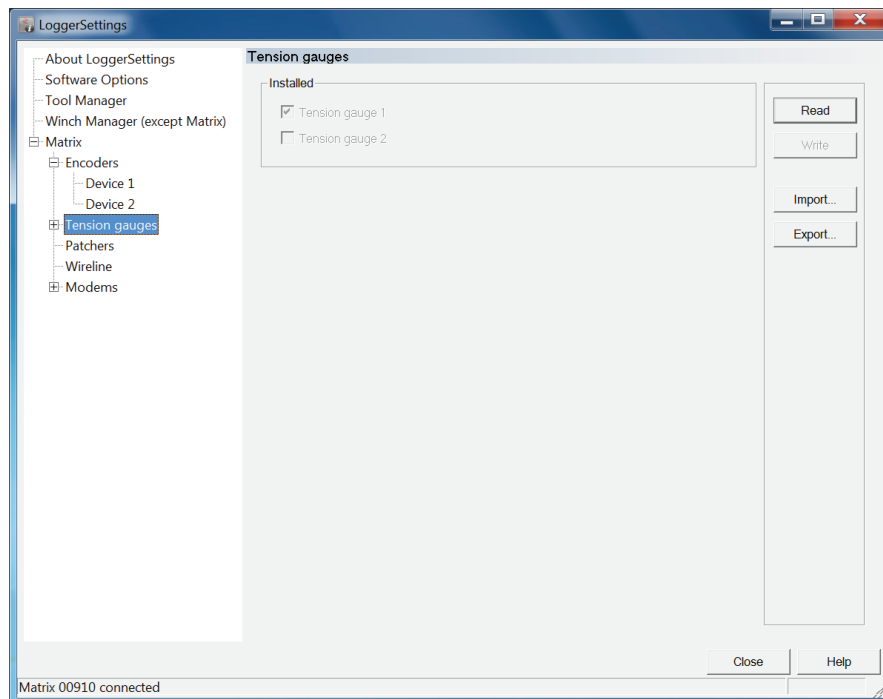
**Wheel Circumference** in meters, this may be a non-integer number like 0.3333 or 1.23456.

**Test Reset:** Press the button to zero the depth. Pull cable from the winch to test the settings.

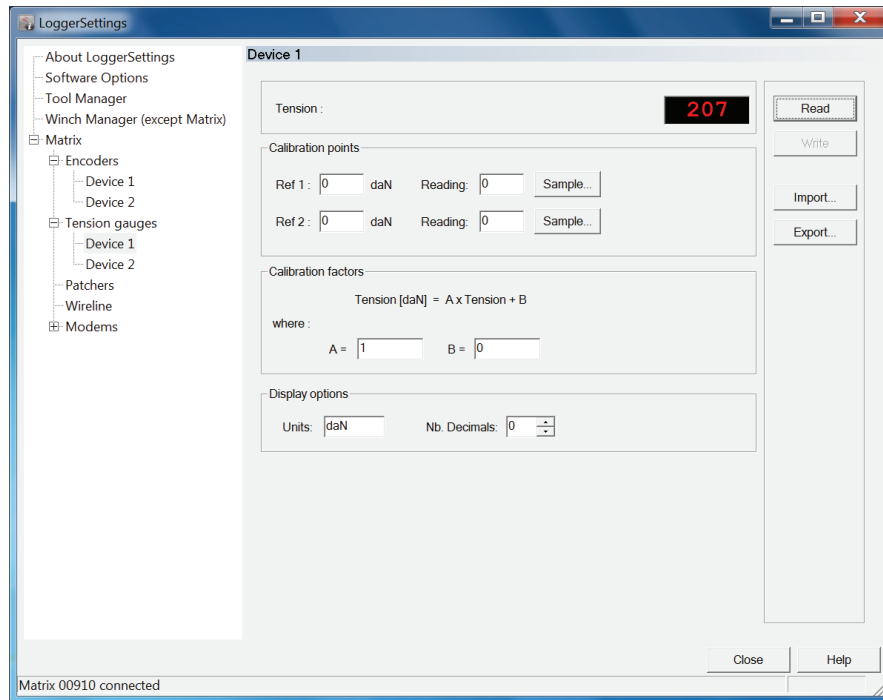
Click **Write** when finished to transfer the new settings to the system.

### 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** Tension device detection



**Figure 4-11** Tension calibration page

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.

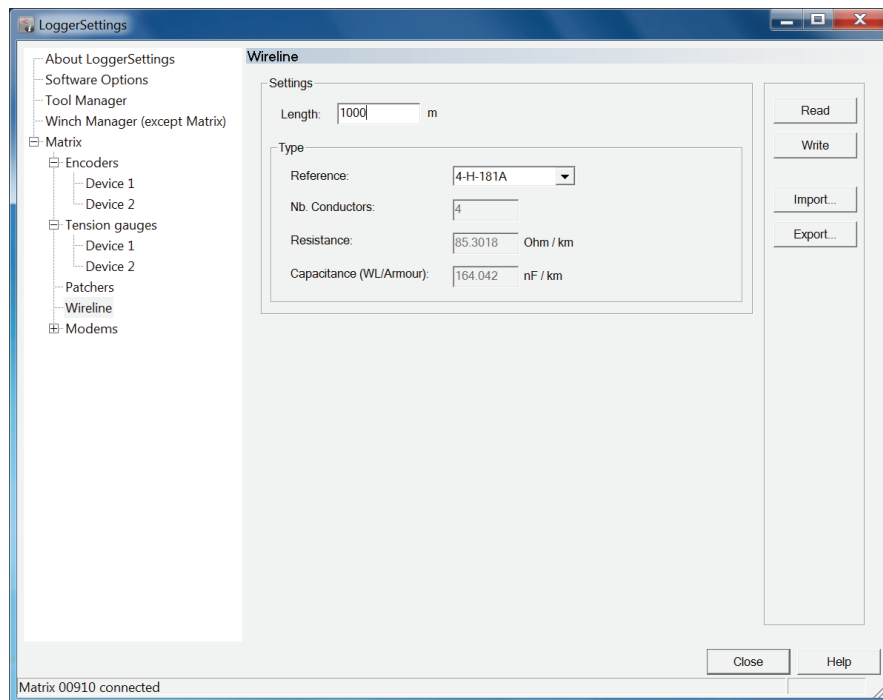
Hang a load of known weight on the end of the cable and enter the weight (or tension value it causes) into the **Ref 2** edit box. Click on the corresponding **Sample** button to update the **Reading** box with a value measured by the system.

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** Wireline settings

**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<br>(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                         |
| 1/4" coax video cable     | 1-H-181M  | 12.5                         |

**Table 1** - Rochester Cable Reference List

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.

---

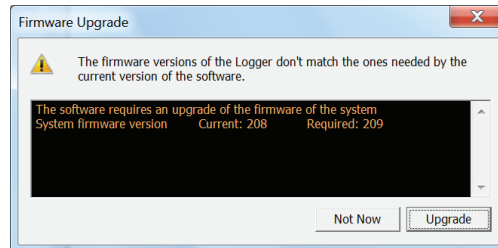
**Note:** The wireline selection is used to calculate the voltage drop on the wireline and therefore the tool power supply voltage. This has no effect on the telemetry settings.

---



## 5 Upgrading Logger Firmware

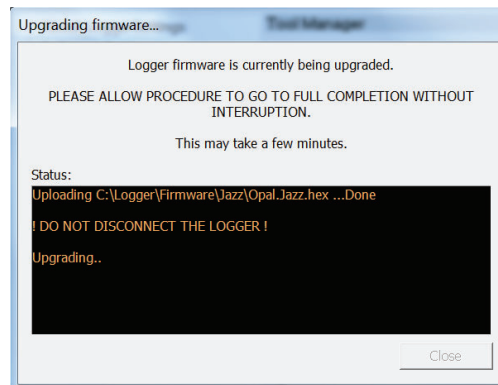
If after upgrading the acquisition software the Logger firmware needs to be updated – the following dialog box will be automatically displayed when starting the application (Figure 5-1). Press “Upgrade” to proceed or “Not Now” to postpone the operation.



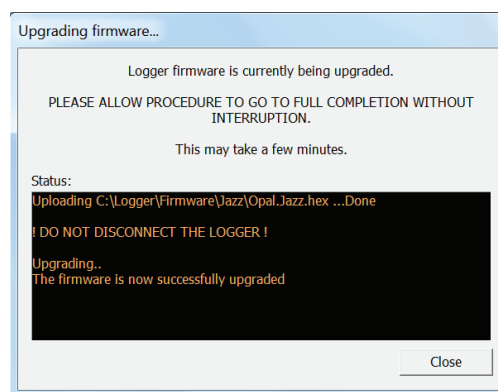
**Figure 5-1** Firmware upgrade

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** Firmware Upgrade Progress Dialog



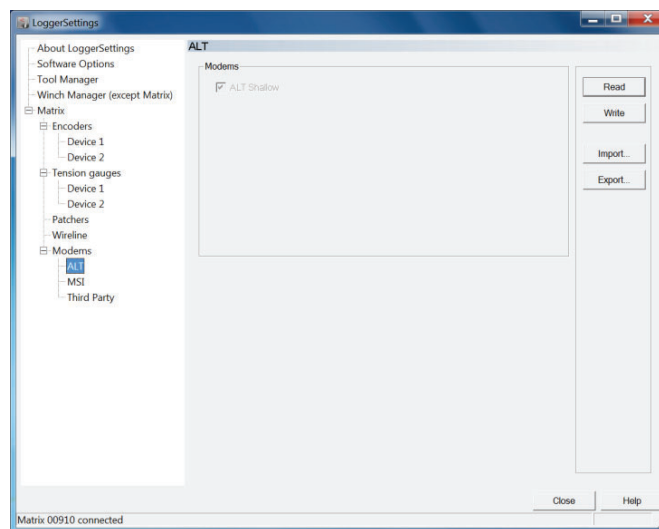
**Figure 5-3** Firmware Upgrade completed

## 6 Appendix

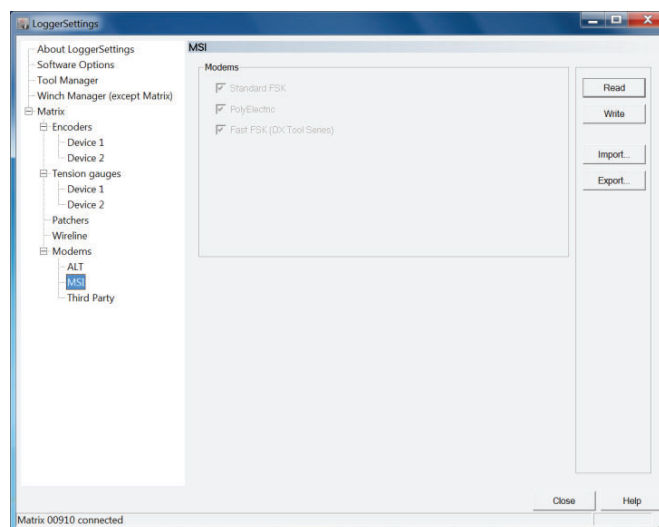
### 6.1 Matrix Modems

To get an overview of the installed modems select the ALT, MSI or Third Party branches (Figure 6-1 to 6-3).

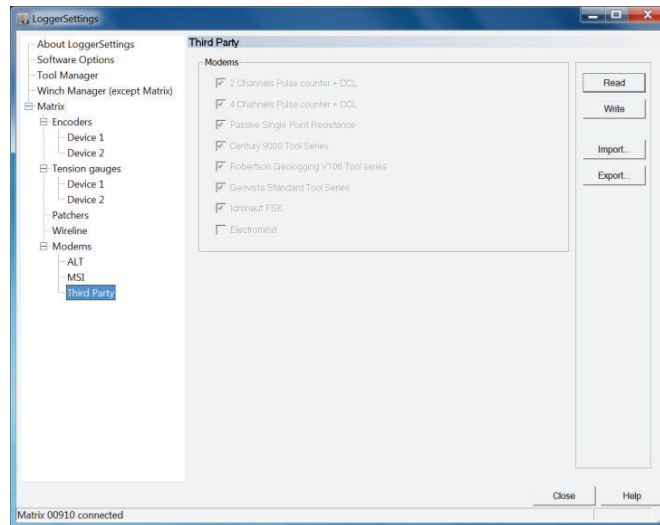
If it becomes necessary to change the installed modems either by adding a new one or removing an already installed one, it will be necessary to export the current configuration, send the exported file to your vendor (ALT or Mount Sopris Instruments) and install the updated file you will receive from your vendor. Please contact ALT or Mount Sopris Instruments for information about available modems.



**Figure 6-1** ALT Modem



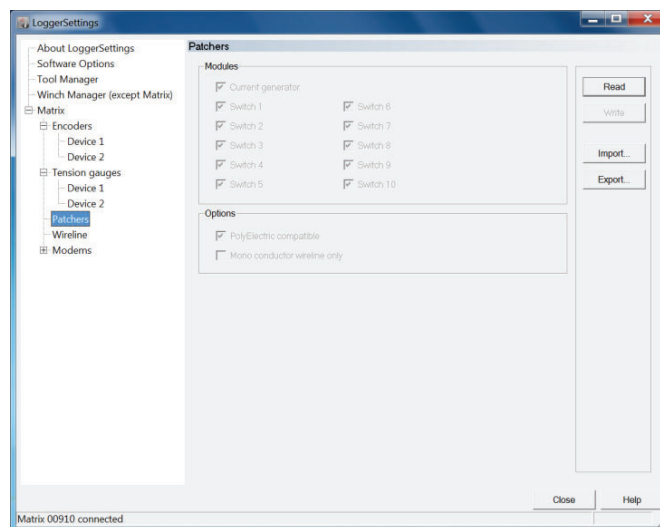
**Figure 6-2** MSI Modems



**Figure 6-3** Third Party Modems

## 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 Patchers information

### 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:** May-22-2021 – 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  | <u>0.37</u> | <u>14.55</u>        | 100.6                        | 12                   | 122                  | -70.0       |                                   |                         |          |  |  |  |

| 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 | 2PCA       | 5032          | 0.01        | 2.5           | 100.66   | 1.89   | up      | 1.90       | 1.88     | 13:30      | 14:40    | IG_BH05_WP05_2PCA_01-01.tfd   |                                       |
| 01-04 | GAMOB1     | 160304        | 0.031/0.016 | 4             | 99.96    | 13.70  | up      | 2.54       | 2.55     | 16:25      | 16:47    | IG_BH05_WP05_GAMOB1_01-04.tfd | Changed brightness from norm to 237us |
| 01-06 | GAMAB1     | 190404        | 0.024/0.002 | 1.6           | 100.01   | 14.56  | up      | 2.68       | 2.72     | 17:36      | 18:31    | IG_BH05_WP05_GAMAB1_01-06.tfd | 288ppt                                |
|       |            |               |             |               |          |        |         |            |          |            |          |                               |                                       |
|       |            |               |             |               |          |        |         |            |          |            |          |                               |                                       |
|       |            |               |             |               |          |        |         |            |          |            |          |                               |                                       |
|       |            |               |             |               |          |        |         |            |          |            |          |                               |                                       |
|       |            |               |             |               |          |        |         |            |          |            |          |                               |                                       |
|       |            |               |             |               |          |        |         |            |          |            |          |                               |                                       |

**Client:** NWMO

**Location:** Ignace – IG\_BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-17-2021 – Shift 02

**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  |            | 0.30          |                     | 1000.63                      |          | 68.5                 | 122                  |            | -70.0       |            | 2                                 |                             |            |
| 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           | 2SFA       | 5032          | 0.050               | 10.0                         | 1.99     | 355.61               | Down                 | 1.99       | 2.46        | 19:50      | 20:50                             | IG_BH05_WP05_2SFA_02-01.tfd |            |
| 02-02           | 2SFA       | 5032          | 0.050               | 10.0                         | 350.00   | 1000.71              | Down                 | 1.99       | 2.46        | 21:10      | 22:30                             | IG_BH05_WP05_2SFA_02-02.tfd |            |
| 02-03           | 2PCA       | 5032          | 0.010               | 2.5                          | 1000.71  | 54.11                | Up                   | 1.99       | 2.46        | 22:38      | 5:53                              | IG_BH05_WP05_2PCA_02-03.tfd |            |
| 02-04           | 2PCA       | 5032          | 0.010               | 2.5                          | 159.80   | 60.00                | Up                   | 1.99       | 2.46        | 6:10       | 6:57                              | IG_BH05_WP05_2PCA_02-04.tfd | Repeat run |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |            |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |            |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |            |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |            |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |            |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-18-2021 – 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  | 0.30        |                     | 1000.63                      | 68.5                 | 122                  | -70.0       | 2                                 |                         |          |  |  |  |

| 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                 |
|-------|------------|---------------|----------|---------------|----------|--------|---------|------------|----------|------------|----------|----------------------------|--------------------------|
| 03-03 | OBI        | 160403        | 0.050    | 10.0          | 1.56     | 145.05 | Down    | 1.56       |          | 14:00      | 14:13    | IG_BH05_WP05_OBI_03-03.tfd | Exposure 540 – to bright |
| 03-04 | OBI        | 160403        | 0.050    | 10.0          | 65.40    | 979.52 | Down    |            |          | 14:23      | 16:11    | IG_BH05_WP05_OBI_03-04.tfd | Exposure 334             |
| 03-05 | OBI        | 160403        | 0.016    | 3.5           | 979.52   | 945.09 | Up      |            |          | 16:15      | 16:30    | IG_BH05_WP05_OBI_03-05.tfd |                          |
| 03-06 | OBI        | 160403        | 0.016    | 3             | 979.68   | 1.81   | Up      |            | 1.88     | 16:42      | 22:14    | IG_BH05_WP05_OBI_03-06.tfd |                          |
| 03-07 | ABI        | 190404        | 0.050    | 10.0          | 117.00   | 3.82   | UP      | 1.73       | 1.83     | 23:58      | 0:30     | IG_BH05_WP05_ABI_03-07.tfd | Poor centralization file |
| 03-08 | ABI        | 190404        | 0.050    | 10.0          | 1.73     | 980.01 | Down    | 1.73       |          | 0:35       | 2:40     | IG_BH05_WP05_ABI_03-08.tfd |                          |
| 03-09 | ABI        | 190404        | 0.002    | 1.0           | 980.01   |        |         |            |          | 2:45       |          | IG_BH05_WP05_ABI_03-09.tfd |                          |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-19-2021 – 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  | 0.30        |                     | 1000.63                      | 68.5                 | 122                  | -70.0       | 2                                 |                         |          |  |  |  |  |

| 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 | ABI        | 190404        | 0.002    | ~ 1.3         | 454.52   | 50.00  | Up      | 1.73       | 2.57     | 16:15      | 21:00    | IG_BH05_WP05_ABI_04-01.tfd |                         |
| 04-02 | ABI        | 190404        | 0.002    | ~1.2          | 265.00   | 280.01 | Down    | 1.73       |          | 22:05      | 22:17    | IG_BH05_WP05_ABI_04-02.tfd |                         |
| 04-03 | ABI        | 190404        | 0.002    | ~1.2          | 300.01   | 321.00 | Down    |            |          | 22:25      | 22:43    | IG_BH05_WP05_ABI_04-03.tfd |                         |
| 04-04 | ABI        | 190404        | 0.002    | 1.2           | 360.00   | 387.01 | Down    |            |          | 22:50      | 23:14    | IG_BH05_WP05_ABI_04-04.tfd |                         |
| 04-05 | ABI        | 190404        | 0.002    | 1.2           | 409.75   | 417.00 | Down    |            |          | 23:22      | 23:28    | IG_BH05_WP05_ABI_04-05.tfd |                         |
| 04-06 | ABI        | 190404        | 0.002    | 1.2           | 444.04   | 442.02 | Up      |            |          | 23:52      | 23:54    | IG_BH05_WP05_ABI_04-06.tfd |                         |
| 04-07 | ABI        | 190404        | 0.002    | 1.2           | 461.04   | 449.01 | Up      |            |          | 23:58      | 0:12     | IG_BH05_WP05_ABI_04-07.tfd |                         |
| 04-08 | ABI        | 190404        | 0.002    | 1.2           | 511.14   | 499.50 | Up      |            |          | 0:12       | 0:33     | IG_BH05_WP05_ABI_04-08.tfd |                         |
| 04-09 | ABI        | 190404        | 0.002    | 1.2           | 601.10   | 562.95 | Up      |            |          | 0:48       | 1:31     | IG_BH05_WP05_ABI_04-09.tfd |                         |
| 04-10 | ABI        | 190404        | 0.002    | 1.2           | 651.01   | 624.03 | Up      |            |          | 1:41       | 2:14     | IG_BH05_WP05_ABI_04-10.tfd |                         |
| 04-11 | ABI        | 190404        | 0.002    | 1.2           | 716.01   | 689.02 | Up      |            |          | 2:31       | 3:12     | IG_BH05_WP05_ABI_04-11.tfd |                         |
| 04-12 | ABI        | 190404        | 0.002    | 1.2           | 796.07   | 729.91 | Up      |            |          | 3:26       | 4:51     | IG_BH05_WP05_ABI_04-12.tfd |                         |
| 04-13 | ABI        | 190404        | 0.002    | 1.2           | 838.63   | 994.40 | Down    |            |          | 5:04       | 6:55     | IG_BH05_WP05_ABI_04-13.tfd | Mud starts 992-993mdeep |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-20-2021 – 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  | 0.30        |                     | 1000.63                      | 68.5                 | 122                  | -70.0       | 2                                 |                         |          |  |  |  |  |

| 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 | ABI        | 190404        | 0.050    | 12.0          | 994.40   | 2.22   | Up      | 1.73       | 2.22     | 7:00       | 9:00     | IG_BH05_WP05_ABI_05-01.tfd      |                                      |
| 05-02 | GAM2NUA    | 5602/6650     | 0.025    | 2.5           | 301.02   | 2.55   | Up      | 2.61       | 2.55     | 13:45      | 16:00    | IG_BH05_WP05_GAM2NUA_05-02.tfd  | Repeat run and top section of the BH |
| 05-03 | 2PGA2PIA   | 2622/2618     | 0.050    | 4.5           | 500.02   | 399.97 | Up      | 2.38       |          | 18:50      | 19:15    | IG_BH05_WP05_2PGA2PIA_05-03.tfd | Repeat run                           |
| 05-04 | 2PGA2PIA   | 2622/2618     | 0.050    | 4.5           | 1000.72  | 167.00 | Up      |            |          | 20:11      | 0:35     | IG_BH05_WP05_2PGA2PIA_05-04.tfd |                                      |
| 05-05 | 2PGA2PIA   | 2622/2618     | 0.050    | 4.5           | 200.03   | 60.02  | Up      |            | 3.36     | 0:38       | 1:12     | IG_BH05_WP05_2PGA2PIA_05-05.tfd |                                      |
| 05-06 | 2FSA       | 5032          | 0.050    | 4.0           | 1.95     | 992.01 | Down    | 1.95       |          | 2:12       | 06:24    | IG_BH05_WP05_2FSA_05-06.tfd     |                                      |
| 05-07 | 2FSA       | 5032          | 0.050    | 15.0          | 992.01   | 2.54   | Up      |            | 2.54     | 06:25      | 07:30    | IG_BH05_WP05_2FSA_05-07.tfd     |                                      |
|       |            |               |          |               |          |        |         |            |          |            |          |                                 |                                      |
|       |            |               |          |               |          |        |         |            |          |            |          |                                 |                                      |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-21-2021 – Shift 06

**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  | 0.30        |                     | 1000.63                      | 68.5                 | 122                  | -70.0       | 3                                 |                         |          |  |  |  |

| 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 | GAM2NUA    | 5602/6650     | 0.025    | 2.5           | 995.04   | 199.01  | Up      | 2.61       | 3.57     | 7:30       | 12:20    | IG_BH05_WP05_GAM2NUA_06-01.tfd  |            |
| 06-02 | GAM2DEN    | 5602/6336     | 0.025    | 2.5           | 301.05   | 198.98  | Up      | 2.94       | 2.93     | 15:10      | 16:45    | IG_BH05_WP05_GAM2DEN_06-02.tfd  | Repeat run |
| 06-03 | 2PGA2PIA   | 2622/2618     | 0.050    | 10.0          | 2.38     | 1000.70 | Down    | 2.38       |          | 18:50      | 20:35    | IG_BH05_WP05_2PGA2PIA_06-03.tfd |            |
| 06-04 | 2PGA2PIA   | 2622/2618     | 0.050    | 4.5           | 1000.70  | 60.01   | Up      |            | 3.26     | 20:45      | 00:17    | IG_BH05_WP05_2PGA2PIA_06-04.tfd |            |
| 06-05 | GAMHMI     | 5602/6766     | 0.0500   | 15.0          | 75.00    | 310.02  | Down    | 3.46       |          | 01:20      | 02:10    | IG_BH05_WP05_GAMHMI_06-05.tfd   |            |
| 06-06 | GAMHMI     | 5602/6766     | 0.0500   | 4.5           | 400.05   | 299.81  | Up      |            |          | 02:18      | 02:45    | IG_BH05_WP05_GAMHMI_06-06.tfd   | Repeat run |
| 06-07 | GAMHMI     | 5602/6766     | 0.0500   | 15.0          | 400.05   | 1000.68 | Down    |            |          | 2:42       | 3:32     | IG_BH05_WP05_GAMHMI_06-07.tfd   |            |
| 06-08 | GAMHMI     | 5602/6766     | 0.0500   | 4.5           | 1000.68  | 64.36   | Up      |            | 4.38     | 3:33       | 7:00     | IG_BH05_WP05_GAMHMI_06-08.tfd   |            |
|       |            |               |          |               |          |         |         |            |          |            |          |                                 |            |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-22-2021 – 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  | 0.30        |                     | 1000.63                      | 68.5                 | 122                  | -70.0       | 3                                 |                         |          |  |  |  |

| 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   |
|-------|------------|---------------|----------|---------------|----------|--------|---------|------------|----------|------------|----------|--------------------------------|------------|
| 07-01 | GAM2DEN    | 5602/6336     | 0.025    | 2.5           | 995.03   | 2.93   | Up      | 2.94       | 2.93     | 8:00       | 16:00    | IG_BH05_WP05_GAM2DEN_07-01.tfd |            |
| 07-02 | 2SNA       | 4116          | 0.025    | 2.25          | 400.00   | 500.00 | Up      | 1.83       |          | 18:42      | 19:40    | IG_BH05_WP05_2SNA_07-02.tfd    | Repeat run |
| 07-03 | 2SNA       | 4116          | 0.025    | 2.3           | 1000.71  | 973.00 | Up      |            |          | 21:09      | 21:32    | IG_BH05_WP05_2SNA_07-03.tfd    |            |
| 07-04 | 2SNA       | 4116          | 0.025    | 2.3           | 980.00   | 966.98 | Up      |            |          | 21:35      | 21:40    | IG_BH05_WP05_2SNA_07-04.tfd    |            |
| 07-05 | 2SNA       | 4116          | 0.025    | 2.3           | 972.00   | 2.76   | Up      |            | 2.81     | 21:46      | 04:39    | IG_BH05_WP05_2SNA_07-05.tfd    |            |
| 07-06 | FWS        | 210306        | 0.050    | 10.0          | 2.99     | 410.30 | Down    | 2.99       |          | 6:09       | 6:53     | IG_BH05_WP05_FWS_07-06.tfd     |            |
| 07-07 | FWS        | 210306        | 0.050    | 2.0           | 500.77   | 395.13 | Up      |            |          | 6:56       | 7:30     | IG_BH05_WP05_FWS_07-07.tfd     | Repeat run |
|       |            |               |          |               |          |        |         |            |          |            |          |                                |            |
|       |            |               |          |               |          |        |         |            |          |            |          |                                |            |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-23-2021 – 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  | 0.30        |                     | 1000.63                      | 68.5                 | 122                  | -70.0       | 3                                 |                         |          |  |  |  |

| 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    | 8.0           | 500.77   | 999.71 | Down    | 2.99       |          | 7:40       | 8:55     | IG_BH05_WP05_FWS_08-01.tfd    |                                |
| 08-02 | FWS        | 210306        | 0.050    | 1.9           | 999.71   | 32.96  | up      |            | 2.66     | 9:00       | 18:00    | IG_BH05_WP05_FWS_08-02.tfd    |                                |
| 08-03 | GAMOB1     | 5602/160403   | 0.016    | 3.5           | 2.61     | 726.80 | Down    | 2.61       |          | 18:20      | 22:30    | IG_BH05_WP05_GAMOB1_08-03.tfd |                                |
| 08-04 | GAMOB1     | 5602/160403   | 0.016    | 2.0           | 690.10   | 985.01 | Down    |            |          | 22:57      | 2:07     | IG_BH05_WP05_GAMOB1_08-04.tfd |                                |
| 08-05 | GAMOB1     | 5602/160403   | 0.016    | 2.0           | 977.00   | 987.54 | Down    |            |          | 2:10       | 02:25    | IG_BH05_WP05_GAMOB1_08-05.tfd |                                |
| 08-06 | GAMOB1     | 5602/160403   | 0.016    | 2.0           | 977.02   | 990.01 | Down    |            |          | 02:30      | 02:35    | IG_BH05_WP05_GAMOB1_08-06.tfd |                                |
| 08-07 | GAMOB1     | 5602/160403   | 0.016    | 2.0           | 977.00   | 992.51 | Down    |            |          | 02:38      | 02:49    | IG_BH05_WP05_GAMOB1_08-07.tfd |                                |
| 08-08 | GAMOB1     | 5602/160403   | 0.016    | 2.0           | 977.02   | 994.30 | Down    |            |          | 02:51      | 03:02    | IG_BH05_WP05_GAMOB1_08-08.tfd | OTV dipped in mud at 993-994 m |
| 08-09 | GAMOB1     | 5602/160403   | 0.016    | 2.0           | 994.07   | 2.46   | Up      |            | 2.46     | 03:05      | 04:15    | IG_BH05_WP05_GAMOB1_08-09.tfd |                                |
| 08-10 | 2SNA       | 4116          | 0.025    | 2.50          | 60.00    | 80.00  | Down    | 1.83       |          | 04:56      | 05:06    | IG_BH05_WP05_2SNA_08-10.tfd   |                                |
| 08-11 | 2SNA       | 4116          | 0.025    | 2.50          | 330.00   | 350.00 | Down    |            |          | 05:18      | 05:27    | IG_BH05_WP05_2SNA_08-11.tfd   |                                |
| 08-12 | 2SNA       | 4116          | 0.025    | 2.50          | 580.01   | 611.41 | Down    |            |          | 05:37      | 05:49    | IG_BH05_WP05_2SNA_08-12.tfd   |                                |
| 08-13 | 2SNA       | 4116          | 0.025    | 2.50          | 609.01   | 630.00 | Down    |            |          | 06:01      | 06:11    | IG_BH05_WP05_2SNA_08-13.tfd   |                                |
| 08-14 | 2SNA       | 4116          | 0.025    | 2.50          | 710.00   | 740.19 | Down    |            |          | 06:15      | 06:28    | IG_BH05_WP05_2SNA_08-14.tfd   |                                |
| 08-15 | 2SNA       | 4116          | 0.025    | 2.50          | 805.01   | 825.00 | Down    |            |          | 06:31      | 06:31    | IG_BH05_WP05_2SNA_08-15.tfd   |                                |
| 08-16 | 2SNA       | 4116          | 0.025    | 2.50          | 910.02   | 950.00 | Down    |            |          | 06:44      | 07:00    | IG_BH05_WP05_2SNA_08-16.tfd   |                                |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-24-2021 – Shift 09

**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  | 0.30        |                     | 1000.63                      | 68.5                 | 122                  | -70.0       | 3                                 |                         |          |  |  |  |

| 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    |
|-------|------------|---------------|------------|---------------|----------|---------|---------|------------|----------|------------|----------|------------------------------|-------------|
| 09-01 | 2SNA       | 4116.00       | 0.025      | 2.10          | 1000.50  | 937.85  | Up      | 1.83       | 1.89     | 10:00      | 10:40    | IG_BH05_WP05_2SNA_09-01.tfd  |             |
| 09-02 | GAMIP      | 5602/5579     | 0.050      | 10.00         | 80.07    | 499.81  | Down    | 11.02      |          | 13:00      | 13:50    | IG_BH05_WP05_GAMIP_09-02.tfd |             |
| 09-03 | GAMIP      | 5602/5579     | 0.025/0.05 | 2.1           | 600.12   | 499.81  | Up      |            |          | 13:50      | 14:40    | IG_BH05_WP05_GAMIP_09-03.tfd | Repeat run  |
| 09-04 | GAMIP      | 5602/5579     | 0.050      | 10.0          | 598.67   | 1000.00 | Down    |            |          | 14:45      | 15:30    | IG_BH05_WP05_GAMIP_09-04.tfd |             |
| 09-05 | GAMIP      | 5602/5579     | 0.025/0.05 | 2.2           | 1000.01  | 672.20  | Up      |            |          | 15:40      | 19:00    | IG_BH05_WP05_GAMIP_09-05.tfd |             |
| 09-06 | GAMIP      | 5602/5579     | 0.025/0.05 | 2.2           | 739.97   | 516.45  | Up      |            |          | 19:35      | 21:32    | IG_BH05_WP05_GAMIP_09-06.tfd |             |
| 09-07 | GAMIP      | 5602/5579     | 0.025/0.05 | 2.2           | 650.01   | 60.00   | Up      |            | 10.72    | 22:10      | 02:27    | IG_BH05_WP05_GAMIP_09-07.tfd |             |
| 09-08 | HFPIM      | 2293          | 20.000     | N/A           | 70.00    |         | Down    | 0.99       |          | 03:30      |          | IG_BH05_WP05_HFPIM_09-08.tfd | In progress |
|       |            |               |            |               |          |         |         |            |          |            |          |                              |             |

**Client:** NWMO

**Location:** Ignace – IG BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-25-2021 – 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  |            | 0.30          |                     | 1000.63                      |          | 68.5                 | 122                  |            | -70.0       |            | 3                                 |                             |              |
| 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     |
| 10-01           | HFPM       | 2293          | 20.000              | N/A                          | 990.0    | 70.0                 | Up                   | 0.99       | 0.34        | 13:10      | 19:00                             | IG_BH05_WP05_HFPM_10-01.tfd | HFPM pumping |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |              |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |              |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |              |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |              |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |              |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |              |
|                 |            |               |                     |                              |          |                      |                      |            |             |            |                                   |                             |              |

**Client:** NWMO

**Location:** Ignace – IG\_BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**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:** Aug-25-2021 – Shift 11

**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  |            | 0.30          |                     | 1000.63                      |          | 68.5                 |         | 122                  |          | -70.0       |          | 3                                 |                         |              |
| 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     |
| 10-01           | HFPM       | 2293          | Variable            | N/A                          | 51.1     | 410.1                | Both    | 0.99                 | 0.83     | 10:50       | 16:25    | IG_BH05_WP05_HFPM_11-01.tfd       |                         | HFPM pumping |
|                 |            |               |                     |                              |          |                      |         |                      |          |             |          |                                   |                         |              |
|                 |            |               |                     |                              |          |                      |         |                      |          |             |          |                                   |                         |              |
|                 |            |               |                     |                              |          |                      |         |                      |          |             |          |                                   |                         |              |
|                 |            |               |                     |                              |          |                      |         |                      |          |             |          |                                   |                         |              |
|                 |            |               |                     |                              |          |                      |         |                      |          |             |          |                                   |                         |              |
|                 |            |               |                     |                              |          |                      |         |                      |          |             |          |                                   |                         |              |
|                 |            |               |                     |                              |          |                      |         |                      |          |             |          |                                   |                         |              |

**Client:** NWMO

**Location:** Ignace – IG\_BH05

**Prepared by:** OF

**Job Number:** 20253946-5050

**Project:** Phase 2 Initial Borehole Drilling

**Verified by:** Christopher Phillips

## RECORD OF GEOPHYSICAL LOGGING

**TO:** Olga Fomenko **Date / Shift:** Aug 21st 2021 - Day - Shift 06  
Chris Phillips **Project Number:** L-675  
**CC:**  **CI:**   
 **Client:** Golder  
 **Distributed By:** R. Morrison

| Tool Data |               |               |                 |                       |                       |              |        |
|-----------|---------------|---------------|-----------------|-----------------------|-----------------------|--------------|--------|
| Run       | Probe Name    | Serial Number | Tool Offset (m) | Sampling Interval (m) | Logging Speed (m/min) | Expected Run |        |
|           |               |               |                 |                       |                       | Top          | Bottom |
| 06-01     | Gamma Neutron | 5602/6650     | 2.61            | 0.025                 | 2.5                   | 199.01       | 995.04 |
| 06-02     | Density Gamma | 5602/6366     |                 | 0.025                 | 2.5                   |              | 301.05 |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |

| Borehole Data                |        |   |          |
|------------------------------|--------|---|----------|
| Depth Reference              | Ground | Casing Diameter (mm) and Casing Depth (m) | 108/67.5 |
| Stickup (m)                  | 0.30   | Inclination                               | 70       |
| Water Level (m bgs)          | 27     | BH Winch Offset From Borehole (m)         | 4        |
| Borehole Total Depth (m bgs) | 1000.7 |   |          |

Please note depth and comments of zones of instability / zones noted during Survey:

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**Client:** Golder **Verified by:** Olga Fomenko  
**Location:** BH05  
**Prepared by:** R. Morrison  
**Page:** 1 of 3

## RECORD OF GEOPHYSICAL LOGGING

|            |  |                        |                                       |
|------------|--|------------------------|---------------------------------------|
| <b>TO:</b> | <u>Olga Fomenko</u><br><u>Chris Phillips</u> | <b>Date / Shift:</b>   | <u>Aug 21st 2021 - Day - Shift 06</u> |
|            |  | <b>Project Number:</b> | <u>675</u>                            |
|            |  | <b>CI:</b>             | <u></u>                               |
| <b>CC:</b> | <u></u><br><u></u><br><u></u>                | <b>Client:</b>         | <u>Golder</u>                         |
|            |  | <b>Distributed By:</b> | <u>R. Morrison</u>                    |

| Run 1 Field Notes   |                           |
|---|---------------------------|
| Probe   | ALT QL Neutron with Gamma |
| Start Time  | 9:10 am                   |
| End Time  | 12:20pm                   |
| Run Direction   | up                        |
| Stick Up (Casing height):   | 0.30                      |
| Zero Start (Depth of Probe Point at Casing Collar):   | 2.61                      |
| START (data)  | 995.04                    |
| END (data)  | 199.01                    |
| Zero Check (Probe Point at Collar)  | 3.57                      |
| File Name   | IG_BH05_WP05_GR2NEU_06-01 |
| <b>Comments:</b> Client file name listed above. Good features around 970 and 916m.<br>repeats well with first file (repeat run), end zero within allowable limits |                           |

|                     |                    |                     |                     |
|---------------------|--------------------|---------------------|---------------------|
| <b>Client:</b>      | <u>Golder</u>      | <b>Verified by:</b> | <u>Olga Fomenko</u> |
| <b>Location:</b>    | <u>BH05</u>        |                     | <u></u>             |
| <b>Prepared by:</b> | <u>R. Morrison</u> |                     | <u></u>             |
| <b>Page:</b>        | <u>2 of 3</u>      |                     |                     |

## RECORD OF GEOPHYSICAL LOGGING

|            |  |                        |                                       |
|------------|--|------------------------|---------------------------------------|
| <b>TO:</b> | <u>Olga Fomenko</u><br><u>Chris Phillips</u> | <b>Date / Shift:</b>   | <u>Aug 21st 2021 - Day - Shift 06</u> |
|            |  | <b>Project Number:</b> | <u>L-675</u>                          |
|            |  | <b>CI:</b>             | <u></u>                               |
| <b>CC:</b> | <u></u><br><u></u><br><u></u>                | <b>Client:</b>         | <u>Golder</u>                         |
|            |  | <b>Distributed By:</b> | <u>R. Morrison</u>                    |

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| Run 2 Field Notes                                   |                            |
|---|----------------------------|
| Probe   | ALT QL Density with Gamma  |
| Start Time  | 3:10pm                     |
| End Time  | 4:45pm                     |
| Run Direction                                       | up                         |
| Stick Up (Casing height):                           | 0.30                       |
| Zero Start (Depth of Probe Point at Casing Collar): | 2.94                       |
| START (data)  | 301.05                     |
| END (data)  | 198.98                     |
| Zero Check (Probe Point at Collar)                  | 2.93                       |
| File Name   | IG_BH05_WP05_GAM2DEN_06-02 |
| <b>Comments:</b> Repeat Run, no issues.             |                            |
|   |                            |

|                     |                    |                     |                     |
|---------------------|--------------------|---------------------|---------------------|
| <b>Client:</b>      | <u>Golder</u>      | <b>Verified by:</b> | <u>Olga Fomenko</u> |
| <b>Location:</b>    | <u>BH05</u>        |                     | <u></u>             |
| <b>Prepared by:</b> | <u>R. Morrison</u> |                     | <u></u>             |
| <b>Page:</b>        | <u>3 of 3</u>      |                     |                     |

## RECORD OF GEOPHYSICAL LOGGING

**TO:** Olga Fomenko **Date / Shift:** Aug 20th 2021 - Day - Shift 5  
Chris Phillips **Project Number:** 675  
**CC:**  **CI:**   
 **Client:** Golder  
 **Distributed By:** R. Morrison

| Tool Data |               |               |                 |                       |                       |              |        |
|-----------|---------------|---------------|-----------------|-----------------------|-----------------------|--------------|--------|
| Run       | Probe Name    | Serial Number | Tool Offset (m) | Sampling Interval (m) | Logging Speed (m/min) | Expected Run |        |
|           |               |               |                 |                       |                       | Top          | Bottom |
| 05-02     | Gamma Neutron | 5602/6650     | 2.61            | 0.025                 | 2.5                   | 2.55         | 301.02 |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |

| Borehole Data                |                  |   |          |
|------------------------------|------------------|---|----------|
| Depth Reference              | Ground High Side | Casing Diameter (mm) and Casing Depth (m) | 108/68.5 |
| Stickup (m)                  | 0.30             | Inclination                               | 70       |
| Water Level (m bgs)          | 27               | BH Winch Offset From Borehole (m)         | 4        |
| Borehole Total Depth (m bgs) | 1000.6           |   |          |

Please note depth and comments of zones of instability / zones noted during Survey:

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**Client:** Golder **Verified by:** Olga Fomenko  
**Location:** BH05  
**Prepared by:** R. Morrison  
**Page:** 1 of 2

## RECORD OF GEOPHYSICAL LOGGING

|     |                |                 |                               |
|-----|----------------|-----------------|-------------------------------|
| TO: | Olga Fomenko   | Date / Shift:   | Aug 20th 2021 - Day - Shift 5 |
|     | Chris Phillips | Project Number: | 675                           |
|     |                | CI:             |                               |
| CC: |                | Client:         | Golder                        |
|     |                | Distributed By: | R. Morrison                   |

| Run 1 Field Notes  |                            |
|--|----------------------------|
| Probe  | ALT QL Gamma Neutron       |
| Start Time   | 1:45pm                     |
| End Time   | 4:00pm                     |
| Run Direction  | up                         |
| Stick Up (Casing height):  | 0.30                       |
| Zero Start (Depth of Probe Point at Casing Collar):  | 2.61                       |
| START (data)   | 301.02                     |
| END (data)   | 2.55                       |
| Zero Check (Probe Point at Collar)   | 2.55                       |
| File Name  | IG_BH05_WP05_GAM2NUA_05-02 |
| <p><b>Comments:</b> Client file name above, internal name is 675_IG-BH05_QLALTNEUGR_u1_082021<br/>Repeat section from 300 to 200. Will log to surface, next run will overlap to 200m</p> |                            |

|              |             |              |              |
|--------------|-------------|--------------|--------------|
| Client:      | Golder      | Verified by: | Olga Fomenko |
| Location:    | BH05        |              |              |
| Prepared by: | R. Morrison |              |              |
| Page:        | 2 of 2      |              |              |

## RECORD OF GEOPHYSICAL LOGGING

**TO:** Olga Fomenko **Date / Shift:** Aug 22nd 2021 - Day - Shift 07  
Chris Phillips **Project Number:** L-675  
**CC:**  **CI:**   
 **Client:** Golder  
 **Distributed By:** R. Morrison

| Tool Data |               |               |                 |                       |                       |              |        |
|-----------|---------------|---------------|-----------------|-----------------------|-----------------------|--------------|--------|
| Run       | Probe Name    | Serial Number | Tool Offset (m) | Sampling Interval (m) | Logging Speed (m/min) | Expected Run |        |
|           |               |               |                 |                       |                       | Top          | Bottom |
| 07-01     | Density Gamma | 5602/6366     | 2.94            | 0.025                 | 2.5                   | 2.93         | 995.03 |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |
|           |               |               |                 |                       |                       |              |        |

| Borehole Data                |        |   |          |
|------------------------------|--------|---|----------|
| Depth Reference              | Ground | Casing Diameter (mm) and Casing Depth (m) | 108/67.5 |
| Stickup (m)                  | 0.30   | Inclination                               | 70       |
| Water Level (m bgs)          | 24     | BH Winch Offset From Borehole (m)         | 4        |
| Borehole Total Depth (m bgs) | 1000.6 |   |          |

Please note depth and comments of zones of instability / zones noted during Survey:

\_\_\_\_\_

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**Client:** Golder **Verified by:** Olga Fomenko  
**Location:** BH05  
**Prepared by:** R. Morrison  
**Page:** 1 of 2

## RECORD OF GEOPHYSICAL LOGGING

|     |  |                 |                                       |
|-----|--|-----------------|---------------------------------------|
| TO: | <u>Olga Fomenko</u><br><u>Chris Phillips</u> | Date / Shift:   | <u>Aug 22nd 2021 - Day - Shift 07</u> |
|     |  | Project Number: | <u>L-675</u>                          |
|     |  | CI:             | <u></u>                               |
| CC: | <u></u><br><u></u><br><u></u>                | Client:         | <u>Golder</u>                         |
|     |  | Distributed By: | <u>R. Morrison</u>                    |

| Run 1 Field Notes  |                            |
|--|----------------------------|
| Probe  | ALT QL Density with Gamma  |
| Start Time   | 8:00am                     |
| End Time   | 4:00pm                     |
| Run Direction  | up                         |
| Stick Up (Casing height):  | 0.30                       |
| Zero Start (Depth of Probe Point at Casing Collar):  | 2.94                       |
| START (data)   | 995.03                     |
| END (data)   | 2.93                       |
| Zero Check (Probe Point at Collar)   | 2.93                       |
| File Name  | IG_BH05_WP05_GAM2DEN_07-01 |
| <b>Comments:</b> Client file name above. Density Main run. Repeats with the repeat file from 082121<br>Good quality overall. |                            |



|              |                    |              |                     |
|--------------|--------------------|--------------|---------------------|
| Client:      | <u>Golder</u>      | Verified by: | <u>Olga Fomenko</u> |
| Location:    | <u>BH05</u>        |              | <u></u>             |
| Prepared by: | <u>R. Morrison</u> |              | <u></u>             |
| Page:        | <u>2 of 2</u>      |              |                     |



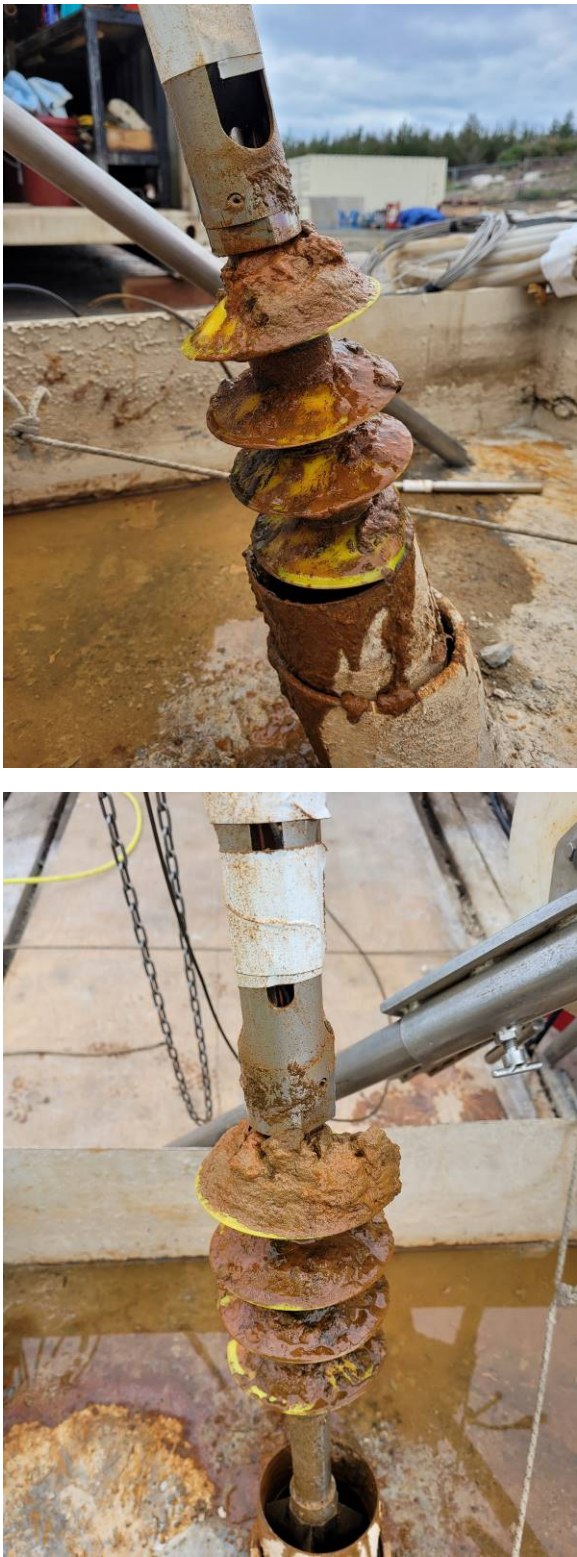
|   |   |   |
|---|---|---|
| AREA<br><b>Ignace Area, Ontario, Canada</b>                               | DRILLHOLE(S)<br><b>IG_BH05</b>              | PERSON(S)<br><b>Petri Heikkinen (PEHE)</b><br><b>Jere Komulainen (JERK)</b> |
| RESPONSIBLE AT THE SITE<br><b>Petri Heikkinen</b>                         | ORGANISATION/CLIENT<br><b>Golder / NWMO</b> |   |
| ADDITIONAL INFORMATION<br><b>Time zone UTC-5 unless otherwise stated.</b> |   | ORDERNUMBER / MEASUREMENT PROGRAM   |

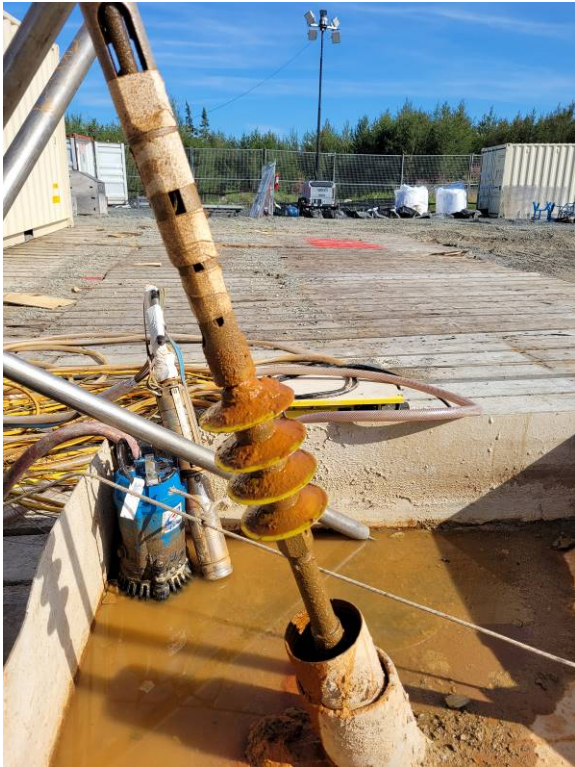
| DATE<br>(YYMMDD) | TIME             |                 | ACTIVITY   | Operator<br>Initials |
|------------------|------------------|-----------------|--|----------------------|
|                  | Start<br>(hh:mm) | Stop<br>(hh:mm) |  |                      |
| <b>20210807</b>  |                  |                 | Travel Thunder Bay – Ignace.   | <b>PEHE</b>          |
| <b>20210808</b>  |                  |                 | Measurement preparation  | <b>PEHE</b>          |
| <b>20210809</b>  | <b>6:15</b>      | <b>7:00</b>     | From Ignace to the BH05.   | <b>PEHE</b>          |
|                  | <b>7:00</b>      | <b>8:00</b>     | Weekly safety meeting. Introduction at the site.                                   | <b>PEHE</b>          |
|                  | <b>8:00</b>      | <b>16:50</b>    | Preparation for the measurements.  | <b>PEHE</b>          |
|                  | <b>12:30</b>     |                 | Electricity connected to the Trailer.  | <b>PEHE</b>          |
|                  | <b>16:50</b>     | <b>17:35</b>    | From BH05 to the Ignace.   | <b>PEHE</b>          |
| <b>20210810</b>  | <b>5:55</b>      | <b>06:40</b>    | From Ignace to the BH05.   | <b>PEHE</b>          |
|                  | <b>6:40</b>      | <b>9:35</b>     | Preparation at the site. Trailer on a place.                                       | <b>PEHE</b>          |
|                  | <b>9:17</b>      |                 | <b>Water level 35.6 m.</b>   | <b>PEHE</b>          |
|                  | <b>9:35</b>      | <b>10:35</b>    | Installation for Dummy-logging.  | <b>PEHE</b>          |
|                  | <b>10:35</b>     | <b>12:34</b>    | Dummy logging downwards. Bottom of borehole 995.6 m (Cable length, not corrected). | <b>PEHE</b>          |
|                  | <b>10:58</b>     |                 | <b>Water level 33.2 m.</b>   | <b>PEHE</b>          |
|                  | <b>11:58</b>     |                 | Borehole filled with water (amount 50 L).  | <b>PEHE</b>          |
|                  | <b>12:04</b>     |                 | <b>Water level 26.6 m.</b>   | <b>PEHE</b>          |
|                  | <b>12:39</b>     |                 | <b>Water level 26.7 m.</b>   | <b>PEHE</b>          |
|                  | <b>12:34</b>     | <b>15:09</b>    | Dummy logging upwards.   | <b>PEHE</b>          |



|          |       |       |   |      |
|----------|-------|-------|---|------|
|          | 15:09 | 17:13 | <p>Emptying and cleaning the Dummy-probe. Some amount of pure-vis came out from the borehole, otherwise it would have been accepted.</p>   | PEHE |
|          | 17:13 | 19:50 | Second Dummy logging downwards.   | PEHE |
|          | 19:18 | 20:00 | From BH05 to the Ignace.  | PEHE |
|          | 20:20 | 21:35 | Dummy logging upwards   | PEHE |
|          | 22:40 | 1:10  | Continuing dummy logging upwards. Remote connection from Finland.   | JERK |
| 20210811 | 6:07  | 6:49  | From Ignace to the BH05.  | PEHE |
|          | 7:00  | 7:15  | Dummy logging upwards (90 m - TOC).   | PEHE |
|          | 7:15  | 7:30  | Tail gate meeting (Shady).  | PEHE |

|          |       |       |  |      |
|----------|-------|-------|--|------|
|          | 7:30  | 7:45  | <p>Emptying and cleaning the Dummy-probe. Small amount of pure-vis came out from the borehole. Dummy logging passed the criteria.</p>   | PEHE |
|          | 7:45  | 8:10  | Preparations and installation for flow measurements (L=5 m, dl=0.5 m).   | PEHE |
|          | 8:10  | 8:45  | Moving the probe to the depth 40 m. Installation for water level sensor.   | PEHE |
|          | 8:26  |       | Water level 28.04 m.   | PEHE |
|          | 8:45  | 11:21 | Moving the tool to the depth 990 m and during the movement EC-logging.   | PEHE |
|          | 11:36 | 16:00 | Flow logging (L=5.0m, dl=0.5 m) without pumping from 989 m upwards. Data processing.   | PEHE |
|          | 16:00 | 16:45 | From BH05 to the Ignace.   | PEHE |
|          | 16:45 | 22:00 | Monitoring the measurement by remote connection.   | PEHE |
|          | 22:30 | 06:00 | Monitoring the measurement by remote connection and data processing.   | JERK |
| 20210812 | 6:00  | 7:52  | Monitoring the measurement by remote connection and data processing.   | PEHE |
|          | 7:52  | 8:35  | From Ignace to the BH05.   | PEHE |
|          | 8:35  | 16:37 | Flow logging (L=5.0m, dl=0.5 m) without pumping from 328 m upwards to the 66 m. Data processing.   | PEHE |
|          | 10:00 | 12:00 | Preparation for pumping.   | PEHE |



|          |       |       |   |      |
|----------|-------|-------|---|------|
|          |       |       | <p>Cleaning the flow sensor (pictures before cleaning).</p>  |      |
|          | 16:37 | 17:30 |   | PEHE |
|          | 17:30 | 17:40 | Moving the probe to the depth 40 m  | PEHE |
|          | 17:40 | 18:54 | Installation of pumping equipment.  | PEHE |
|          | 18:54 | 19:42 | From BH05 to the Ignace.  | PEHE |
| 20210813 | 6:06  | 6:53  | From Ignace to the BH05.  | PEHE |
|          | 7:15  | 7:30  | Tail gate meeting (Shady).  | PEHE |
|          | 7:30  | 8:05  | Preparation for pumping and measurements.   | PEHE |
|          | 8:05  |       | Pumping started. Target drawdown 15 m.  | PEHE |

|          |       |       |   |      |
|----------|-------|-------|---|------|
|          | 8:05  | 8:22  | Pump adjustment. Drawdown of c. 15 m was achieved which is good.  | PEHE |
|          | 8:22  | 10:36 | Moving the tool to the depth 990 m and during the movement EC-logging.  | PEHE |
|          | 10:36 | 10:36 | Preparation for flow logging (L=5.0m, dl=0.5 m) with pumping:   | PEHE |
|          | 10:42 | 16:30 | Flow logging (L=5.0m, dl=0.5 m) with pumping from 989 m upwards. Data processing.   | PEHE |
|          | 12:20 |       | Pumping rate is below the lower limit of the meter. Pumping rate have to be measured with a vessel.<br>Pumping rate 0.28 L / min. | PEHE |
|          | 15:20 |       | Pumping rate 0.24 L / min.  | PEHE |
|          | 16:30 |       | Flow logging (L=5.0m, dl=0.5 m) with pumping at the depth 812 m upwards.  | PEHE |
|          | 16:30 | 17:15 | From BH05 to the Ignace.  | PEHE |
|          | 17:15 | 22:00 | Monitoring the measurement by remote connection and data processing.  | PEHE |
|          | 22:30 | 06:00 | Monitoring of measurement by remote connection from Finland.  | JERK |
| 20210814 | 6:07  | 6:47  | From Ignace to the BH05.  | PEHE |
|          | 6:47  |       | Flow logging (L=5.0m, dl=0.5 m) with pumping at the depth 361 m upwards.  | PEHE |
|          | 6:47  | 16:16 | Flow logging (L=5.0m, dl=0.5 m) with pumping upwards to 66 m. Data processing.  | PEHE |
|          | 7:00  |       | Pumping rate 0.195 L / min.   | PEHE |
|          | 7:00  | 7:15  | Tail gate meeting (Shady).  | PEHE |
|          | 13:00 |       | Pumping rate 0.185 L / min.   | PEHE |
|          | 16:18 |       | Pumping stopped   | PEHE |
|          | 16:18 | 16:33 | Pumping equipment was lifted away and probe was moved from 66 m to the top of casing.   | PEHE |
|          | 16:33 | 16:37 | <p>The probe was lifted out.</p>              | PEHE |

|          |       |       |  |      |
|----------|-------|-------|--|------|
|          |       |       | <p>Cleaning the sensors (pictures before cleaning).</p>   | PEHE |
|          | 17:50 | 18:20 | Installation for Flow logging (L=0.5 m, dl=0.1m) and moving from TOC to 50 m.  | PEHE |
|          | 19:15 | 20:01 | From BH05 to the Ignace.   | PEHE |
| 20210815 | 6:22  | 7:06  | From Ignace to the BH05.   | PEHE |
|          | 7:15  | 7:30  | Tail gate meeting (Shady).   | PEHE |
|          | 7:30  | 8:15  | Preparation at the site.   | PEHE |
|          | 8:15  | 8:45  | Posiva discussion with NWMO and Golder.  | PEHE |
|          | 10:20 | 10:48 | Installation of pumping equipment.   | PEHE |
|          | 10:48 |       | Pumping started.   | PEHE |
|          | 10:48 | 11:17 | Pump adjustment.   | PEHE |
|          | 11:17 | 11:47 | Moving the tool to the depth 236 m.  | PEHE |

|          |       |       |   |            |
|----------|-------|-------|---|------------|
|          | 11:47 | 11:53 | Moving the tool and SPR measurement from 236 m to 232.5 m.  | PEHE       |
|          | 11:53 | 12:11 | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 232.5 m to 230 m. Data processing.   | PEHE       |
|          | 12:11 | 12:46 | Moving the tool and SPR measurement from 230 m to 172 m.  | PEHE       |
|          | 12:46 | 14:19 | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 172 m to 159 m. Data processing.     | PEHE       |
|          | 13:00 |       | Pumping rate 0.23 L / min.  | PEHE       |
|          | 14:19 | 14:45 | Moving the tool and SPR measurement from 159 m to 97 m.   | PEHE       |
|          | 14:45 | 15:02 | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 97 m to 94.5 m. Data processing.     | PEHE       |
|          | 15:02 | 16:04 | Moving the tool from 94.5 m to 325 m.   | PEHE       |
|          | 16:04 | 16:09 | Moving the tool and SPR measurement from 325 m to 322.5 m.  | PEHE       |
|          | 16:09 | 17:27 | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 322.5 m to 312 m. Data processing.   | PEHE       |
|          | 17:00 |       | Pumping rate 0.21 L / min.  | PEHE       |
|          | 17:27 | 18:09 | Moving the tool from 312 m to 396 m.  | PEHE       |
|          | 18:09 | 18:11 | Moving the tool and SPR measurement from 325 m to 322.5 m.  | PEHE       |
|          | 18:11 | 19:18 | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 395.5 m to 386.4 m. Data processing. | PEHE       |
|          | 18:33 | 19:13 | From BH05 to the Ignace.  | PEHE       |
|          |       |       | Remote connection from Ignace.  | PEHE       |
|          | 19:22 | 20:58 | Moving the tool from 386.4 m to 582 m.  | PEHE       |
|          | 20:58 | 21:01 | Moving the tool and SPR measurement from 582 m to 581.5 m.  | PEHE       |
|          | 21:03 | 23:11 | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 581.5 m to 565 m. Data processing.   | PEHE       |
|          | 23:11 | 00:26 | Moving the probe below next depth zone.   | JERK       |
| 20210816 | 00:26 | 01:11 | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 631 m to 625.2 m. Data processing.   | JERK       |
|          | 01:11 | 2:34  | Moving the probe below next depth zone.   | JERK       |
|          | 2:34  | 3:20  | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 706.5 m to 700.8 m. Data processing. | JERK       |
|          | 3:20  | 4:23  | Moving the probe below next depth zone.   | JERK       |
|          | 4:23  | 5:15  | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 792 m to 785.9 m. Data processing.   | JERK       |
|          | 5:15  | 6:01  | Moving the probe below next depth zone.   | JERK       |
|          | 6:01  | 6:52  | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 858.5 m to 852 m. Data processing.   | JERK, PEHE |
|          | 6:06  | 6:55  | From Ignace to the BH05.  | PEHE       |
|          | 6:55  | 7:33  | Moving the probe below next depth zone.   | PEHE       |
|          | 7:15  | 7:30  | Tail gate meeting (Shady).  | PEHE       |
|          | 7:45  |       | Pumping rate 0.18 L / min.  | PEHE       |
|          | 7:33  | 8:14  | Flow logging (L=0.5 m, dl=0.1m) with pumping preselected depths from 984 m to 979.1 m. Data processing.   | PEHE       |
|          | 8:33  |       | Pumping stopped   | PEHE       |
|          | 8:33  | 12:20 | Moving the tool from 979.1 m to TOC. Pumping equipment was lifted away.                                   | PEHE       |
|          | 12:20 | 13:00 | Cleaning the sensors.   | PEHE       |
|          | 13:00 | 14:45 | Installation for Flow logging (Flow along the borehole) and pumping.                                      | PEHE       |

|          |       |       |   |               |
|----------|-------|-------|---|---------------|
|          | 14:45 |       | Pumping started.  | PEHE          |
|          | 14:45 | 15:30 | Moving the probe to the measurement place.                              | PEHE          |
|          | 15:30 | 18:02 | Flow measurement along the borehole at the depth 74 m. Data processing. | PEHE          |
|          | 18:02 | 18:42 | From BH05 to the Ignace.  | PEHE          |
|          | 23:08 |       | Stopping measurement at depth of 74 m.                                  | JERK          |
|          | 23:08 | 23:28 | Flow along borehole measurement at depth of 93 m.                       | JERK          |
| 20210817 | 23:38 | 0:24  | Flow along borehole measurement at depth of 97 m.                       | JERK          |
|          | 0:57  | 1:18  | Flow along borehole measurement at depth of 158 m.                      | JERK          |
|          | 1:33  | 2:01  | Flow along borehole measurement at depth of 175 m.                      | JERK          |
|          | 2:17  | 2:43  | Flow along borehole measurement at depth of 177 m.                      | JERK          |
|          | 3:10  | 3:50  | Flow along borehole measurement at depth of 226 m.                      | JERK          |
|          | 4:00  | 4:28  | Flow along borehole measurement at depth of 235 m.                      | JERK          |
|          | 5:00  | 6:20  | Flow along borehole measurement at depth of 308 m.                      | JERK          |
|          | 6:34  | 8:23  | Flow along borehole measurement at depth of 321 m.                      | JERK,<br>PEHE |
|          | 6:05  | 6:45  | From Ignace to the BH05.  | PEHE          |
|          | 8:43  | 9:44  | Flow along borehole measurement at depth of 394.5 m.                    | PEHE          |
|          | 9:54  | 10:25 | Flow along borehole measurement at depth of 388.5 m.                    | PEHE          |
|          | 11:45 | 12:19 | Flow along borehole measurement at depth of 864 m.                      | PEHE          |
|          | 12:35 | 13:31 | Flow along borehole measurement at depth of 847 m.                      | PEHE          |
|          | 15:27 | 16:00 | Flow along borehole measurement at depth of 74 m.                       | PEHE          |
|          | 16:05 | 16:11 | Flow along borehole measurement at depth of 70.2 m.                     | PEHE          |
|          | 16:12 | 16:18 | Flow along borehole measurement at depth of 70 m.                       | PEHE          |
|          | 16:20 | 16:25 | Flow along borehole measurement at depth of 68 m.                       | PEHE          |
|          | 16:29 | 16:37 | Flow along borehole measurement at depth of 60 m.                       | PEHE          |
|          | 16:43 | 16:45 | Flow along borehole measurement at depth of 65 m.                       | PEHE          |
|          | 16:46 |       | Pumping stopped.  | PEHE          |
|          | 16:46 | 17:30 | Uninstallation for pumping and flow sensor.                             | PEHE          |
|          | 17:30 | 18:30 | Data processing.  | PEHE          |
|          | 18:30 | 19:15 | From BH05 to the Ignace.  | PEHE          |
| 20210818 | 6:07  | 6:49  | From Ignace to the BH05.  | PEHE          |
|          | 6:49  | 11:50 | Service and maintenance of PFL-equipments.                              | PEHE          |
|          | 7:15  | 7:30  | Tail gate meeting (Kirk).   | PEHE          |
|          | 11:50 | 12:20 | Posiva meeting with NWMO and Golder.                                    | PEHE          |
|          | 12:20 | 15:57 | Service, maintenance and packing of PFL-equipments.                     | PEHE          |
|          | 15:57 | 16:47 | From BH05 to the Ignace.  | PEHE          |
|          |       |       |   |               |



[illegible]

**APPENDIX D**

# Probe. TOL Files

*[Description]*

*ToolName=2CAA-FTR S/N: TEST\_AR1 \*\*\* After Power On, wait 90 seconds for data to be valid! \*\*\**

*DriverName=MULTICH*

*;5-15-06 auto voltage, recip.ch, patcher ind. pls x*

*;6-07-06 no DC ch, Calibration enable updates pls*

*;2-08-08 std adapter config pls*

*;7-11-08 verified 4mxa,4mxc tel set pls*

*;7-23-08 review and approve jrs*

*;5-05-09 operating voltage rev pls*

*; \*\*\*\*\**

*; Data browsers*

*;*

*[Process]*

*Process1=mch/MChProc.exe*

*Process2=mch/MChNum.exe*

*Process3=mch/MChCurve.exe*

*;Process4=mch/RecDebug.exe*

*[Process Info]*

*Process1=processor,start*

*Process2=browser,start*

*Process3=browser,start*

*;Process4=browser,Nostart*

*; \*\*\*\*\**

*; Tool default power-up settings*

*;*

*[Default]*

*TimeSamplingRate=1000*

*DepthSamplingRate=0.049873*

*; \*\*\*\*\**

*; Tool power supply requirements*

*;*

*[PowerSupply]*

*Voltage=60*

*Current=250*

*ToolTopNominalVoltage=53*

*ToolTopNominalCurrent=80*

*AutoAdjust=yes*

*VoltMeterYellow=45*

*VoltMeterGreen=80*

**VoltMeterRed=100**  
**AmpMeterYellow=25**  
**AmpMeterGreen=50**  
**AmpMeterRed=80**

**[Patcher]**  
**;positive voltage**  
**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=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=3200  
NegativePulseDiscriminatorLevel=-1920

[ToolAdapterConfig1]  
Name=4MXA 500M 1/8" single  
Description=  
Gain=X8  
PositivePulseEnable=yes  
PositivePulseAutomaticDiscriminator=yes  
NegativePulseEnable=yes  
NegativePulseAutomaticDiscriminator=yes  
AutomaticGain=yes  
PositivePulseDiscriminatorLevel=512  
NegativePulseDiscriminatorLevel=-6912

[ToolAdapterConfig2]  
Name=4MXC 1000M 1/8" single  
Description=  
Gain=X4  
PositivePulseEnable=yes  
PositivePulseAutomaticDiscriminator=yes  
NegativePulseEnable=yes  
NegativePulseAutomaticDiscriminator=yes  
AutomaticGain=no  
PositivePulseDiscriminatorLevel=4352  
NegativePulseDiscriminatorLevel=-2816

; \*\*\*\*\*  
; Caliper  
;  
[Caliper]  
Caliper=no

; \*\*\*\*\*  
; Tool channels description & calibration  
;  
[MultiCh]  
NbCh=10  
NbRawCh=6  
NbProcessedCh=4  
ToolLength=1.97

[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=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({Ch6} > 0, ({Ch4}-1)/{Ch6},0)  
**Name**=Temperature  
**Producer**=MChProc  
**ChShift**=0.08  
**Unit**=deg C  
**CalA**=0.0187482  
**CalB**=-24.1407  
**Reference1**=7.3  
**Reference2**=72  
**NumberFormat**=%6.2f  
**Low**=0  
**High**=50  
**NbDecade**=1  
**Mode**=Linear  
**ReverseScale**=no  
**GridEnable**=yes  
**Grid**=5  
**Left**=40  
**Right**=100  
**PenStyle**=solid  
**PenWidth**=2  
**PenColor**=ff  
**Filter**=15  
**CalDate**=06/10/05 09:48  
**DisplayedName**=Temperature

**[Ch8]**  
**DisplayEnable**=yes  
**CalibrationEnable**=yes  
**Formula**=if({Ch5} > 0, ({Ch3}-1)/{Ch5},0)  
**Name**=FRes  
**Producer**=MChProc  
**ChShift**=0.05  
**Unit**=Ohm-m  
**CalA**=-0.00293282  
**CalB**=94.264  
**Reference1**=19.4  
**Reference2**=86.69  
**NumberFormat**=%6.2f  
**Low**=0  
**High**=50  
**NbDecade**=1  
**Mode**=Linear  
**ReverseScale**=no  
**GridEnable**=no



**Grid=5**  
**Left=40**  
**Right=100**  
**PenStyle=solid**  
**PenWidth=2**  
**PenColor=400040**  
**Filter=26/04/06 14:50**  
**DisplayedName=FRes**  
**CalDate=07/04/21 13:03**

**[Ch9]**  
**DisplayEnable=yes**  
**CalibrationEnable=no**  
**Formula=1 / {Ch8} \* 10000**  
**Name=FCond**  
**Producer=MChProc**  
**ChShift=0.05**  
**Unit=uS/cm**  
**Offset=28**  
**DataType=double**  
**CalA=1**  
**CalB=0**  
**NumberFormat=%6.2f**  
**Low=0**  
**High=2000**  
**NbDecade=1**  
**Mode=Linear**  
**ReverseScale=no**  
**GridEnable=yes**  
**Grid=200**  
**Left=0**  
**Right=30**  
**PenStyle=solid**  
**PenWidth=2**  
**PenColor=8000**  
**Filter=5**  
**DisplayedName=FCond**  
**QCLow=0**  
**QCHigh=0**  
**QCLowRangeColor=2**  
**QCMedRangeColor=1**  
**QCHighRangeColor=2**  
**QCLowRangeText=Invalid**  
**QCMedRangeText=Valid**  
**QCHighRangeText=Invalid**

**QCLowRangeBeep=no**  
**QCMedRangeBeep=no**  
**QCHighRangeBeep=no**

**[Ch10]**  
**DisplayEnable=yes**  
**CalibrationEnable=no**  
**Formula=({Ch9}\*({Ch7}+21.5))/46.5**  
**Name=FCond 25'C**  
**Producer=MChProc**  
**ChShift=0.05**  
**Unit=uS/cm**  
**CalA=1**  
**CalB=0**  
**NumberFormat=%6.2f**  
**Low=0**  
**High=2000**  
**NbDecade=1**  
**Mode=Linear**  
**ReverseScale=no**  
**GridEnable=no**  
**Grid=200**  
**Left=0**  
**Right=30**  
**PenStyle=dash**  
**PenWidth=2**  
**PenColor=8000**  
**Filter=5**  
**DisplayedName=FCond 25'C**  
**QCLow=0**  
**QCHigh=0**  
**QCLowRangeColor=2**  
**QCMedRangeColor=1**  
**QCHighRangeColor=2**  
**QCLowRangeText=Invalid**  
**QCMedRangeText=Valid**  
**QCHighRangeText=Invalid**  
**QCLowRangeBeep=no**  
**QCMedRangeBeep=no**  
**QCHighRangeBeep=no**

**; \*\*\*\*\***  
**; Data browsers default settings**  
**;**

**[RecDebug]**

**XOffset=135**

**YOffset=162**

**XSize=579**

**YSize=562**

**Minimized=no**

**[MChNum]**

**XOffset=772**

**YOffset=315**

**XSize=230**

**YSize=200**

**Minimized=no**

**NumDisplay1=Ch7**

**NumDisplay2=Ch8**

**NumDisplay3=Ch9**

**NumDisplay4=Ch10**

**NbNumDisplay=4**

**[MChCurve]**

**DepthScale=100**

**ForceTimeMode=yes**

**DepthSpacing=10**

**Grid=yes**

**GridSpacing=1**

**DepthColLeft=0.3**

**DepthColRight=0.4**

**XOffset=238**

**YOffset=0**

**XSize=1298**

**YSize=824**

**Minimized=no**

**[MChProc]**

**XOffset=201**

**YOffset=201**

**XSize=302**

**YSize=147**

**Minimized=yes**

*[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*  
*QCOutOfRangeColor=2*  
*QCInRangeText=Open*  
*QCOutOfRangeText=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 + 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=2**  
**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=yes**  
**PositivePulseDiscriminatorLevel=4096**  
**NegativePulseDiscriminatorLevel=-4608**

**[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=0.230613*

**CalB=-2830.07**  
**Reference1=0**  
**Reference2=102**  
**NumberFormat=%6.2f**  
**PenColor=400040**  
**PenStyle=solid**  
**PenWidth=2**  
**Left=40**  
**Right=100**  
**Low=0**  
**High=50**  
**GridEnable=yes**  
**Grid=50**  
**NbDecade=1**  
**ReverseScale=no**  
**Mode=Linear**  
**Filter=5**  
**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=21/08/21 19:42**

**[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=0.7  
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=100  
GridEnable=no  
Grid=10  
NbDecade=1  
ReverseScale=no  
Mode=Linear  
Filter=1  
DisplayedName=Ind Res  
QCLow=0



**QCHigh=0**  
**QCLowRangeColor=2**  
**QCMedRangeColor=1**  
**QCHighRangeColor=2**  
**QCLowRangeText=Invalid**  
**QCMedRangeText=Valid**  
**QCHighRangeText=Invalid**  
**QCLowRangeBeep=no**  
**QCMedRangeBeep=no**  
**QCHighRangeBeep=no**

**[MChNum]**  
**Minimized=no**  
**XOffset=335**  
**YOffset=93**  
**XSize=341**  
**YSize=290**  
**NumDisplay1=Ch7**  
**NumDisplay2=Ch8**  
**NumDisplay3=Ch3**  
**NbNumDisplay=4**  
**NumDisplay4=Ch4**

**[MChCurve]**  
**DepthScale=200**  
**ForceTimeMode=yes**  
**DepthSpacing=2**  
**Grid=yes**  
**GridSpacing=0.2**  
**XOffset=1154**  
**YOffset=16**  
**XSize=743**  
**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 for Matrix*

*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=0.01*

*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=*

*TxAplitude=8859*

```
; *****  
; 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=ff0000*  
*Filter=1*  
*DisplayedName=SP*  
*NumberFormat=%5.1f*  
*QCLow=0*  
*QCHigh=0*  
*QCLowRangeColor=2*  
*QCMedRangeColor=1*  
*QCHighRangeColor=2*  
*QCLowRangeText=Invalid*  
*QCMedRangeText=Valid*  
*QCHighRangeText=Invalid*  
*QCLowRangeBeep=no*  
*QCMedRangeBeep=no*  
*QCHighRangeBeep=no*

*[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=yes**  
**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**  
**DisplayedName=Resistance**  
**Low=0**  
**High=300**  
**NbDecade=1**  
**Mode=Linear**  
**ReverseScale=no**  
**GridEnable=no**  
**Grid=0**  
**Left=0**  
**Right=100**  
**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

[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=60  
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  
QCLow=0  
QCHigh=0  
QCLowRangeColor=2  
QCMedRangeColor=1  
QCHighRangeColor=2  
QCLowRangeText=Invalid  
QCMedRangeText=Valid  
QCHighRangeText=Invalid  
QCLowRangeBeep=no  
QCMedRangeBeep=no  
QCHighRangeBeep=no

[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=369**  
**YOffset=21**  
**XSize=228**  
**YSize=176**  
**Minimized=yes**

**[SNA1000Spectra]**  
**CountLow=0.1**  
**CountHigh=20**  
**CountScaleAuto=yes**  
**LinearCountScale=no**  
**DisplayRawSpectrum=yes**  
**DisplayStackedSpectrum=yes**  
**DisplayEnergyWindows=no**  
**CountGrid=10**  
**DisplayCountGrid=no**  
**XOffset=723**  
**YOffset=608**  
**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=334  
YOffset=455  
XSize=341  
YSize=530  
Minimized=no*

*[MChCurve]  
DepthScale=1000  
ForceTimeMode=yes  
DepthSpacing=10  
Grid=yes  
GridSpacing=1  
XOffset=368  
YOffset=0  
XSize=1458  
YSize=989  
Minimized=no  
DepthColLeft=0.3  
DepthColRight=0.4*

*[RecDebug]  
XOffset=206  
YOffset=216  
XSize=786  
YSize=689  
Minimized=no*

**[Description]**

**ToolName** = **BH05\_MSI\_BRIDLE\_GAM5602\_IP5579**  
**DriverName** = **TOOLSTACK**  
**FamilyName** =

**[Subs]**

**Sub1** = **QL40-12\QL40-Msi1BRIDLE-1.sub**  
**Sub2** = **QL40-12\QL40-GRA-5602.sub**  
**Sub3** = **QL40-12\QL40-IP-5579.sub**  
**Sub4** = **QL40-12\QL40-PLUG.sub**

**[WellCAD]**

**Template1** =

**[Header]**

**HeaderForm** =

**; channels -----**

**[Tool.GRA.SYSTEMSTATUS.Time]**

**NumberFormat** = **%8.3f**  
**DisplayEnable** = **no**

**[Tool.GRA.SYSTEMSTATUS.TCPU]**

**NumberFormat** = **%5.1f**  
**DisplayEnable** = **no**

**[Tool.GRA.CHANNELS.EHT]**

**NumberFormat** = **%5.0f**  
**DisplayEnable** = **no**

**[Tool.GRA.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.IP.SYSTEMSTATUS.Time*]  
*DisplayedName* = Time  
*DisplayEnable* = no  
*NumberFormat* = %.3f

[*Tool.IP.SYSTEMSTATUS.TCPU*]  
*DisplayedName* = TCPU  
*DisplayEnable* = no  
*NumberFormat* = %5.1f

[*Tool.IP.ELOG.VSP*]  
*DisplayedName* = VSP  
*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

[*Tool.IP.ELOG.VSPR*]  
*DisplayedName* = VSPR  
*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*

**[Tool.IP.ELOG.I]**

**DisplayedName** = *I*  
**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*

**[Tool.IP.ELOG.V16]**

**DisplayedName** = *V16*  
**DisplayEnable** = *yes*  
**NumberFormat** = *%8.3f*

**[Tool.IP.ELOG.V64]**

**DisplayedName** = *V64*  
**DisplayEnable** = *yes*  
**NumberFormat** = *%8.3f*

**[Tool.IP.ELOG.V8]**

**DisplayedName** = *V8*  
**DisplayEnable** = *yes*  
**NumberFormat** = *%8.3f*

**[Tool.IP.ELOG.V32]**

**DisplayedName** = *V32*  
**DisplayEnable** = *yes*  
**NumberFormat** = *%8.3f*

**[Tool.IP.IPLIN.Vinj16]**

**DisplayedName** = *Vinj16*  
**DisplayEnable** = *no*

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.NbWinLin]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.1]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.1]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.2]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.2]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.3]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.3]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.4]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.4]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.5]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.5]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.6]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.6]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.7]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.7]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.8]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.8]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.9]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.9]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tlin.10]**

**DisplayEnable = no**

**NumberFormat = %8.3f**

**[Tool.IP.IPLIN.WLin16.10]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.1]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.2]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.3]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.4]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.5]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.6]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.7]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.8]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.9]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.WLin64.10]**

**DisplayEnable = no**

**NumberFormat = %8.0f**

**[Tool.IP.IPLIN.Tinj]**

**DisplayEnable = no**

**NumberFormat = %g**

**[Tool.IP.IPLIN.TRel]**

**DisplayEnable = no**

**NumberFormat = %g**

**[Tool.IP.IPLIN.Vinj64]**

*DisplayEnable* = *no*  
*NumberFormat* = *%8.0f*

*[MChProc.SPR]*

*DisplayedName* = *SPR*  
*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*  
*Low* = *0*

*[MChProc.N16]*

*DisplayedName* = *N16*  
*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*  
*Low* = *0*

*[MChProc.N64]*

*DisplayedName* = *N64*  
*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  
**Low** = 0

**[MChProc.N8]**  
**DisplayedName** = N8  
**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  
**Low** = 0

**[MChProc.N32]**  
**DisplayedName** = N32  
**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  
**Low** = 0

**[MChProc.IPlin16.1]**  
**DisplayEnable** = no

|                     |                 |
|---------------------|-----------------|
| <b>NumberFormat</b> | <b>= %4.3f</b>  |
| <b>High</b>         | <b>= 200</b>    |
| <b>PenStyle</b>     | <b>= solid</b>  |
| <b>Mode</b>         | <b>= Linear</b> |
| <b>PenColor</b>     | <b>= ff</b>     |
| <b>Grid</b>         | <b>= 0</b>      |
| <b>Left</b>         | <b>= 40</b>     |
| <b>ReverseScale</b> | <b>= no</b>     |
| <b>GridEnable</b>   | <b>= yes</b>    |
| <b>PenWidth</b>     | <b>= 2</b>      |
| <b>Right</b>        | <b>= 70</b>     |
| <b>NbDecade</b>     | <b>= 5</b>      |
| <b>Low</b>          | <b>= 0</b>      |

**[MChProc.IPLin16.2]**

|                      |                 |
|----------------------|-----------------|
| <b>DisplayEnable</b> | <b>= no</b>     |
| <b>NumberFormat</b>  | <b>= %4.3f</b>  |
| <b>High</b>          | <b>= 200</b>    |
| <b>PenStyle</b>      | <b>= solid</b>  |
| <b>Mode</b>          | <b>= Linear</b> |
| <b>PenColor</b>      | <b>= ff0000</b> |
| <b>Grid</b>          | <b>= 0</b>      |
| <b>Left</b>          | <b>= 40</b>     |
| <b>ReverseScale</b>  | <b>= no</b>     |
| <b>GridEnable</b>    | <b>= no</b>     |
| <b>PenWidth</b>      | <b>= 2</b>      |
| <b>Right</b>         | <b>= 70</b>     |
| <b>NbDecade</b>      | <b>= 5</b>      |
| <b>Low</b>           | <b>= 0</b>      |

**[MChProc.IPLin16.3]**

|                      |                 |
|----------------------|-----------------|
| <b>DisplayEnable</b> | <b>= no</b>     |
| <b>NumberFormat</b>  | <b>= %4.3f</b>  |
| <b>High</b>          | <b>= 200</b>    |
| <b>PenStyle</b>      | <b>= solid</b>  |
| <b>Mode</b>          | <b>= Linear</b> |
| <b>PenColor</b>      | <b>= ff0000</b> |
| <b>Grid</b>          | <b>= 0</b>      |
| <b>Left</b>          | <b>= 40</b>     |
| <b>ReverseScale</b>  | <b>= no</b>     |
| <b>GridEnable</b>    | <b>= no</b>     |
| <b>PenWidth</b>      | <b>= 2</b>      |
| <b>Right</b>         | <b>= 70</b>     |
| <b>NbDecade</b>      | <b>= 5</b>      |
| <b>Low</b>           | <b>= 0</b>      |

**[MChProc.IPLin16.4]**

**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  
**Low** = 0

**[MChProc.IPLin16.5]**

**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  
**Low** = 0

**[MChProc.IPLin16.6]**

**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  
**Low** = 0

**[MChProc.IPLin16.7]**

**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  
**Low** = 0

**[MChProc.IPLin16.8]**

**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  
**Low** = 0

**[MChProc.IPLin16.9]**

**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*  
**Low** = *0*

**[MChProc.IPLin16.10]**

**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*  
**Low** = *0*

**[MChProc.IPLin64.1]**

**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*  
**Low** = *0*

**[MChProc.IPLin64.2]**

**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  
**Low** = 0

**[MChProc.IPLin64.3]**

**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  
**Low** = 0

**[MChProc.IPLin64.4]**

**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  
**Low** = 0

**[MChProc.IPLin64.5]**

**DisplayEnable** = no  
**NumberFormat** = *%4.3f*

|                     |                 |
|---------------------|-----------------|
| <i>High</i>         | <i>= 200</i>    |
| <i>PenStyle</i>     | <i>= solid</i>  |
| <i>Mode</i>         | <i>= Linear</i> |
| <i>PenColor</i>     | <i>= ff0000</i> |
| <i>Grid</i>         | <i>= 0</i>      |
| <i>Left</i>         | <i>= 70</i>     |
| <i>ReverseScale</i> | <i>= no</i>     |
| <i>GridEnable</i>   | <i>= no</i>     |
| <i>PenWidth</i>     | <i>= 2</i>      |
| <i>Right</i>        | <i>= 100</i>    |
| <i>NbDecade</i>     | <i>= 5</i>      |
| <i>Low</i>          | <i>= 0</i>      |

*[MChProc.IPLin64.6]*

|                      |                 |
|----------------------|-----------------|
| <i>DisplayEnable</i> | <i>= no</i>     |
| <i>NumberFormat</i>  | <i>= %4.3f</i>  |
| <i>High</i>          | <i>= 200</i>    |
| <i>PenStyle</i>      | <i>= solid</i>  |
| <i>Mode</i>          | <i>= Linear</i> |
| <i>PenColor</i>      | <i>= ff0000</i> |
| <i>Grid</i>          | <i>= 0</i>      |
| <i>Left</i>          | <i>= 70</i>     |
| <i>ReverseScale</i>  | <i>= no</i>     |
| <i>GridEnable</i>    | <i>= no</i>     |
| <i>PenWidth</i>      | <i>= 2</i>      |
| <i>Right</i>         | <i>= 100</i>    |
| <i>NbDecade</i>      | <i>= 5</i>      |
| <i>Low</i>           | <i>= 0</i>      |

*[MChProc.IPLin64.7]*

|                      |                 |
|----------------------|-----------------|
| <i>DisplayEnable</i> | <i>= no</i>     |
| <i>NumberFormat</i>  | <i>= %4.3f</i>  |
| <i>High</i>          | <i>= 200</i>    |
| <i>PenStyle</i>      | <i>= solid</i>  |
| <i>Mode</i>          | <i>= Linear</i> |
| <i>PenColor</i>      | <i>= ff0000</i> |
| <i>Grid</i>          | <i>= 0</i>      |
| <i>Left</i>          | <i>= 70</i>     |
| <i>ReverseScale</i>  | <i>= no</i>     |
| <i>GridEnable</i>    | <i>= no</i>     |
| <i>PenWidth</i>      | <i>= 2</i>      |
| <i>Right</i>         | <i>= 100</i>    |
| <i>NbDecade</i>      | <i>= 5</i>      |
| <i>Low</i>           | <i>= 0</i>      |

**[MChProc.IPLin64.8]**

**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  
**Low** = 0

**[MChProc.IPLin64.9]**

**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  
**Low** = 0

**[MChProc.IPLin64.10]**

**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  
*Low* = 0

*[MChProc.Ma]*  
*DisplayedName* = *Ma*  
*DisplayEnable* = *no*  
*NumberFormat* = *%0.1f*

*[Tool.IP.IPFW16.IPFW16]*  
*DisplayEnable* = *no*

*[Tool.IP.IPFW64.IPFW64]*  
*DisplayEnable* = *no*

*[Logger.Speed]*  
*DisplayEnable* = *no*

*[Logger.Tension]*  
*DisplayEnable* = *no*

*[Logger.ToolPowerVoltage]*  
*DisplayEnable* = *no*

*[Logger.ToolPowerCurrent]*  
*DisplayEnable* = *no*

*; browsers and processors -----*

*[MChProc]*  
*Minimized* = *yes*

*[MChCurve]*  
*DepthScale* = 100  
*GridSpacing* = 0.5  
*XOffset* = 432  
*ForceTimeMode* = *yes*  
*YSize* = 977  
*DepthColLeft* = 0.3  
*XSize* = 848  
*DepthSpacing* = 5  
*DepthColRight* = 0.4  
*Minimized* = *no*  
*YOffset* = 0  
*Grid* = *yes*

|                     |                           |
|---------------------|---------------------------|
| <b>[MChNum]</b>     |                           |
| <b>XOffset</b>      | <b>= 446</b>              |
| <b>YSize</b>        | <b>= 869</b>              |
| <b>XSize</b>        | <b>= 230</b>              |
| <b>Minimized</b>    | <b>= no</b>               |
| <b>YOffset</b>      | <b>= 0</b>                |
| <b>NumDisplay1</b>  | <b>= MChProc.GR</b>       |
| <b>NumDisplay2</b>  | <b>= Tool.IP.ELOG.VSP</b> |
| <b>NumDisplay3</b>  | <b>= MChProc.SPR</b>      |
| <b>NumDisplay4</b>  | <b>= MChProc.N8</b>       |
| <b>NumDisplay5</b>  | <b>= MChProc.N16</b>      |
| <b>NumDisplay6</b>  | <b>= MChProc.N32</b>      |
| <b>NumDisplay7</b>  | <b>= MChProc.N64</b>      |
| <b>NumDisplay8</b>  | <b>= MChProc.Ma</b>       |
| <b>NbNumDisplay</b> | <b>= 8</b>                |

**[IpWave]**

**[Description]**

**ToolName** = **MSI\_GRA5602\_HMI453**  
**DriverName** = **TOOLSTACK**  
**FamilyName** =

**[Subs]**

**Sub1** = **QL40-12\QL40-MSI1-1.sub**  
**Sub2** = **QL40-12\QL40-GRA-5602.sub**  
**Sub3** = **QL40-12\QL40-HMI453-6766.sub**

**[WellCAD]**

**Template1** =

**[Header]**

**HeaderForm** =

**; channels -----**

**[Tool.GRA.SYSTEMSTATUS.Time]**

**NumberFormat** = **%8.3f**  
**DisplayEnable** = **no**

**[Tool.GRA.SYSTEMSTATUS.TCPU]**

**NumberFormat** = **%5.1f**  
**DisplayEnable** = **no**

**[Tool.GRA.CHANNELS.EHT]**

**NumberFormat** = **%5.0f**  
**DisplayEnable** = **no**

**[Tool.GRA.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.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* = 0  
*Right* = 30  
*PenStyle* = solid  
*PenWidth* = 2  
*PenColor* = ff

*[MChProc.Conductivity]*

*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*

*[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*

*[Logger.Speed]*

*DisplayEnable* = *no*

*[Logger.Tension]*

*DisplayEnable* = *no*

*[Logger.ToolPowerVoltage]*

*DisplayEnable* = *no*

*[Logger.ToolPowerCurrent]*

*DisplayEnable* = *no*

*; browsers and processors -----*

*[MChProc]*

*Minimized* = *yes*

*[MChCurve]*

*DepthScale* = *1000*  
*GridSpacing* = *5*

|                      |              |
|----------------------|--------------|
| <i>XOffset</i>       | <i>= 995</i> |
| <i>ForceTimeMode</i> | <i>= yes</i> |
| <i>YSize</i>         | <i>= 733</i> |
| <i>DepthColLeft</i>  | <i>= 0.3</i> |
| <i>XSize</i>         | <i>= 923</i> |
| <i>DepthSpacing</i>  | <i>= 50</i>  |
| <i>DepthColRight</i> | <i>= 0.4</i> |
| <i>Minimized</i>     | <i>= no</i>  |
| <i>YOffset</i>       | <i>= 6</i>   |
| <i>Grid</i>          | <i>= yes</i> |

|                     |                               |
|---------------------|-------------------------------|
| <i>[MChNum]</i>     |                               |
| <i>NumDisplay1</i>  | <i>= MChProc.GR</i>           |
| <i>NbNumDisplay</i> | <i>= 4</i>                    |
| <i>NumDisplay2</i>  | <i>= MChProc.MagSus</i>       |
| <i>NumDisplay3</i>  | <i>= MChProc.Conductivity</i> |
| <i>NumDisplay4</i>  | <i>= MChProc.Resistivity</i>  |
| <i>XOffset</i>      | <i>= 658</i>                  |
| <i>YOffset</i>      | <i>= 725</i>                  |
| <i>XSize</i>        | <i>= 341</i>                  |
| <i>YSize</i>        | <i>= 290</i>                  |
| <i>Minimized</i>    | <i>= no</i>                   |

**[Description]**

**ToolName** = **MSI\_GRA5602-OBI160403**  
**DriverName** = **TOOLSTACK**  
**FamilyName** =

**[Subs]**

**Sub1** = **QL40-12\QL40-MSI1-1.sub**  
**Sub2** = **QL40-12\QL40-GRA-5602.sub**  
**Sub3** = **QL40-12\QL40-OBI2G-160403.sub**

**[WellCAD]**

**Template1** =

**[Header]**

**HeaderForm** =

**; channels -----**

**[Tool.GRA.SYSTEMSTATUS.Time]**

**NumberFormat** = **%8.3f**  
**DisplayEnable** = **no**

**[Tool.GRA.SYSTEMSTATUS.TCPU]**

**NumberFormat** = **%5.1f**  
**DisplayEnable** = **no**

**[Tool.GRA.CHANNELS.EHT]**

**NumberFormat** = **%5.0f**  
**DisplayEnable** = **no**

**[Tool.GRA.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.OBI40.SYSTEMSTATUS.TCAM]**

**NumberFormat** = %6.1f  
**DisplayEnable** = no  
**DisplayedName** = TCAM  
**Low** = 0  
**High** = 70  
**NbDecade** = 1  
**Mode** = Linear  
**ReverseScale** = no  
**GridEnable** = yes  
**Grid** = 10  
**Left** = 70  
**Right** = 100  
**PenStyle** = solid  
**PenWidth** = 2  
**PenColor** = ff0000  
**Filter** = 1  
**QCLow** = 0  
**QCHigh** = 95  
**QCLowRangeColor** = 1  
**QCMedRangeColor** = 1  
**QCHighRangeColor** = 2  
**QCLowRangeText** = OK  
**QCMedRangeText** = OK  
**QCHighRangeText** = OVERHEAT  
**QCLowRangeBeep** = no  
**QCMedRangeBeep** = no  
**QCHighRangeBeep** = no

**[Tool.OBI40.SYSTEMSTATUS.WorkLoad]**

**NumberFormat** = %3.0f  
**DisplayEnable** = no

**[Tool.OBI40.SYSTEMSTATUS.FRate]**

**NumberFormat** = %3.0f  
**DisplayEnable** = no

**[Tool.OBI40.APS544.Roll]**

**NumberFormat** = %6.1f  
**DisplayEnable** = no

**DisplayedName** = *Roll*  
**Low** = *0*  
**High** = *360*  
**NbDecade** = *1*  
**Mode** = *Linear*  
**ReverseScale** = *no*  
**GridEnable** = *no*  
**Grid** = *0*  
**Left** = *70*  
**Right** = *100*  
**PenStyle** = *solid*  
**PenWidth** = *1*  
**PenColor** = *0*

**[Tool.OBI40.APS544.MRoll]**

**NumberFormat** = *%6.1f*  
**DisplayEnable** = *no*  
**DisplayedName** = *MRoll*  
**Low** = *0*  
**High** = *360*  
**NbDecade** = *1*  
**Mode** = *Linear*  
**ReverseScale** = *no*  
**GridEnable** = *no*  
**Grid** = *0*  
**Left** = *70*  
**Right** = *100*  
**PenStyle** = *solid*  
**PenWidth** = *1*  
**PenColor** = *0*

**[Tool.OBI40.APS544.Tilt]**

**NumberFormat** = *%7.1f*  
**DisplayEnable** = *yes*  
**DisplayedName** = *Tilt*  
**Low** = *0*  
**High** = *15*  
**NbDecade** = *1*  
**Mode** = *Linear*  
**ReverseScale** = *no*  
**GridEnable** = *yes*  
**Grid** = *2.5*  
**Left** = *40*  
**Right** = *70*  
**PenStyle** = *solid*

**PenWidth** = 2  
**PenColor** = ff

**[Tool.OBI40.APS544.MagnField]**

**NumberFormat** = %6.2f  
**DisplayEnable** = yes  
**DisplayedName** = MagnField  
**Low** = 45  
**High** = 55  
**NbDecade** = 1  
**Mode** = Linear  
**ReverseScale** = no  
**GridEnable** = yes  
**Grid** = 1  
**Left** = 70  
**Right** = 100  
**PenStyle** = solid  
**PenWidth** = 2  
**PenColor** = 4080

**[Tool.OBI40.APS544.Azimuth]**

**NumberFormat** = %7.1f  
**DisplayEnable** = yes  
**DisplayedName** = Azimuth  
**Low** = 0  
**High** = 360  
**NbDecade** = 1  
**Mode** = Linear  
**ReverseScale** = no  
**GridEnable** = no  
**Grid** = 0  
**Left** = 40  
**Right** = 70  
**PenStyle** = solid  
**PenWidth** = 2  
**PenColor** = ff0000

**[Tool.OBI40.APS544.Gravity]**

**NumberFormat** = %6.4f  
**DisplayEnable** = yes  
**DisplayedName** = Gravity  
**Low** = 0.9  
**High** = 1.1  
**NbDecade** = 1  
**Mode** = Linear

*ReverseScale* = *no*  
*GridEnable* = *no*  
*Grid* = *0*  
*Left* = *70*  
*Right* = *100*  
*PenStyle* = *solid*  
*PenWidth* = *2*  
*PenColor* = *80ff*

*[Tool.OBI40.APS544.TAPS]*

*NumberFormat* = *%7.2f*  
*DisplayEnable* = *no*  
*DisplayedName* = *TAPS*  
*Low* = *0*  
*High* = *70*  
*NbDecade* = *1*  
*Mode* = *Linear*  
*ReverseScale* = *no*  
*GridEnable* = *no*  
*Grid* = *0*  
*Left* = *70*  
*Right* = *100*  
*PenStyle* = *solid*  
*PenWidth* = *2*  
*PenColor* = *ff00*

*[Tool.OBI40.IMAGE.Image]*

*NumberFormat* = *%g*  
*DisplayEnable* = *no*

*[Logger.Speed]*

*DisplayEnable* = *no*

*[Logger.Tension]*

*DisplayEnable* = *no*

*[Logger.ToolPowerVoltage]*

*DisplayEnable* = *no*

*[Logger.ToolPowerCurrent]*

*DisplayEnable* = *no*

*; browsers and processors -----*

*[ObiProc]*



**DepthInterval** = 0.2

**[MChProc]**

**Minimized** = no  
**XOffset** = 958  
**YOffset** = 423  
**XSize** = 339  
**YSize** = 175

**[MChCurve]**

**DepthScale** = 100  
**GridSpacing** = 0.5  
**XOffset** = 650  
**ForceTimeMode** = no  
**YSize** = 1020  
**DepthColLeft** = 0.3  
**XSize** = 285  
**DepthSpacing** = 5  
**DepthColRight** = 0.4  
**Minimized** = no  
**YOffset** = 0  
**Grid** = yes

**[MChNum]**

**NumDisplay1** = MChProc.GR  
**NbNumDisplay** = 7  
**NumDisplay2** = Tool.OBI40.SYSTEMSTATUS.TCAM  
**NumDisplay3** = Tool.OBI40.APS544.Azimuth  
**NumDisplay4** = Tool.OBI40.APS544.Tilt  
**NumDisplay5** = Tool.OBI40.APS544.MagnField  
**NumDisplay6** = Tool.OBI40.APS544.Gravity  
**NumDisplay7** = Tool.OBI40.APS544.Roll  
**LedDisplay1** = Tool.OBI40.SYSTEMSTATUS.TCAM  
**NbLedDisplay** = 1  
**XOffset** = 334  
**YOffset** = 504  
**XSize** = 341  
**YSize** = 485  
**Minimized** = no

**[Obi40Img]**

**DepthScale** = 40  
**GridSpacing** = 0.04  
**XOffset** = 836  
**ForceTimeMode** = no

**YSize** = 1020  
**XSize** = 1084  
**DepthSpacing** = 0.4  
**WorkloadMeterRange** = 0,90,100,120  
**FrameRateMeterRange** = 0,100,100,120  
**Minimized** = no  
**YOffset** = 0  
**Grid** = no  
**OrientTo** = HighSide

**[ObiHisto]**

**XOffset** = 471  
**YSize** = 596  
**XSize** = 746  
**Minimized** = yes  
**YOffset** = 41

**[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.ECH01.WndTime]*

*NumberFormat* = %6.2f  
*DisplayEnable* = no

*[Tool.ABI40.ECH01.WndAmpl]*

*NumberFormat* = %6.2f  
*DisplayEnable* = no

*[Tool.ABI40.ECH01.TravelTime]*

*[Tool.ABI40.ECH01.Amplitude]*

*[Tool.ABI40.ECH02.TravelTime2]*

*[Tool.ABI40.ECH02.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*



|                      |               |
|----------------------|---------------|
| <i>DepthScale</i>    | <i>= 100</i>  |
| <i>XOffset</i>       | <i>= 889</i>  |
| <i>ForceTimeMode</i> | <i>= yes</i>  |
| <i>YSize</i>         | <i>= 571</i>  |
| <i>DepthColLeft</i>  | <i>= 0.3</i>  |
| <i>XSize</i>         | <i>= 1029</i> |
| <i>DepthSpacing</i>  | <i>= 5</i>    |
| <i>DepthColRight</i> | <i>= 0.4</i>  |
| <i>Minimized</i>     | <i>= yes</i>  |
| <i>YOffset</i>       | <i>= 592</i>  |
| <i>Grid</i>          | <i>= yes</i>  |

**[Description]**

**ToolName** = **MSI1-FWS40-PLUG**  
**DriverName** = **TOOLSTACK**  
**FamilyName** =

**[Subs]**

**Sub1** = **QL40-12\QL40-MSI1-1.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**

*[Logger.Speed]*  
*DisplayEnable* = *no*

*[Logger.Tension]*  
*DisplayEnable* = *no*

*[Logger.ToolPowerVoltage]*  
*DisplayEnable* = *no*

*[Logger.ToolPowerCurrent]*  
*DisplayEnable* = *no*

*; browsers and processors -----*

*[FwsProc]*  
*FirstArrivalProcessWave* = *0*  
*XOffset* = *873*  
*YSize* = *210*  
*XSize* = *380*  
*CementBondProcessWave* = *0*  
*Minimized* = *no*  
*YOffset* = *750*

*[MChProc]*  
*Minimized* = *no*  
*XOffset* = *875*  
*YOffset* = *569*  
*XSize* = *339*  
*YSize* = *175*

*[MChNum]*  
*NumDisplay1* = *FwsProc.RX1-1A - dt*  
*NbNumDisplay* = *9*  
*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*  
*XOffset* = *423*  
*YOffset* = *423*  
*XSize* = *341*  
*YSize* = *490*

*Minimized* = *no*

*[FwsWave]*

*XOffset* = *850*

*YSize* = *915*

*XSize* = *968*

*Minimized* = *no*

*YOffset* = *15*

*DisplayRx8* = *no*

*DisplayRx7* = *no*

*DisplayRx6* = *no*

*DisplayRx5* = *no*

*DisplayRx4* = *yes*

*DisplayRx3* = *yes*

*DisplayRx2* = *yes*

*DisplayRx1* = *yes*

*DisplayTxB* = *no*

*DisplayTxA* = *yes*

*DisplayExtendedWaves* = *no*

**[Description]**

**ToolName** = **MSI1-OBI\_160403**  
**DriverName** = **TOOLSTACK**  
**FamilyName** =

**[Subs]**

**Sub1** = **QL40-12\QL40-MSI1-100.sub**  
**Sub2** = **QL40-12\QL40-OBI2G-160403.sub**

**[WellCAD]**

**Template1** =

**[Header]**

**HeaderForm** =

**; channels -----**

**[Tool.OBI40.SYSTEMSTATUS.TCAM]**

**NumberFormat** = **%6.1f**  
**DisplayEnable** = **no**  
**DisplayedName** = **TCAM**  
**Low** = **0**  
**High** = **70**  
**NbDecade** = **1**  
**Mode** = **Linear**  
**ReverseScale** = **no**  
**GridEnable** = **yes**  
**Grid** = **10**  
**Left** = **70**  
**Right** = **100**  
**PenStyle** = **solid**  
**PenWidth** = **2**  
**PenColor** = **ff0000**  
**Filter** = **1**  
**QCLow** = **0**  
**QCHigh** = **95**  
**QCLowRangeColor** = **1**  
**QCMedRangeColor** = **1**  
**QCHighRangeColor** = **2**  
**QCLowRangeText** = **OK**  
**QCMedRangeText** = **OK**  
**QCHighRangeText** = **OVERHEAT**  
**QCLowRangeBeep** = **no**  
**QCMedRangeBeep** = **no**  
**QCHighRangeBeep** = **no**

**[Tool.OBI40.SYSTEMSTATUS.WorkLoad]**

**NumberFormat = %3.0f**

**DisplayEnable = no**

**[Tool.OBI40.SYSTEMSTATUS.FRate]**

**NumberFormat = %3.0f**

**DisplayEnable = no**

**[Tool.OBI40.APS544.Roll]**

**NumberFormat = %6.1f**

**DisplayEnable = no**

**DisplayedName = Roll**

**Low = 0**

**High = 360**

**NbDecade = 1**

**Mode = Linear**

**ReverseScale = no**

**GridEnable = no**

**Grid = 0**

**Left = 70**

**Right = 100**

**PenStyle = solid**

**PenWidth = 1**

**PenColor = 0**

**[Tool.OBI40.APS544.MRoll]**

**NumberFormat = %6.1f**

**DisplayEnable = no**

**DisplayedName = MRoll**

**Low = 0**

**High = 360**

**NbDecade = 1**

**Mode = Linear**

**ReverseScale = no**

**GridEnable = no**

**Grid = 0**

**Left = 70**

**Right = 100**

**PenStyle = solid**

**PenWidth = 1**

**PenColor = 0**

**[Tool.OBI40.APS544.Tilt]**

**NumberFormat = %7.1f**

|                         |                  |
|-------------------------|------------------|
| <i>DisplayEnable</i>    | <i>= yes</i>     |
| <i>DisplayedName</i>    | <i>= Tilt</i>    |
| <i>Low</i>              | <i>= 0</i>       |
| <i>High</i>             | <i>= 90</i>      |
| <i>NbDecade</i>         | <i>= 1</i>       |
| <i>Mode</i>             | <i>= Linear</i>  |
| <i>ReverseScale</i>     | <i>= no</i>      |
| <i>GridEnable</i>       | <i>= yes</i>     |
| <i>Grid</i>             | <i>= 10</i>      |
| <i>Left</i>             | <i>= 40</i>      |
| <i>Right</i>            | <i>= 70</i>      |
| <i>PenStyle</i>         | <i>= solid</i>   |
| <i>PenWidth</i>         | <i>= 2</i>       |
| <i>PenColor</i>         | <i>= ff</i>      |
| <i>QCLow</i>            | <i>= 0</i>       |
| <i>QCHigh</i>           | <i>= 0</i>       |
| <i>QCLowRangeColor</i>  | <i>= 2</i>       |
| <i>QCMedRangeColor</i>  | <i>= 1</i>       |
| <i>QCHighRangeColor</i> | <i>= 2</i>       |
| <i>QCLowRangeText</i>   | <i>= Invalid</i> |
| <i>QCMedRangeText</i>   | <i>= Valid</i>   |
| <i>QCHighRangeText</i>  | <i>= Invalid</i> |
| <i>QCLowRangeBeep</i>   | <i>= no</i>      |
| <i>QCMedRangeBeep</i>   | <i>= no</i>      |
| <i>QCHighRangeBeep</i>  | <i>= no</i>      |
| <i>Filter</i>           | <i>= 1</i>       |

*[Tool.OBI40.APS544.MagnField]*

|                      |                    |
|----------------------|--------------------|
| <i>NumberFormat</i>  | <i>= %6.2f</i>     |
| <i>DisplayEnable</i> | <i>= yes</i>       |
| <i>DisplayedName</i> | <i>= MagnField</i> |
| <i>Low</i>           | <i>= 45</i>        |
| <i>High</i>          | <i>= 55</i>        |
| <i>NbDecade</i>      | <i>= 1</i>         |
| <i>Mode</i>          | <i>= Linear</i>    |
| <i>ReverseScale</i>  | <i>= no</i>        |
| <i>GridEnable</i>    | <i>= yes</i>       |
| <i>Grid</i>          | <i>= 1</i>         |
| <i>Left</i>          | <i>= 70</i>        |
| <i>Right</i>         | <i>= 100</i>       |
| <i>PenStyle</i>      | <i>= solid</i>     |
| <i>PenWidth</i>      | <i>= 2</i>         |
| <i>PenColor</i>      | <i>= 4080</i>      |
| <i>QCLow</i>         | <i>= 0</i>         |
| <i>QCHigh</i>        | <i>= 0</i>         |

**QCLowRangeColor** = 2  
**QCMedRangeColor** = 1  
**QCHighRangeColor** = 2  
**QCLowRangeText** = Invalid  
**QCMedRangeText** = Valid  
**QCHighRangeText** = Invalid  
**QCLowRangeBeep** = no  
**QCMedRangeBeep** = no  
**QCHighRangeBeep** = no  
**Filter** = 1

**[Tool.OBI40.APS544.Azimuth]**

**NumberFormat** = %7.1f  
**DisplayEnable** = yes  
**DisplayedName** = Azimuth  
**Low** = 0  
**High** = 360  
**NbDecade** = 1  
**Mode** = Linear  
**ReverseScale** = no  
**GridEnable** = no  
**Grid** = 0  
**Left** = 40  
**Right** = 70  
**PenStyle** = solid  
**PenWidth** = 2  
**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

**[Tool.OBI40.APS544.Gravity]**

**NumberFormat** = %6.4f  
**DisplayEnable** = yes  
**DisplayedName** = Gravity  
**Low** = 0.9



*High* = 1.1  
*NbDecade* = 1  
*Mode* = Linear  
*ReverseScale* = no  
*GridEnable* = no  
*Grid* = 0  
*Left* = 70  
*Right* = 100  
*PenStyle* = solid  
*PenWidth* = 2  
*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

**[Tool.OBI40.APS544.TAPS]**

*NumberFormat* = %7.2f  
*DisplayEnable* = no  
*DisplayedName* = TAPS  
*Low* = 0  
*High* = 70  
*NbDecade* = 1  
*Mode* = Linear  
*ReverseScale* = no  
*GridEnable* = no  
*Grid* = 0  
*Left* = 70  
*Right* = 100  
*PenStyle* = solid  
*PenWidth* = 2  
*PenColor* = ff00

**[Tool.OBI40.IMAGE.Image]**

*NumberFormat* = %g  
*DisplayEnable* = no

**[Logger.Speed]**  
**DisplayEnable** = no

**[Logger.ToolPowerVoltage]**  
**DisplayEnable** = no

**[Logger.ToolPowerCurrent]**  
**DisplayEnable** = no

**; browsers and processors -----**

**[ObiProc]**  
**DepthInterval** = 0.2

**[MChNum]**  
**NumDisplay1** = Tool.OBI40.SYSTEMSTATUS.TCAM  
**NbNumDisplay** = 6  
**NumDisplay2** = Tool.OBI40.APS544.Azimuth  
**NumDisplay3** = Tool.OBI40.APS544.Tilt  
**NumDisplay4** = Tool.OBI40.APS544.Roll  
**NumDisplay5** = Tool.OBI40.APS544.MagnField  
**NumDisplay6** = Tool.OBI40.APS544.Gravity  
**LedDisplay1** = Tool.OBI40.SYSTEMSTATUS.TCAM  
**NbLedDisplay** = 1  
**XOffset** = 296  
**YOffset** = 149  
**XSize** = 304  
**YSize** = 366  
**Minimized** = no

**[Obi40Img]**  
**DepthScale** = 40  
**GridSpacing** = 0.2  
**XOffset** = 885  
**ForceTimeMode** = yes  
**YSize** = 1030  
**XSize** = 1018  
**DepthSpacing** = 2  
**WorkloadMeterRange** = 0,90,100,120  
**FrameRateMeterRange** = 0,100,100,120  
**Minimized** = no  
**YOffset** = 0  
**Grid** = no

**[MChCurve]**

|                      |               |
|----------------------|---------------|
| <i>DepthScale</i>    | <i>= 1000</i> |
| <i>GridSpacing</i>   | <i>= 5</i>    |
| <i>XOffset</i>       | <i>= 296</i>  |
| <i>ForceTimeMode</i> | <i>= yes</i>  |
| <i>YSize</i>         | <i>= 1030</i> |
| <i>DepthColLeft</i>  | <i>= 0.3</i>  |
| <i>XSize</i>         | <i>= 611</i>  |
| <i>DepthSpacing</i>  | <i>= 50</i>   |
| <i>DepthColRight</i> | <i>= 0.4</i>  |
| <i>Minimized</i>     | <i>= no</i>   |
| <i>YOffset</i>       | <i>= 0</i>    |
| <i>Grid</i>          | <i>= yes</i>  |

|                   |               |
|-------------------|---------------|
| <i>[ObiHisto]</i> |               |
| <i>XOffset</i>    | <i>= 471</i>  |
| <i>YSize</i>      | <i>= 929</i>  |
| <i>XSize</i>      | <i>= 1186</i> |
| <i>Minimized</i>  | <i>= yes</i>  |
| <i>YOffset</i>    | <i>= 41</i>   |

-----  
-  
[Description]

ToolName = DEN  
SerialNumber = 6366\_Q1246  
FamilyName = Nuclear  
DriverName = TOOLSTACK  
SubDriverName = MULTICH

; DIMENSIONS  
-----

-----  
[Dimension]

Length = 1.835  
Weight = 19.2  
OD = 51  
ODMax = 153  
TemperatureRating = 85  
PressureRating = 206  
ToolJoint = QL40-12  
BottomSub = yes  
TopSub = no  
TelemetrySub = yes  
Bitmap = QL40-DEN.bmp  
ToolJointTop=QL40-12;QLBUS0,QLBUS1,QLBUS2,QLBUS3  
ToolJointBottom=NONE;NONE  
Wiring=QL

; ASSOCIATED SUBS  
-----

-----  
[AssociatedSubs]

Sub1 =

; POWER SUPPLY  
-----

-----  
[PowerSupply]

Mode = Voltage  
Voltage = 120  
Current = 250  
VoltageRange = 0,80,150,180  
CurrentRange = 0,15,90,150

; TELEMETRY

-----  
-----  
[ToolAdapter]

Name = ALTShallow

[Protocol]

ID = 27

TimeOut1 = 20

TimeOut2 = 20

BaudrateHandler = 730,32000000

; CALIPER

-----  
-----  
[Caliper]

Caliper = yes

OpenTime = 85

CloseTime = 85

; TOOL SETTINGS

-----  
-----  
[Default]

TimeSamplingRate =1000

DepthSamplingRate =0.05

; Tool channels description & calibration

-----  
[Id]

SYSTEMSTATUS = 1

CHANNELS = 2

[MultiCh]

NbCh = 15

NbRawCh = 7

NbProcessedCh = 8

[Ch1]

Name = Time

Producer = Tool.SYSTEMSTATUS

ChShift = 0.0

Unit =sec

Offset = 0

DataType = dword

CalA =0.001

**CalB** = 0  
**CalibrationEnable**= no  
**NumberFormat** = %8.3f  
**DisplayEnable**= no

**[Ch2]**

**Name** = TCPU  
**Producer** = Tool.SYSTEMSTATUS  
**ChShift** = 0.0  
**Unit** = 'C'  
**Offset** = 4  
**DataType** = word  
**CalA** = 0.217226  
**CalB** = -61.11  
**CalibrationEnable**= no  
**NumberFormat** = %5.1f  
**DisplayEnable**= no

**[Ch3]**

**Name** = MOT  
**Producer** = Tool.SYSTEMSTATUS  
**ChShift** = 0.0  
**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

**[Ch4]**

**Name** = HV  
**Producer** = Tool.CHANNELS

**ChShift** = 0.0  
**Unit** =Volts  
**Offset** = 0  
**DataType** = WORD  
**CalA** =4.87465  
**CalB** =1.53203  
**CalibrationEnable**= no  
**NumberFormat** = %5.0f  
**DisplayEnable**= no

**[Ch5]**

**Name** = SSDCNT  
**Producer** = Tool.CHANNELS  
**ChShift** = 0.171  
**Unit** =counts  
**Offset** = 2  
**DataType** = DWORD  
**CalA** =1.0  
**CalB** =0.0  
**CalibrationEnable**=no  
**NumberFormat** = %5.0f  
**DisplayEnable**=no

**[Ch6]**

**Name** = LSDCNT  
**Producer** = Tool.CHANNELS  
**ChShift** = 0.246  
**Unit** =counts  
**Offset** = 6  
**DataType** = DWORD  
**CalA** =1.0  
**CalB** =0.0  
**CalibrationEnable**=no  
**NumberFormat** = %5.0f  
**DisplayEnable**=no

**[Ch7]**

**Name** = CALCNT  
**Producer** = Tool.CHANNELS  
**ChShift** = 0.437  
**Unit** =counts  
**Offset** = 10  
**DataType** = DWORD  
**CalA** =1.0  
**CalB** =0.0

**CalibrationEnable=no**  
**NumberFormat = %5.0f**  
**DisplayEnable=no**

**[Ch8]**

**Name = CALCPS**  
**Producer = MChProc**  
**Formula = {Ch7}/{Ch1}**  
**ChShift = 0**  
**Unit =cps**  
**CalibrationEnable = no**  
**CalibrationType=**  
**CalA =1**  
**CalB =0**  
**NumberFormat = %6.2f**  
**DisplayEnable=no**

**[Ch9]**

**Name=CAL**  
**Producer=MChProc**  
**Formula=(-1.2E-09\*{ch8}\*{ch8}+0.000804\*{ch8}+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**

**[Ch10]**

**Name=SSDCPS**



**Producer=MChProc**  
**Formula={ch5}/{ch1}**  
**ChShift=0.171**  
**Unit=cps**  
**CalibrationEnable=no**  
**CalA=1**  
**CalB=0**  
**NumberFormat=%6.2f**  
**DisplayEnable=yes**

**[Ch11]**  
**Name=RHOSSD**  
**Producer=MChProc**  
**Formula=if({ch10}>0, Ln({ch10}), 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**

**[Ch12]**  
**Name=LSDCPS**  
**Producer=MChProc**  
**Formula={ch6}/{ch1}**  
**ChShift=0.246**  
**Unit=cps**

**CalibrationEnable=no**  
**CalA=1**  
**CalB=0**  
**NumberFormat=%6.2f**  
**DisplayEnable=yes**

**[Ch13]**  
**Name=RHOLSD**  
**Producer=MChProc**  
**Formula=if({ch12}>0,ln({ch12}),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**

**[Ch14]**  
**Name=RHOB**  
**Producer=MChProc**  
**Formula=((0.77 \* {ch13}) +(0.228 \* {ch11}))**  
**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

[Ch15]  
Name=DRHO  
Producer=MChProc  
Formula={ch14}-{ch13}  
ChShift=0.1575  
Unit=g/cc  
CalibrationEnable=no  
CalA=1  
CalB=0  
NumberFormat=%6.2f  
DisplayEnable=no  
; PROCESSORS & BROWSERS

-----  
--

[Process]  
Process1 = Browser,Start,Mch\MChProc.exe  
Process2 = Browser,Start,Mch\MChCurve.exe  
Process3 = Browser,Start,Mch\MChNum.exe

[MChNum]  
XOffset=481  
YSize=315  
XSize=240  
Minimized=no  
YOffset=445  
NbLedDisplay = 1  
LedDisplay1 = Ch3  
NbNumDisplay = 3

*NumDisplay1 = Ch9*  
*NumDisplay2 = Ch14*  
*NumDisplay3 = Ch15*

*[MChProc]*  
*Minimized=yes*

*[MChCurve]*  
*XOffset=733*  
*YOffset=58*  
*XSize=811*  
*YSize=664*  
*Minimized=no*  
*DepthScale=100*  
*ForceTimeMode=yes*  
*DepthSpacing=5*  
*Grid=yes*  
*GridSpacing=0.5*  
*DepthColLeft=0.3*  
*DepthColRight=0.40*

**; DESCRIPTION**

**[Description]**

**ToolName** = **QL40 SNN**  
**SerialNumber** = **6650\_71-1-409G**  
**FamilyName** = **Nuclear**  
**DriverName** = **TOOLSTACK**  
**SubDriverName** = **MULTICH**

**;02-19-20 clb tool file created w 32 bit gamma counter**  
**;04-22-21 Added calibration from Bells Corners**

**; DIMENSIONS**

**[Dimension]**

**Length** = **1.50**  
**Weight** = **5.1**  
**OD** = **40**  
**TemperatureRating**= **70**  
**PressureRating** = **200**  
**ToolJoint** = **QL40-12**  
**BottomSub** = **yes**  
**TopSub** = **no**  
**TelemetrySub** = **yes**  
**Bitmap** = **DGI-PNN.bmp**  
**ToolJointTop**=**QL40-12;QLBUS0,QLBUS1,QLBUS2,QLBUS3**  
**ToolJointBottom**=**NONE;NONE**  
**Wiring**=**QL**

**; ASSOCIATED SUBS**

**[AssociatedSubs]**

**Sub1** =

**; POWER SUPPLY**

**[PowerSupply]**

**Mode** =**Voltage**  
**Voltage** = **120**  
**Current** = **100**

**VoltageRange** = 0,80,150,180  
**CurrentRange** = 0,15,50,100

**; TELEMETRY**

-----  
-----

**[ToolAdapter]**

**Name** = ALTShallow

**[Protocol]**

**ID** = 28

**TimeOut1** = 20

**TimeOut2** = 20

**BaudrateHandler** = 730,32000000

**; TOOL SETTINGS**

-----  
-----

**[Default]**

**TimeSamplingRate** =1000

**DepthSamplingRate** =0.05

**; Tool channels description & calibration**

-----

**[Id]**

**SYSTEMSTATUS** = 1

**CHANNELS** = 2

**[MultiCh]**

**NbRawCh** = 4

**NbProcessedCh** = 4

**; system status**

**[Ch1]**

**Name=Time**

**Producer=Tool.SYSTEMSTATUS**

**ChShift=0.171**

**Unit=sec**

**Offset=0**

**DataType=dword**

**CalA=0.001**

**CalB=0.0**

**CalibrationEnable=no**

*NumberFormat=%8.3f*  
*DisplayEnable= no*

*[Ch2]*  
*Name=TCPU*  
*Producer=Tool.SYSTEMSTATUS*  
*ChShift=0.21*  
*Unit='C*  
*Offset=4*  
*DataType=word*  
*CalA=0.217226*  
*CalB=-61.11*  
*CalibrationEnable=no*  
*NumberFormat=%5.1f*  
*DisplayEnable=no*

*; Pulse channels*

*[Ch3]*  
*Name= SSN CNT*  
*Producer=Tool.CHANNELS*  
*ChShift=0.27*  
*Unit=*  
*Offset=0*  
*DataType=dword*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*NumberFormat=%5.0f*  
*DisplayEnable= no*

*[Ch4]*  
*Name= LSN CNT*  
*Producer=Tool.CHANNELS*  
*ChShift=0.70*  
*Unit=*  
*Offset=4*  
*DataType=dword*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*NumberFormat=%5.0f*  
*DisplayEnable= no*

*; Formula*

### **[Ch5]**

**Name** = SSN  
**Producer** = MChProc  
**Formula** = {Ch3}/{ch1}  
**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

### **[Ch6]**

**Name** = LSN  
**Producer** = MChProc  
**Formula** = {Ch4}/{ch1}  
**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**

**[Ch7]**  
**Name = SSN\_POR**  
**Producer = MChProc**  
**Formula =  $19.98223157 * \text{Exp}(-0.000315937 * \{Ch5\} * \text{Log}(10)) * 100$**   
**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**

**[Ch8]**  
**Name = LSN\_POR**  
**Producer = MChProc**  
**Formula =  $1.058210915 * \text{Exp}(-0.001957069 * \{Ch6\} * \text{Log}(10)) * 100$**   
**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*

*; PROCESSORS & BROWSERS*

-----  
--

*[Process]*  
*Process1=Processor,Start,mch\MChProc.exe*  
*Process2=Browser,Start,mch\MChCurve.exe*  
*Process3=Browser,Start,mch\MChNum.exe*

*[MChProc]*  
*Minimized=yes*

*[MChNum]*  
*XSize=230*  
*YSize=388*  
*Minimized=no*  
*XOffset=450*  
*YOffset=596*  
*NbNumDisplay=4*  
*NumDisplay1=Ch5*  
*NumDisplay2=Ch6*  
*NumDisplay3=Ch7*  
*NumDisplay4=Ch8*

*[MChCurve]  
GridSpacing=0.5  
Grid=yes  
ForceTimeMode=yes  
XSize=477  
DepthSpacing=5  
YSize=585  
DepthScale=100  
Minimized=no  
XOffset=842  
YOffset=3  
DepthColLeft=0.3  
DepthColRight=0.4*

*;LS HV Setting 1550Vdc Disc 70mV  
;SS HV Setting 1550Vdc Disc 70mV*

***; DESCRIPTION***

***[Description]***

***ToolName = GRA***  
***SerialNumber = 5602***  
***FamilyName = Nuclear***  
***DriverName = TOOLSTACK***  
***SubDriverName = MULTICH***

***;3-23-12 32 bit gamma counter ChSift to match QL40-GAM pls***

***; DIMENSIONS***

***[Dimension]***

***Length = 1.027***  
***Weight = 4.150***  
***OD = 40***  
***TemperatureRating= 70***  
***PressureRating = 200***  
***ToolJoint = QL40-12***  
***BottomSub = no***  
***TopSub = no***  
***TelemetrySub = yes***  
***Bitmap = QL40-GR.bmp***  
***ToolJointTop=QL40-12;QLBUS***  
***ToolJointBottom=QL40-12;QLBUS***  
***Wiring=QL***

***; ASSOCIATED SUBS***

***[AssociatedSubs]***

***Sub1 =***

***; POWER SUPPLY***

***[PowerSupply]***

***Mode =Voltage***  
***Voltage = 120***  
***Current = 100***  
***VoltageRange = 0,80,150,180***

**CurrentRange** = 0,15,50,100

**; TELEMETRY**

-----  
-----

**[ToolAdapter]**

**Name** = ALTShallow

**[Protocol]**

**ID** = 16

**Timeout1** = 20

**Timeout2** = 20

**BaudrateHandler** = 730,32000000

**; TOOL SETTINGS**

-----  
-----

**[Default]**

**TimeSamplingRate** =500

**DepthSamplingRate** =0.05

**; Tool channels description & calibration**

-----

**[Id]**

**SYSTEMSTATUS** = 1

**CHANNELS** = 2

**[MultiCh]**

**NbRawCh** = 4

**NbProcessedCh** = 1

**; system status**

**[Ch1]**

**Name=Time**

**Producer=Tool.SYSTEMSTATUS**

**ChShift=0.185**

**Unit=sec**

**Offset=0**

**DataType=dword**

**CalA=0.001**

**CalB=0.0**

**CalibrationEnable=no**

**NumberFormat=%8.3f**

*DisplayEnable= no*

*[Ch2]*

*Name=TCPU*

*Producer=Tool.SYSTEMSTATUS*

*ChShift=0.21*

*Unit='C*

*Offset=4*

*DataType=word*

*CalA=0.217226*

*CalB=-61.11*

*CalibrationEnable=no*

*NumberFormat=%5.1f*

*DisplayEnable=no*

*; Pulse channels*

*[Ch3]*

*Name=EHT*

*Producer=Tool.CHANNELS*

*ChShift=0.185*

*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.CHANNELS*

*ChShift=0.18*

*Unit=*

*Offset=2*

*DataType=dword*

*CalA=1.0*

*CalB=0.0*

*CalibrationEnable=no*

*NumberFormat=%5.0f*

*DisplayEnable= no*

**; Formula**

**[Ch5]**

**Name = GR**

**Producer = MChProc**

**Formula = {Ch4}/{ch1}**

**ChShift = 0.185**

**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**

**Reference1=0**

**Reference2=1**

**CalDate=23/03/12 15:52**

**; PROCESSORS & BROWSERS**

-----  
--

**[Process]**

**Process1=Processor,Start,mch\MChProc.exe**

**Process2=Browser,Start,mch\MChCurve.exe**

**Process3=Browser,Start,mch\MChNum.exe**

**[MChProc]**

**Minimized=yes**

**[MChNum]**

XSize=230  
YSize=388  
Minimized=no  
XOffset=450  
YOffset=596  
NbNumDisplay=1  
NumDisplay1=Ch5

[MChCurve]  
GridSpacing=0.5  
Grid=yes  
ForceTimeMode=yes  
XSize=477  
DepthSpacing=5  
YSize=585  
DepthScale=100  
Minimized=no  
XOffset=842  
YOffset=3  
DepthColLeft=0.3  
DepthColRight=0.4

;Tube SN98909, Crystal SN090412C  
;HV = -1125Vdc



**; DESCRIPTION //////////////////////////////////////**

**[Description]**

**ToolName=IP**

**SerialNumber=5579**

**FamilyName=Resistivity**

**DriverName=TOOLSTACK**

**SubDriverName=IP**

**;3-31-10 from calibrated sub pls**

**;6-02-10 wave offsets pls**

**;7-22-10 depth column pls**

**;11-09-10 modified by Patrick, for v10.5 or later, checked pls**

**;11-30-11 DisplayedName=, DisplayEnable, CalibrationEnable settings pls**

**;12-01-11 Ch2 name TCPU pls**

**;12-12-11 turn on v ch calibration pls**

**;**

**; DIMENSIONS //////////////////////////////////////**

**[Dimension]**

**Length=1.894**

**Weight=8.8**

**OD=43**

**TemperatureRating=70**

**PressureRating=200**

**TopSub=no**

**BottomSub=no**

**TelemetrySub=yes**

**ToolJoint=QL40-12**

**Bitmap=QL40-EL0G4.bmp**

**ODMax=43**

**; ASSOCIATED SUBS //////////////////////////////////////**

**[AssociatedSubs]**

**Sub1=**

**; POWER SUPPLY //////////////////////////////////////**

**[PowerSupply]**

**Mode=Voltage**

**Current=300**

**Voltage=120**

**CurrentRange=0,50,110,150**

**VoltageRange=0,80,150,180**

**; TELEMETRY //////////////////////////////////////**

**[ToolAdapter]**

**Name=ALTShallow**

**[Protocol]**

**ID=22**

**DateTimeOut1=20**

**DateTimeOut2=20**

**ParamTimeOut1=20**

**ParamTimeOut2=20**

**BaudrateHandler=730,32000000**

**; TOOL SETTINGS //////////////////////////////////////**

**[Default]**

**DepthSamplingRate=0.05**

**ReleaseTime=0**

**InjectionTime=50**

**TimeSamplingRate=1000**

**; PROCESSORS & BROWSERS //////////////////////////////////////**

**[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**

**[WellCAD]**

**Template1=**

**[MChProc]**

**Minimized=yes**

**[MChNum]**

**XOffset=446**

**YOffset=0**

**XSize=230**

**YSize=869**

**Minimized=no**

**NbLedDisplay=0**

**NbNumDisplay=7**

**NumDisplay1=Ch3**

**NumDisplay2=Ch45**

**NumDisplay3=Ch48**

**NumDisplay4=Ch46**

**NumDisplay5=Ch49**

**NumDisplay6=Ch47**

**NumDisplay7=Ch70**

**[MChCurve]**  
**GridSpacing=0.5**  
**Grid=yes**  
**ForceTimeMode=yes**  
**XSize=848**  
**DepthSpacing=5**  
**YSize=977**  
**DepthColLeft=0.3**  
**DepthColRight=0.4**  
**DepthScale=100**  
**Minimized=no**  
**XOffset=432**  
**YOffset=0**

**; TOOL CHANNELS //////////////////////////////////////**

**[Id]**  
**SYSTEMSTATUS=1**  
**ELOG=5**  
**IPLIN=7**  
**IPLOG=8**  
**IPFW16=10**  
**IPFW64=11**

**[MultiCh]**  
**NbProcessedCh=26**  
**NbCh=72**  
**NbRawCh=46**

**[Ch1]**  
**Name=Time**  
**DisplayedName= Time**  
**Producer=Tool.SYSTEMSTATUS**  
**Unit=sec**  
**ChShift=0**  
**DataType=DWord**  
**Offset=0**  
**CalA=0.001**  
**CalB=0**  
**CalibrationEnable=no**  
**DisplayEnable=no**  
**NumberFormat=%.3f**

**[Ch2]**

*Name=TCPU*  
*DisplayedName= TCPU*  
*Producer=Tool.SYSTEMSTATUS*  
*Unit='C*  
*ChShift=0.0*  
*DataType=word*  
*Offset=4*  
*CalA=0.217226*  
*CalB=-61.11*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%5.1f*

*[Ch3]*  
*Name=VSP*  
*DisplayedName= VSP*  
*Producer=Tool.ELOG*  
*Unit=mV*  
*ChShift=1.689*  
*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*

*[Ch4]*  
*Name=VSPR*  
*DisplayedName= VSPR*

*Producer=Tool.ELOG*  
*Unit=V*  
*ChShift=0.062*  
*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*

*[Ch5]*  
*Name=I*  
*DisplayedName= I*  
*Producer=Tool.ELOG*  
*Unit=mA*  
*ChShift=0.062*  
*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**

**[Ch6]**  
**Name=V16**  
**DisplayedName= V16**  
**Producer=Tool.ELOG**  
**Unit=V**  
**ChShift=0.266**  
**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**

**[Ch7]**  
**Name=V64**  
**DisplayedName= V64**  
**Producer=Tool.ELOG**  
**Unit=V**  
**ChShift=0.874**  
**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**

**[Ch8]**

**Name=V8**  
**DisplayedName= V8**  
**Producer=Tool.ELOG**  
**Unit=V**  
**ChShift=0.164**  
**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**

**[Ch9]**  
**Name=V32**  
**DisplayedName= V32**  
**Producer=Tool.ELOG**  
**Unit=V**  
**ChShift=0.467**  
**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**

**[Ch10]**  
**Name=Vinj16**  
**DisplayedName= Vinj16**  
**Producer=Tool.IPLIN**  
**Unit=**  
**ChShift=0.266**  
**DataType=Long**  
**Offset=4**  
**CalA=1.0**  
**CalB=0.0**  
**CalibrationEnable=no**  
**DisplayEnable=no**

***NumberFormat=%8.0f***

***[Ch11]***

***Name=NbwinLin***

***Producer=Tool.IPLIN***

***Unit=***

***ChShift=0.0***

***DataType=byte***

***Offset=12***

***CalA=1.0***

***CalB=0.0***

***CalibrationEnable=no***

***DisplayEnable=no***

***NumberFormat=%8.0f***

***[Ch12]***

***Name=Tlin.1***

***Producer=Tool.IPLIN***

***Unit=ms***

***ChShift=0***

***DataType=Long***

***Offset=13***

***CalA=0.0001***

***CalB=0***

***CalibrationEnable=no***

***DisplayEnable=no***

***NumberFormat=%8.3f***

***[Ch13]***

***Name=WLin16.1***

***Producer=Tool.IPLIN***

***Unit=***

***ChShift=0.266***

***DataType=Long***

***Offset=17***

***CalA=1.0***

***CalB=0.0***

***CalibrationEnable=no***

***DisplayEnable=no***

***NumberFormat=%8.0f***

***[Ch14]***

***Name=Tlin.2***

***Producer=Tool.IPLIN***

***Unit=ms***



*ChShift=0.0*  
*DataType=Long*  
*Offset=25*  
*CalA=0.0001*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch15]*  
*Name=WLin16.2*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.266*  
*DataType=Long*  
*Offset=29*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch16]*  
*Name=Tlin.3*  
*Producer=Tool.IPLIN*  
*Unit=ms*  
*ChShift=0.0*  
*DataType=Long*  
*Offset=37*  
*CalA=0.0001*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch17]*  
*Name=WLin16.3*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.266*  
*DataType=Long*  
*Offset=41*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*

*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch18]*

*Name=Tlin.4*  
*Producer=Tool.IPLIN*  
*Unit=ms*  
*ChShift=0.0*  
*DataType=Long*  
*Offset=49*  
*CalA=0.0001*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch19]*

*Name=WLin16.4*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.266*  
*DataType=Long*  
*Offset=53*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch20]*

*Name=Tlin.5*  
*Producer=Tool.IPLIN*  
*Unit=ms*  
*ChShift=0.0*  
*DataType=Long*  
*Offset=61*  
*CalA=0.0001*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch21]*

*Name=WLin16.5*  
*Producer=Tool.IPLIN*

Unit=  
ChShift=0.266  
DataType=Long  
Offset=65  
CalA=1.0  
CalB=0.0  
CalibrationEnable=no  
DisplayEnable=no  
NumberFormat=%8.0f

[Ch22]  
Name=Tlin.6  
Producer=Tool.IPLIN  
Unit=ms  
ChShift=0.0  
DataType=Long  
Offset=73  
CalA=0.0001  
CalB=0.0  
CalibrationEnable=no  
DisplayEnable=no  
NumberFormat=%8.3f

[Ch23]  
Name=WLin16.6  
Producer=Tool.IPLIN  
Unit=  
ChShift=0.266  
DataType=Long  
Offset=77  
CalA=1.0  
CalB=0.0  
CalibrationEnable=no  
DisplayEnable=no  
NumberFormat=%8.0f

[Ch24]  
Name=Tlin.7  
Producer=Tool.IPLIN  
Unit=ms  
ChShift=0.0  
DataType=Long  
Offset=85  
CalA=0.0001  
CalB=0.0

*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch25]*

*Name=WLin16.7*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.266*  
*DataType=Long*  
*Offset=89*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch26]*

*Name=Tlin.8*  
*Producer=Tool.IPLIN*  
*Unit=ms*  
*ChShift=0.0*  
*DataType=Long*  
*Offset=97*  
*CalA=0.0001*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch27]*

*Name=WLin16.8*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.266*  
*DataType=Long*  
*Offset=101*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch28]*

*Name=Tlin.9*

*Producer=Tool.IPLIN*  
*Unit=ms*  
*ChShift=0.0*  
*DataType=Long*  
*Offset=109*  
*CalA=0.0001*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch29]*  
*Name=WLin16.9*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.266*  
*DataType=Long*  
*Offset=113*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch30]*  
*Name=Tlin.10*  
*Producer=Tool.IPLIN*  
*Unit=ms*  
*ChShift=0.0*  
*DataType=Long*  
*Offset=121*  
*CalA=0.0001*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.3f*

*[Ch31]*  
*Name=WLin16.10*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.266*  
*DataType=Long*  
*Offset=125*  
*CalA=1.0*

*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch32]*  
*Name=WLin64.1*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.875*  
*DataType=Long*  
*Offset=21*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch33]*  
*Name=WLin64.2*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.875*  
*DataType=Long*  
*Offset=33*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch34]*  
*Name=WLin64.3*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.875*  
*DataType=Long*  
*Offset=45*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch35]*

**Name=WLin64.4**  
**Producer=Tool.IPLIN**  
**Unit=**  
**ChShift=0.875**  
**DataType=Long**  
**Offset=57**  
**CalA=1.0**  
**CalB=0.0**  
**CalibrationEnable=no**  
**DisplayEnable=no**  
**NumberFormat=%8.0f**

**[Ch36]**  
**Name=WLin64.5**  
**Producer=Tool.IPLIN**  
**Unit=**  
**ChShift=0.875**  
**DataType=Long**  
**Offset=69**  
**CalA=1.0**  
**CalB=0.0**  
**CalibrationEnable=no**  
**DisplayEnable=no**  
**NumberFormat=%8.0f**

**[Ch37]**  
**Name=WLin64.6**  
**Producer=Tool.IPLIN**  
**Unit=**  
**ChShift=0.875**  
**DataType=Long**  
**Offset=81**  
**CalA=1.0**  
**CalB=0.0**  
**CalibrationEnable=no**  
**DisplayEnable=no**  
**NumberFormat=%8.0f**

**[Ch38]**  
**Name=WLin64.7**  
**Producer=Tool.IPLIN**  
**Unit=**  
**ChShift=0.875**  
**DataType=Long**  
**Offset=93**

*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch39]*  
*Name=WLin64.8*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.875*  
*DataType=Long*  
*Offset=105*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch40]*  
*Name=WLin64.9*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.875*  
*DataType=Long*  
*Offset=117*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*

*[Ch41]*  
*Name=WLin64.10*  
*Producer=Tool.IPLIN*  
*Unit=*  
*ChShift=0.875*  
*DataType=Long*  
*Offset=129*  
*CalA=1.0*  
*CalB=0.0*  
*CalibrationEnable=no*  
*DisplayEnable=no*  
*NumberFormat=%8.0f*



**[Ch42]**

**Name=Tinj**

**Producer=Tool.IPLIN**

**Unit=s**

**ChShift=0**

**DataType=Word**

**Offset=0**

**CalA=0.001**

**CalB=0**

**CalibrationEnable=no**

**DisplayEnable=no**

**NumberFormat=%g**

**[Ch43]**

**Name=TReL**

**Producer=Tool.IPLIN**

**Unit=s**

**ChShift=0**

**DataType=Word**

**Offset=2**

**CalA=0.001**

**CalB=0**

**CalibrationEnable=no**

**DisplayEnable=no**

**NumberFormat=%g**

**[Ch44]**

**Name=Vinj64**

**Producer=Tool.IPLIN**

**Unit=**

**ChShift=0.875**

**DataType=Long**

**Offset=8**

**CalA=1.0**

**CalB=0.0**

**CalibrationEnable=no**

**DisplayEnable=no**

**NumberFormat=%8.0f**

**[Ch45]**

**Name=SPR**

**DisplayedName= SPR**

**Producer=MChProc**

**Unit=Ohm**

**ChShift=0.063**

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\*{Ch4}/{Ch5}  
Low=0  
Reference1=1  
Reference2=0  
CalDate=08/03/17 10:39

[Ch46]  
Name=N16  
DisplayedName= N16  
Producer=MChProc  
Unit=Ohm.m  
ChShift=0.266  
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\*{Ch6}/{Ch5}

Low=0  
Reference1=1  
Reference2=0  
CalDate=08/03/17 10:39

[Ch47]  
Name=N64  
DisplayedName= N64  
Producer=MChProc  
Unit=Ohm.m  
ChShift=0.875  
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= $20428 * \{Ch7\} / \{Ch5\}$   
Low=0

[Ch48]  
Name=N8  
DisplayedName= N8  
Producer=MChProc  
Unit=Ohm.m  
ChShift=0.164  
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\*{Ch8}/{Ch5}**  
**Low=0**

**[Ch49]**  
**Name=N32**  
**DisplayedName= N32**  
**Producer=MChProc**  
**Unit=Ohm.m**  
**ChShift=0.469**  
**CalA=1**  
**CalB=0**  
**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\*{Ch9}/{Ch5}**  
**Low=0**

**[Ch50]**  
**Name=IPLin16.1**  
**Producer=MChProc**  
**Unit=mV/V**  
**ChShift=0.266**  
**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\*{Ch13}/{Ch10}  
Low=0

[Ch51]  
Name=IPLin16.2  
Producer=MChProc  
Unit=mV/V  
ChShift=0.266  
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\*{Ch15}/{Ch10}  
Low=0

[Ch52]  
Name=IPLin16.3  
Producer=MChProc  
Unit=mV/V  
ChShift=0.266  
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\*{Ch17}/{Ch10}  
Low=0

[Ch53]  
Name=IPLin16.4  
Producer=MChProc  
Unit=mV/V  
ChShift=0.2660  
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\*{Ch19}/{Ch10}  
Low=0

[Ch54]  
Name=IPLin16.5  
Producer=MChProc  
Unit=mV/V

*ChShift=0.266*  
*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\*{Ch21}/{Ch10}*  
*Low=0*

*[Ch55]*  
*Name=IPLin16.6*  
*Producer=MChProc*  
*Unit=mV/V*  
*ChShift=0.266*  
*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\*{Ch23}/{Ch10}*  
*Low=0*

*[Ch56]*

**Name=IPLin16.7**  
**Producer=MChProc**  
**Unit=mV/V**  
**ChShift=0.266**  
**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\*{Ch25}/{Ch10}**  
**Low=0**

**[Ch57]**  
**Name=IPLin16.8**  
**Producer=MChProc**  
**Unit=mV/V**  
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**DisplayEnable=no**



**APPENDIX E**

# Geophysical Logs

Log Title:

Deviation Log

Project Number:

20253946-5050

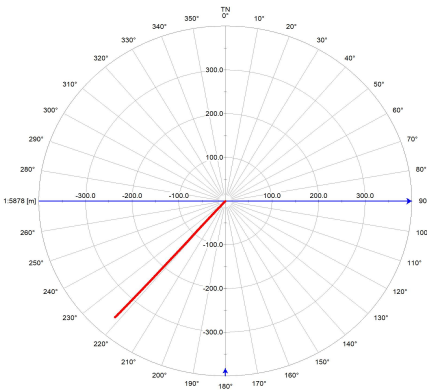
Client:

Nuclear Waste Management Organization

Date:

September 2022

Bull's Eye



Datum:

NAD83(CSRS), Zone 15N

Easting:

556,069.05 m

Northing:

5,486,535.85 m

Elevation:

432.29 m asl

Mean Inclination:

69.0 deg

Mean Azimuth (TN):

221 deg MN

Location:

Ignace, Ontario

Log Date:

August, 2021

Logged By:

PL, PG, OF

Depth Reference:

"0" at Ground

Drilled Depth:

1000.63 m bgs

Borehole Diameter:

96 mm

Casing Diameter:

102 mm

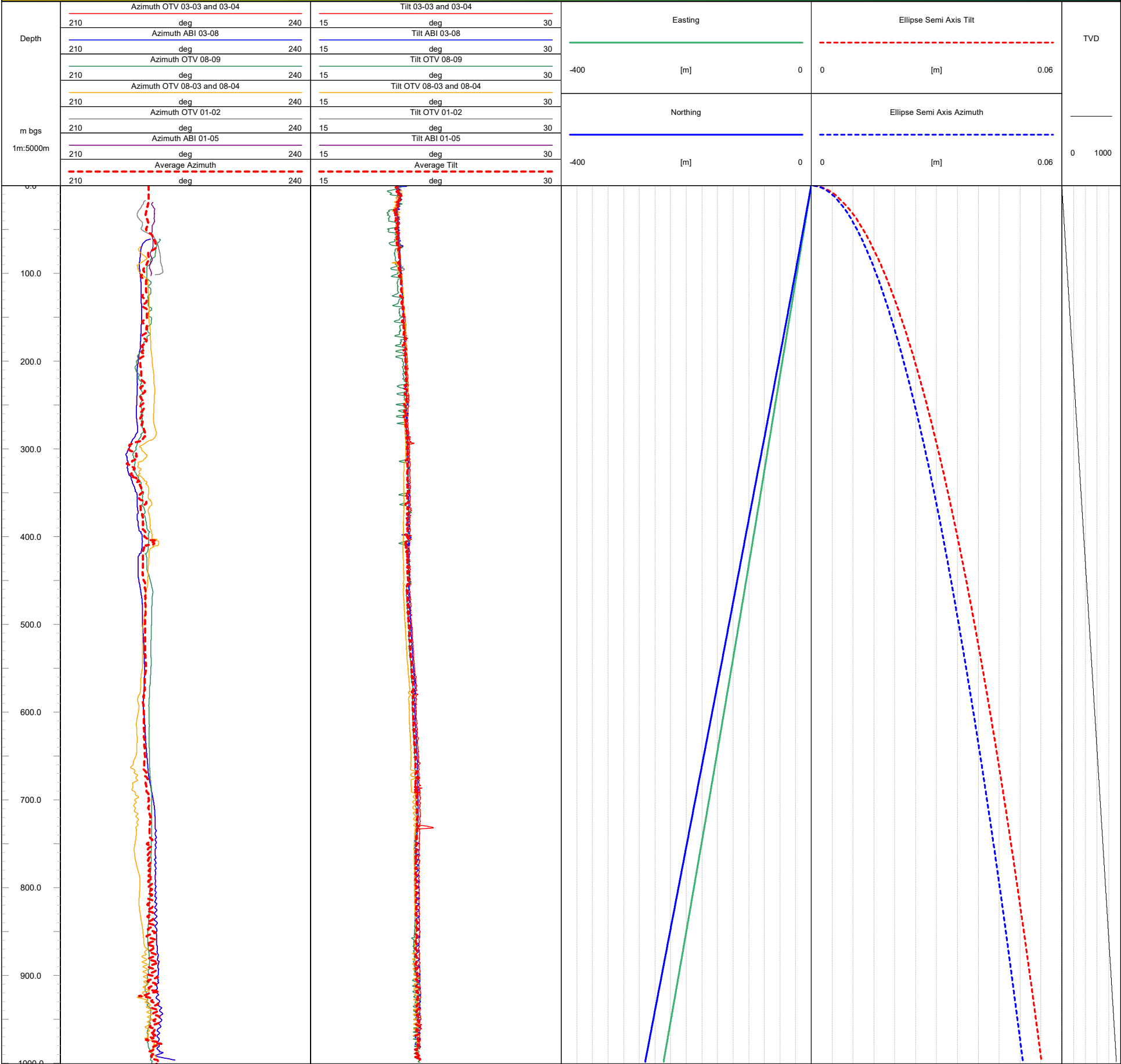
Casing Depth:

68.30 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.



Log Title:

Engineering Log

Project Number:

20253946-5050

Client:

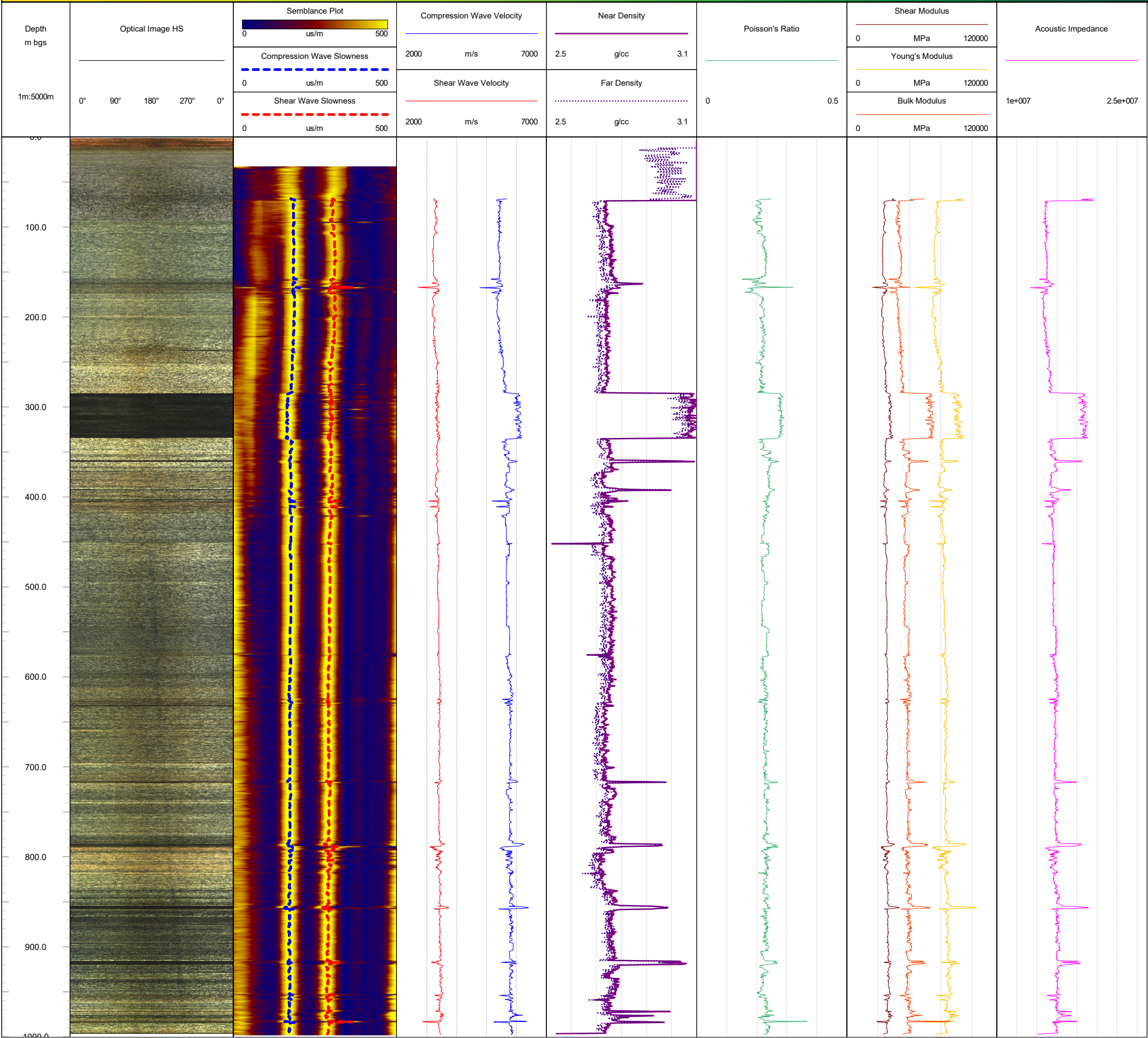
Nuclear Waste Management Organization

Date:

September 2022

|                   |                       |                           |               |                              |             |                   |                 |
|-------------------|-----------------------|---------------------------|---------------|------------------------------|-------------|-------------------|-----------------|
| <b>Datum:</b>     | NAD83(CSRs), Zone 15N | <b>Depth Reference:</b>   | "0" at Ground | <b>Casing Depth:</b>         | 68.30 m bgs | <b>Location:</b>  | Ignace, Ontario |
| <b>Easting:</b>   | 556,069.05 m          | <b>Drilled Depth:</b>     | 1000.63 m bgs | <b>Water Level:</b>          | Variable    | <b>Log Date:</b>  | August, 2021    |
| <b>Northing:</b>  | 5,486,535.85 m        | <b>Borehole Diameter:</b> | 96 mm         | <b>Borehole Inclination:</b> | 69.0 deg    | <b>Logged By:</b> | PL, CM, OF      |
| <b>Elevation:</b> | 432.29 m asl          | <b>Casing Diameter:</b>   | 102 mm        | <b>Borehole Azimuth:</b>     | 221 deg MN  |                   |                 |

Notes:





Log Title:

Hydrogeology Log

Project Number:

20253946-5050

Client:

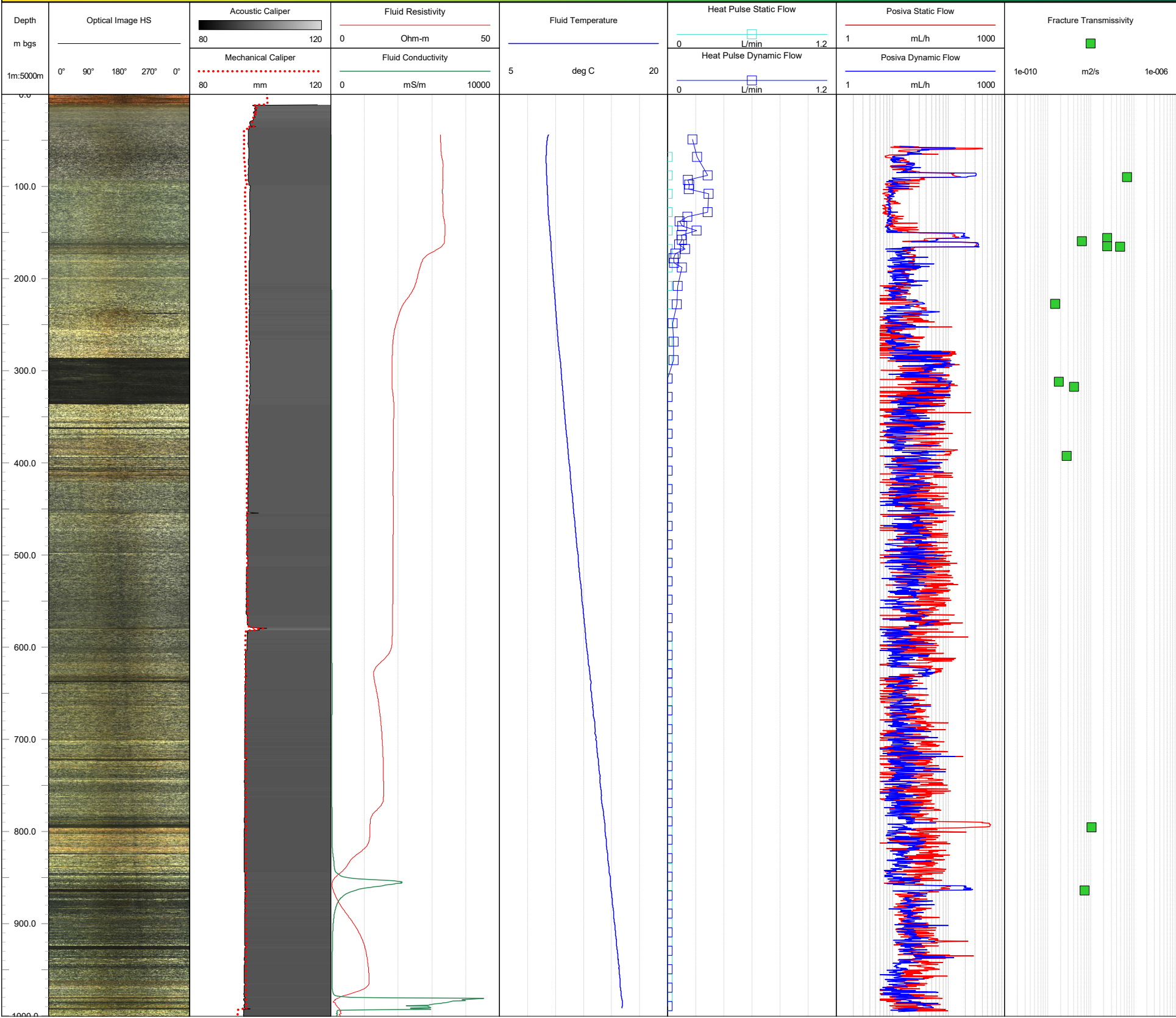
Nuclear Waste Management Organization

Date:

September 2022

|                   |                       |                           |               |                              |             |                   |                 |
|-------------------|-----------------------|---------------------------|---------------|------------------------------|-------------|-------------------|-----------------|
| <b>Datum:</b>     | NAD83(CSRs), Zone 15N | <b>Depth Reference:</b>   | "0" at Ground | <b>Casing Depth:</b>         | 68.30 m bgs | <b>Location:</b>  | Ignace, Ontario |
| <b>Easting:</b>   | 556,069.05 m          | <b>Drilled Depth:</b>     | 1000.63 m bgs | <b>Water Level:</b>          | Variable    | <b>Log Date:</b>  | August, 2021    |
| <b>Northing:</b>  | 5,486,535.85 m        | <b>Borehole Diameter:</b> | 96 mm         | <b>Borehole Inclination:</b> | 69.0 deg    | <b>Logged By:</b> | PL, CM, OF      |
| <b>Elevation:</b> | 432.29 m asl          | <b>Casing Diameter:</b>   | 102 mm        | <b>Borehole Azimuth:</b>     | 221 deg MN  |                   |                 |

**Notes:** Fluid conductivity measurements lose accuracy below 10 mS/m.



Log Title:

Lithology Log

Project Number:

20253946-5050

Client:

Nuclear Waste Management Organization

Date:

September 2022

Datum:

NAD83(CSRs), Zone 15N

Easting:

556,069.05 m

Northing:

5,486,535.85 m

Elevation:

432.29 m asl

Depth Reference:

"0" at Ground

Drilled Depth:

1000.63 m bgs

Borehole Diameter:

96 mm

Casing Diameter:

102 mm

Casing Depth:

68.30 m bgs

Water Level:

Variable

Borehole Inclination:

69.0 deg

Borehole Azimuth:

221 deg MN

Location:

Ignace, Ontario

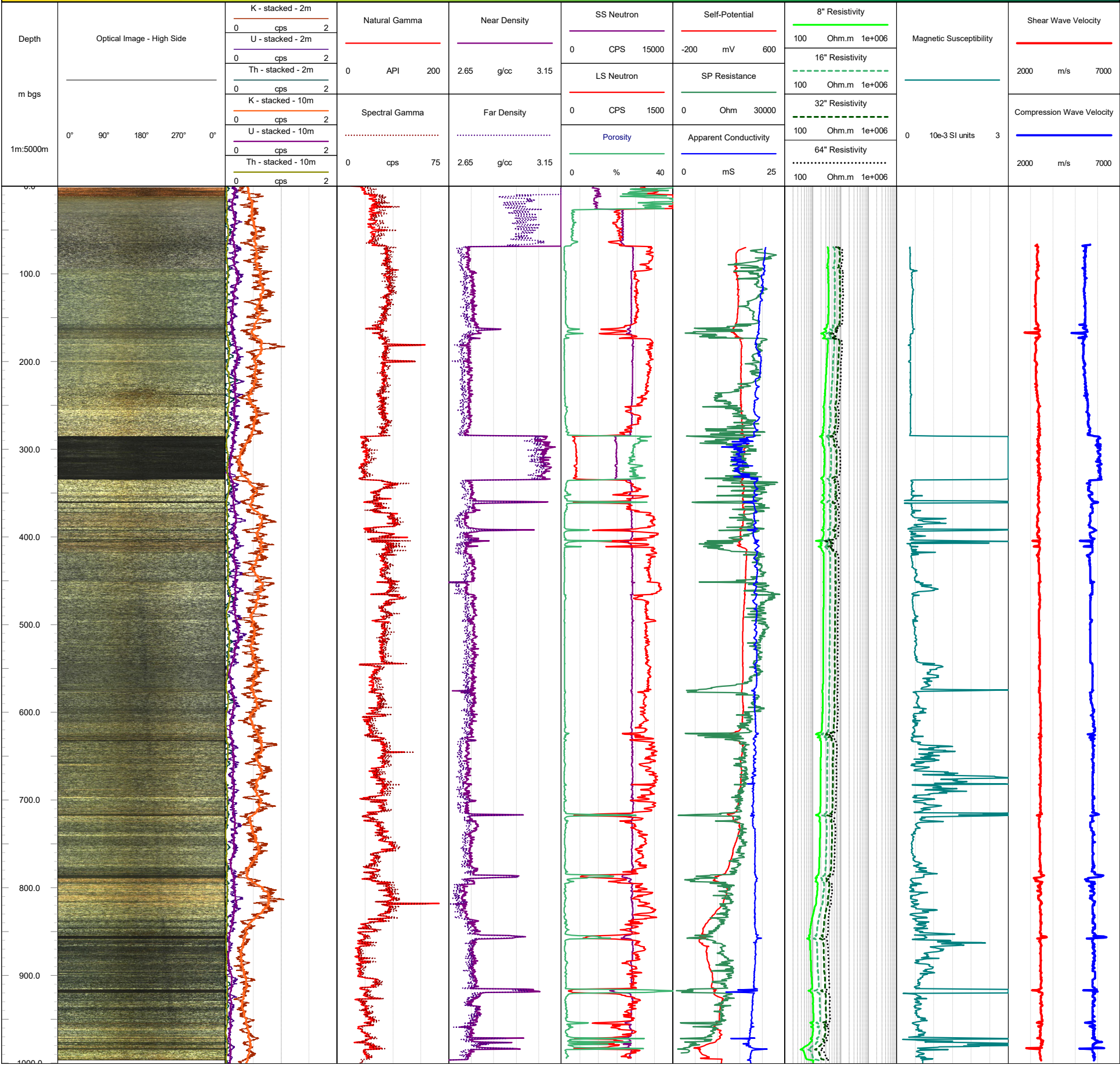
Log Date:

August, 2021

Logged By:

PL, CM, OF

Notes:





Log Title:

Structural Log

Project Number:

20253946-5050

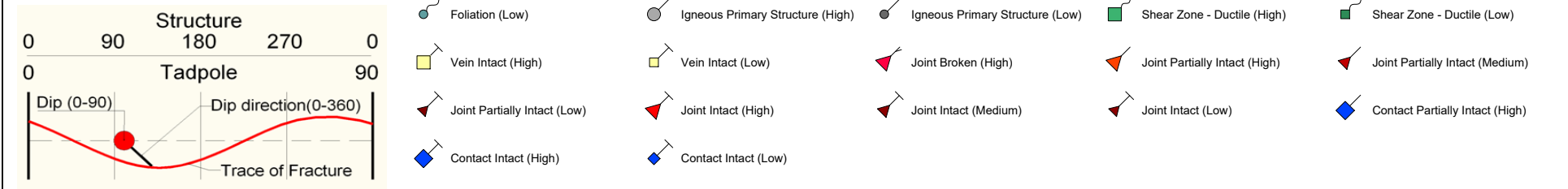
Client:

Nuclear Waste Management Organization

Date:

September 2022

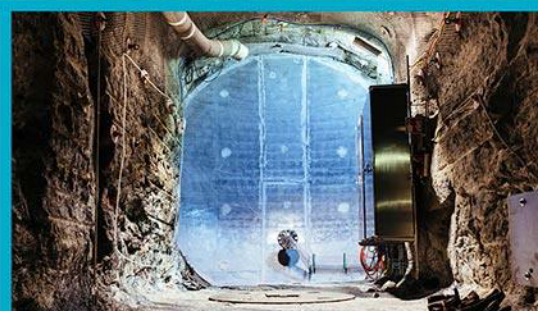
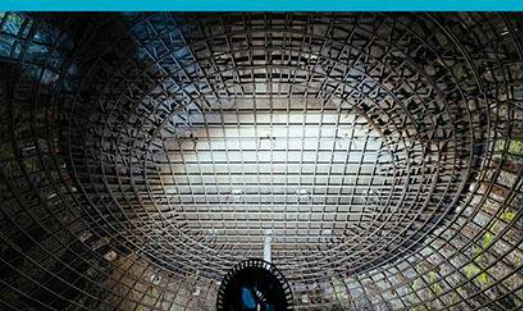
|                   |                       |                           |               |                              |             |                   |                 |
|-------------------|-----------------------|---------------------------|---------------|------------------------------|-------------|-------------------|-----------------|
| <b>Datum:</b>     | NAD83(CSRS), Zone 15N | <b>Depth Reference:</b>   | "0" at Ground | <b>Casing Depth:</b>         | 68.30 m bgs | <b>Location:</b>  | Ignace, Ontario |
| <b>Easting:</b>   | 556,069.05 m          | <b>Drilled Depth:</b>     | 1000.63 m bgs | <b>Water Level:</b>          | Variable    | <b>Log Date:</b>  | August, 2021    |
| <b>Northing:</b>  | 5,486,535.85 m        | <b>Borehole Diameter:</b> | 96 mm         | <b>Borehole Inclination:</b> | 69.0 deg    | <b>Logged By:</b> | PL, CM, OF      |
| <b>Elevation:</b> | 432.29 m asl          | <b>Casing Diameter:</b>   | 102 mm        | <b>Borehole Azimuth:</b>     | 221 deg MN  |                   |                 |



**APPENDIX F**

# 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\_BH05

16.3.2022  
PS-001044  
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**Posiva**  
Solutions



## **POSIVA FLOW LOG MEASUREMENTS AT THE IGNACE SITE IN ONTARIO, CANADA, BOREHOLE IG\_BH05**

### **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 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\_BH05 at the Ignace site in August 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 hydraulic head ( $h$ ) of zones were calculated from the obtained flow and pressure results.

In addition to 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 measurement section and therefore EC results might not represent the actual borehole water EC at certain depth in borehole.

The measurement covered 919.4 meters (68.3 m – 987.7 m) of borehole and eleven water flowing fractures were found. The largest flow was 549 ml/h in unpumped conditions and 3810 ml/h while pumped drawdown was c. 14 meters. The highest transmissivity was  $7.00 \cdot 10^{-8} \text{ m}^2/\text{s}$ .

**Keywords:** Groundwater, flow, measurement, bedrock, borehole, electrical conductivity, Posiva Flow Log.

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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. Monitoring of measurement was supported via remote connection from Posiva Solutions' office in Finland. Data processing and preparing daily documentation was supported from Posiva Solutions' 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.

|                                   |   |
|-----------------------------------|---|
| <b>masl</b>                       | Metres above sea level  |
| <b>PFL DIFF</b>                   | 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 |
| <b>SPR</b>                        | Single Point Resistance   |
| <b>EC</b>                         | Electrical conductivity   |
| <b>T<sub>PFL-value</sub> or T</b> | Transmissivity of fracture (m <sup>2</sup> /s), measured with PFL   |
| <b>T<sub>min</sub></b>            | Minimum transmissivity based on measurement accuracy  |
| <b>T<sub>max</sub></b>            | Maximum transmissivity based on measurement accuracy  |
| <b>HeadOff<sub>min</sub></b>      | Minimum head of fracture based on measurement accuracy  |
| <b>HeadOff<sub>max</sub></b>      | 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 the 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 depth interval can be measured directly using the method. This makes it possible to determine the transmissivity of the fractures and the hydraulic head in fractures. One advantage of the method is that it is faster than the conventional double-packer injection test.

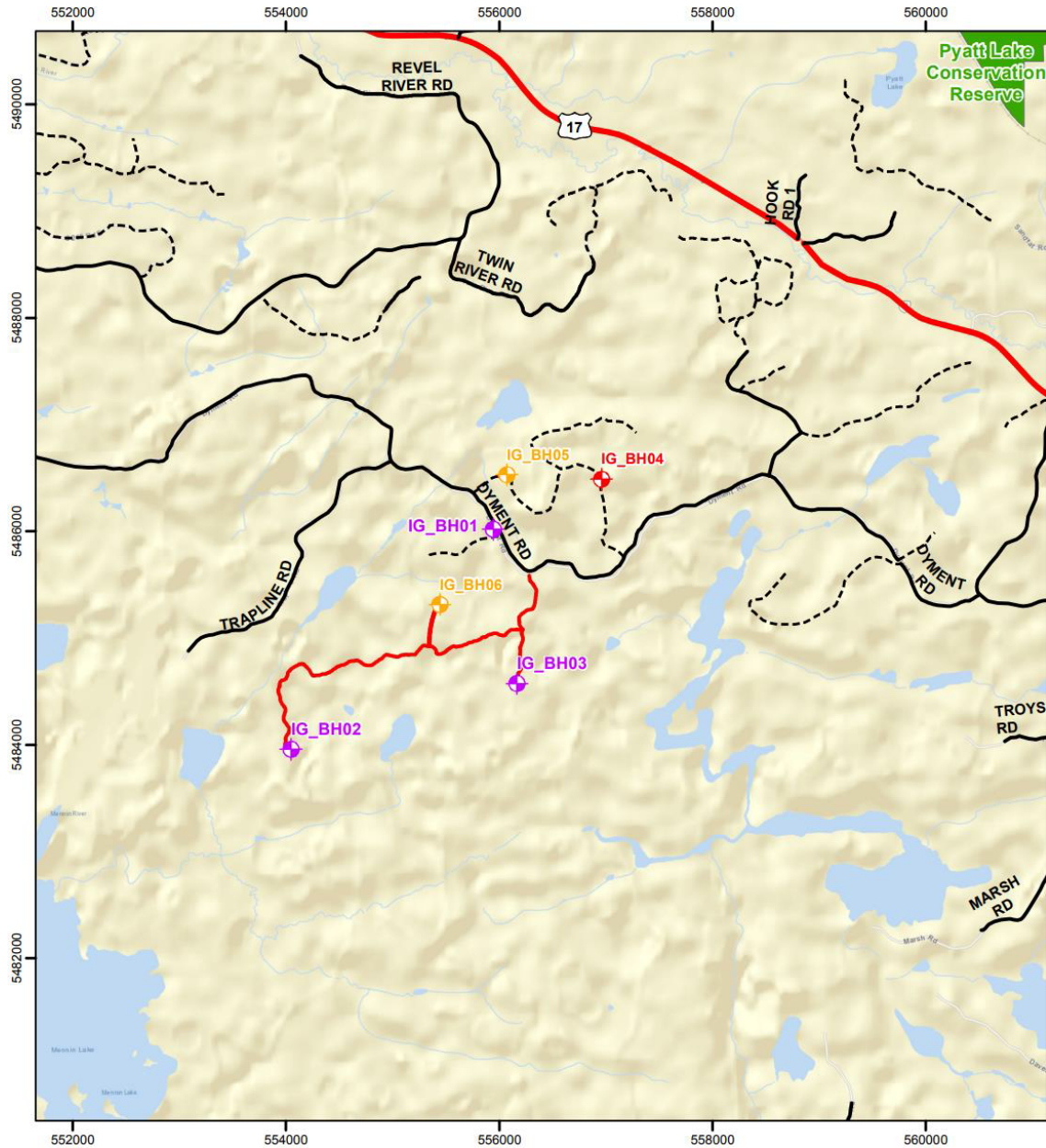
The equipment employed in the PFL DIFF method (a trailer-mounted winch and cable, a downhole probe and a computer) can be used in boreholes of depths up to 1500 m which are 56 mm or more in diameter.

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 hydraulic head along the borehole.

Measurements using the PFL DIFF method were performed in borehole IG\_BH05 at the Ignace site between August 9<sup>th</sup> and August 17<sup>th</sup> 2021. Technical information of the core drilled holes is given in Table 1-1. The location of borehole IG\_BH05 as Ignace site is presented in *Figure 1-1*.

**Table 1-1.** *Technical information of the borehole.*

| Borehole | Diameter<br>(mm) | Reference level coordinates |            |          | Azimuth<br>(degrees) | Inclination<br>(degrees) | Max.<br>length<br>(m) | Casing               |   |
|----------|------------------|-----------------------------|------------|----------|----------------------|--------------------------|-----------------------|----------------------|---|
|          |                  | Y (m) north                 | X (m) east | Z (masl) |                      |                          |                       | Casing<br>length (m) | Casing<br>above ref-<br>erence<br>level (m) |
| IG_BH05  | 96               | 5486535.97                  | 556068.96  | 431.9    | 220.3                | -70.1                    | 1000.63               | 68.3                 | 0.81  |



**Figure 1-1.** Location of borehole IG\_BH05 at Ignace site.





**Figure 1-2.** Borehole IG\_BH05 and PFL measurement equipment..

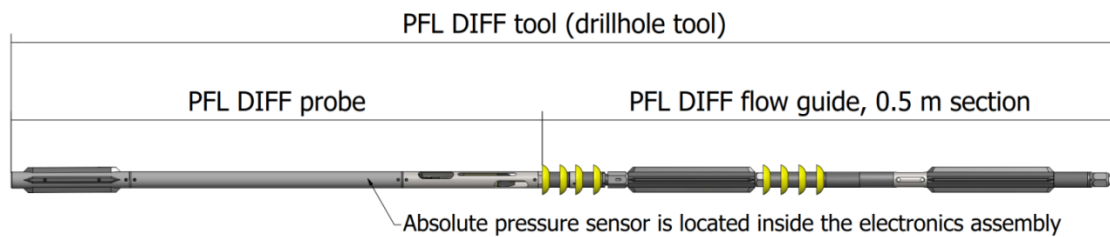
This report documents the execution of field work, represents the obtained measurement results and derived results and describes data processing.



## 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.

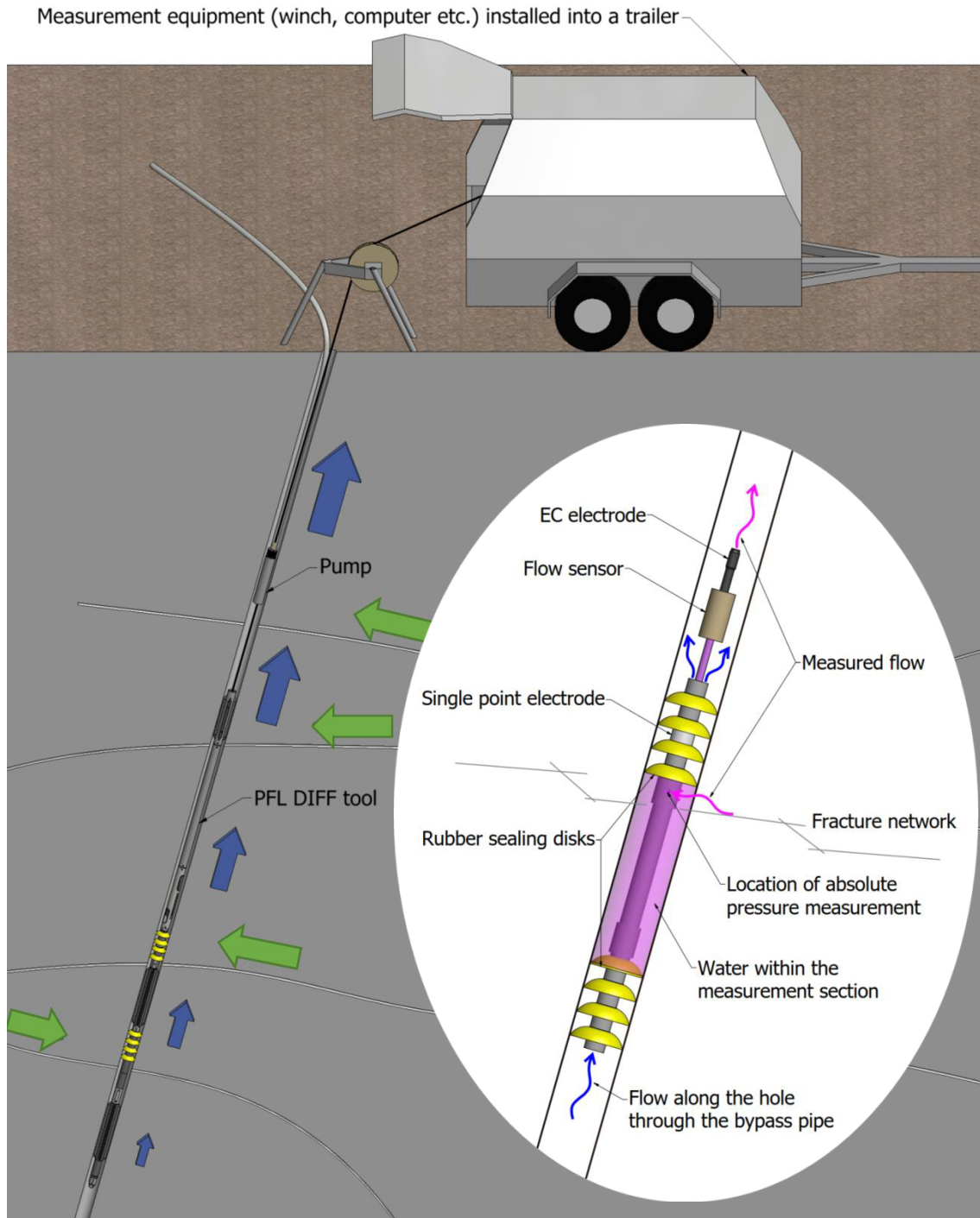
Rubber sealing disks are used to isolate the flow of water in the test section from the flow in rest of the borehole, see Figure 2-2. Flow into or out from the test section is directed through the flow sensor. Flow along the borehole is directed around the test section by means of a bypass pipe and is 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 a measurement section are measured in unpumped conditions and while water level in the 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. All flow measurement runs are conducted upwards in borehole.

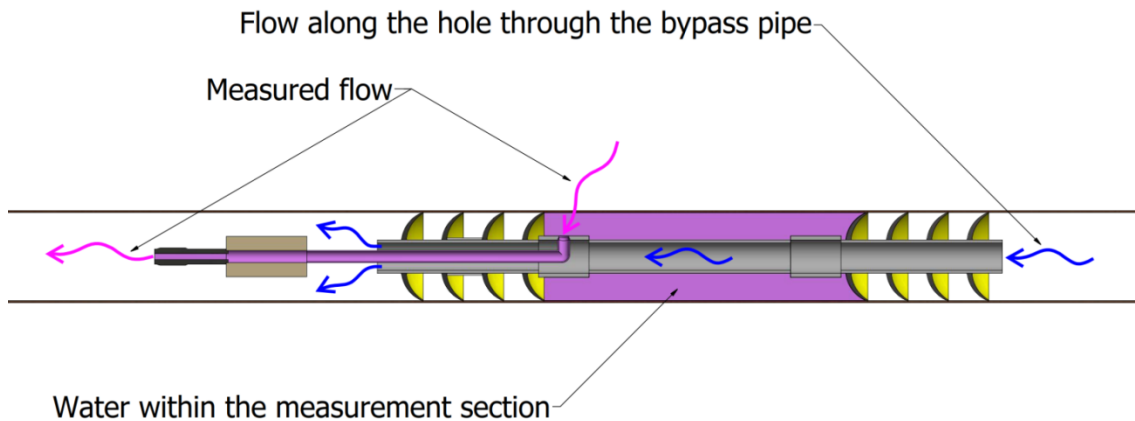
In addition to incremental changes in flow, the PFL DIFF probe can also be used to measure:

- 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 depth 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 depth reference point is the ground level (depth 0 m). The measurement depth point is situated in the PFL DIFF probe at the upper end of the test section (see Figure 2-2). The depth 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 depth error in the results. Depth 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. Depth errors have been determined in the boreholes where there are known depth marks on the wall of the borehole. The error has been approximately 1 m (before the depth correction based on the depth marks) at the depth 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 depth 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  $\pm 0.05$  m. A similar error can occur when the flow along the borehole is measured.

The total worst case depth error can be estimated. In the worst case all the errors are summed up in the worst possible way. The maximum depth 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 depth of the probe (m) and

$x$  is the depth increment of flow measurement (m)

0.05 m comes from reporting fracture locations with 0.1 m resolution

During measurements in IG\_BH05 the highest tension was c. 190 kg when the measurement run was started at bottom of the borehole. Therefore the estimation above is valid for the results presented in this report.

The depth error can be essentially decreased if there are known depth marks on the borehole wall that can be synchronized with the PFL DIFF log. The depth marks are features on the borehole wall that can be detected by the PFL DIFF, usually by the single point resistance electrode. The depth 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 the casing pipe is usually used as such a depth 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 flow measurements. The measurement computer is used to control the measurement and to display measurement data from the ongoing 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, the measurement is fully automatized and can be monitored remotely. This property 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 is 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 stationary and three thermistors should give the same temperature value) and comparing the flow rates 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 possible changes caused by the stretching of the cable, the locations of length markings are checked as a part of calibration. 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 ( $\Omega$ ), 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  $\Omega$  and 200 k $\Omega$  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 track 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 depth determination is estimated to be less than one metre at a depth 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 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 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 hydraulic head can then be calculated.

The hydraulic head ( $h$ ) at a certain elevation  $z$  is calculated using the following expression:

$$h = \frac{p_{\text{abs}} - p_{\text{b}}}{\rho \cdot g} + z \quad 4-1$$

Where

- $h$  is the hydraulic head (masl)
- $p_{\text{abs}}$  is the absolute pressure (Pa)
- $p_{\text{b}}$  is the barometric (atmospheric) pressure (Pa)
- $\rho$  is the density of water 1000 kg/m<sup>3</sup>
- $g$  is the standard gravity 9.80665 m/s<sup>2</sup>
- $z$  is the elevation at the measurement location (masl)

Exact  $z$ -coordinates are important in calculating hydraulic head as an error in the  $z$ -coordinate leads to an equal error in the calculated head.

### 4.2 Transmissivity and 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):

$$h_f - h = \frac{Q}{T \cdot a} \quad 4-2$$

Where

- $h$  is the hydraulic head in the borehole (at borehole radius  $r_0$ )
- $h_f$  is the 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:

$$a = \frac{2\pi}{\ln(R/r_0)} \quad 4-3$$

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) 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:

$$Q_0 = T_f \cdot a \cdot (h_f - h_0) \text{ and} \quad 4-4$$

$$Q_1 = T_f \cdot a \cdot (h_f - h_1) \quad 4-5$$

Where

$h_0$  and  $h_1$  are the 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 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 ( $T_{PFL} \approx \Delta Q/\Delta h$ ).

Hydraulic head  $h_s$  and the PFL transmissivity  $T_{PFL,f}$  can be calculated using the results from two separate measurements applying the following equations,

$$h_f = \frac{h_0 - b h_1}{1 - b} \text{ and} \quad 4-6$$

$$T_{PFL,f} = \frac{1}{a} \cdot \frac{Q_0 - Q_1}{h_1 - h_0} \quad 4-7$$

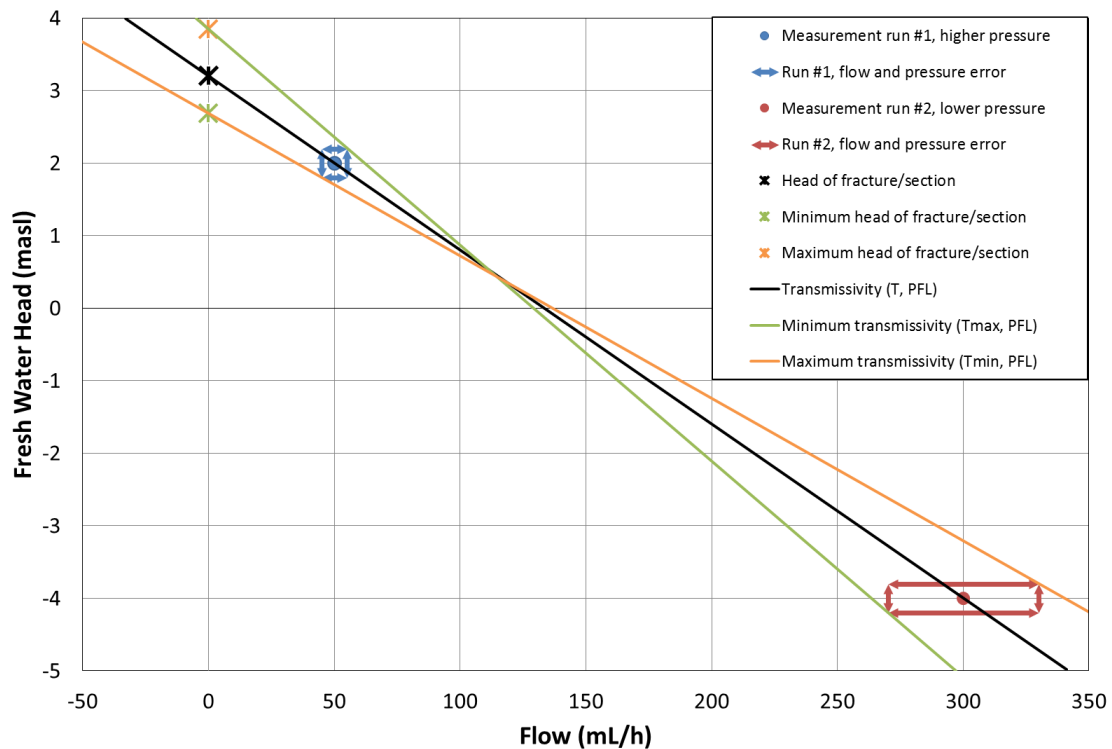
Where  $b = Q_0/Q_1$

### 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 if they are not the same. The difference between the pressures must 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 through 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  $\pm 10\%$  of the measured value, and the accuracy of absolute pressure sensor  $\pm 2$  kPa which implies  $\pm 0.2$  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 ( $\pm 10\%$  in flow,  $\pm 0.2$  m in head). A rectangle shape formed from the lines represents the accuracy of the measurements, i.e. the measurement value should be within the rectangles when errors are considered. 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  $1.89 \cdot 10^{-9} \text{ m}^2/\text{s}$  can be missed when 10 m drawdown is applied.

## 5 EXECUTION OF MEASUREMENTS

Before flow measurements are conducted, a dummy logging is performed in boreholes to assess the borehole suitability for the PFL measurements. The dummy collects loose solid material from the borehole wall. The solid material collected by the dummy is used to evaluate whether it is safe to start 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 from a borehole. Dummy logging does not 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\_BH05 was dummy logged two times. After the first run there was large amount of elastic material (mixture of Pure-vis and drilling debris and other impurities in borehole *Figure 5-2*) but no rocks. The second dummy run was conducted as the borehole clearly contained material that could cause the flow logging probe to get stuck into the borehole. After the second run amount of material was clearly smaller and it was assumed that there is no substantial risk for probe to get stuck into the borehole. This decision was made based on basic evaluation of dummy logging that is conducted to assess stability of borehole and safety of borehole for flow logging probe. The evaluation did not consider the aspect that borehole might contain substances that can affect the performance of measurement equipment. In this case impurities affected the performance of measurement equipment and it would have been beneficial to clean the borehole before starting the flow logging. One of the functions of drilling muds is to seal permeable formations (Lake et al. 2007). We are however not able to estimate, did this happen or affect the results in IG\_BH05.



**Figure 5-2.** Content of dummy probe after the first run in IG\_BH05.

The measurements in IG\_BH05 were carried out between August 9<sup>th</sup> and 17<sup>th</sup> 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. There were additional measurements conducted which have not been listed in the programme above. These measurement runs have been presented 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\_BH05.

| Started         | Finished        | Depths (m)  | Activity  |
|-----------------|-----------------|---|---|
| 11.8.2021 11:36 | 12.8.2021 16:37 | 59.39–987.65  | Flow logging without pumping, section length 5 m. |
| 13.8.2021 10:42 | 14.8.2021 16:16 | 59.4–987.67   | Flow logging with pumping, section length 5 m.    |
| 15.8.2021 11:53 | 16.8.2021 8:14  | 94.76–92.25<br>170.17–157.1<br>230.92–228.39<br>321.2–310.66<br>394.54–385.54<br>581.47–564.96<br>631.21–625.4<br>707.17–701.47 | Flow logging with pumping, section length 0.5 m.  |

|                 |                 |   |   |
|-----------------|-----------------|---|---|
|                 |                 | 792.97–786.87<br>859.66–853.10<br>985.60–980.69   |   |
| 16.8.2021 15:30 | 17.8.2021 16:45 | 48.17<br>58.17<br>68.17<br>72.17<br>91.18<br>95.18<br>156.26<br>173.27<br>175.28<br>224.3<br>233.31<br>306.34<br>319.35<br>392.89<br>386.89<br>862.64<br>845.63 | Flow logging of flow along the borehole. Total flow from interval between reported depth and bottom of the borehole was measured. |

## 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\_BH05.1.1 – IG\_BH05.1.48 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 depth scale together with their locations. As they are interpreted based on flow curves, they represent transmissive fractures. Black and grey 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 987.67 m. In this location the measurement section covered depth interval from 987.67 m to 992.67 m. Based on these dimensions lower end of weights was lowered to depth of 997.87 m. Length of borehole is 1000.63 m.

Magnitude of fracture-specific flow rates based on 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 the 5 m long measurement section was used, and that measurement run was used to determine the fracture flow rate in unpumped conditions. If a fracture has been found but flow rate cannot be determined either in unpumped conditions or in pumped conditions, detection limit is reported instead. Total of 11 water flowing fractures were detected. At three of these fractures flow rate was below detection limit in unpumped conditions.

In general, the detection limit throughout the borehole was below 30 ml/h meaning that all flows above 30 ml/h have most probably been detected.

## 6.2 Transmissivity and hydraulic head in fractures

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\_BH05.2 titled “Transmissivity and head of detected fractures”. Hydraulic head in measured fractures is stated in the plots if both flow values at the same depth were non-zero. Transmissivity is stated for every detected fracture.

The measured flow rates, transmissivity and hydraulic head for each detected fracture in a tabulated form are presented in Appendix IG\_BH05.3 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  $7.00 \cdot 10^{-8} \text{ m}^2/\text{s}$  and the lowest  $1.49 \cdot 10^{-9} \text{ m}^2/\text{s}$ . The uncertainty limits for fracture transmissivities are quite small for all detected fractures. The reported transmissivity value for fractures in which flow was not detected either in unpumped or pumped conditions has been calculated assuming zero flow. Detection limit of flow rate at the depth has been marked instead of actual flow rate in these cases. Certainty limits have been calculated based on these limits.

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\_BH05.4 titled “Hydraulic conductivity (K) of 5 m sections” and Appendix IG\_BH05.5 titled “Table of hydraulic conductivity of 5 m sections”.



### 6.3 Hydraulic head, water level, air pressure and pumping rate

Hydraulic head in the borehole during the flow measurements, as described in Section 4.1, is presented in Appendix IG\_BH05.6. The freshwater head increases towards bottom of the borehole which is most likely due to inaccuracy of Z-coordinate of measurement location. In this case electrical conductivity of water was low throughout the borehole so water density changes do not explain this head change. Water level in the borehole, air pressure and pumping rate during the performed flow measurements are presented in Appendix IG\_BH05.7.

PFL flow logging was started about three days after drilling rods were removed from the borehole. The water level in the borehole was monitored during dummy probing and it was observed that water level rose during dummy probing. The change was so slow that it was estimated that water level will not stabilize before starting flow logging. 50 litres of water was added into borehole about 24 hours before starting of flow logging. During the flow logging run 1 water level changed a little (c. 0.45 m). Flow logging run 2 was conducted with a 13 m drawdown and run 3 was conducted with a 14 m drawdown. The pumped drawdown remained stable. Pumping rate was below the range of pump flow meter therefore pumping rate was measured with a graduated bucket and a stopwatch.

Water was not pumped out of the borehole during measurement run 1. Therefore all water coming into borehole should also exit the borehole. Sum of fracture flows from bedrock into borehole was 617 ml/h and from borehole into bedrock was 715 ml/h. There is a slight unbalance between in and outflows, but it can be partly due to that fracture flows at three detected fractures were below detection limit. At the fracture at 789.9 m, flow was detected only while borehole was not pumped. This is unusual as fracture flows are usually detected while borehole water pressure is lowered by pumping water out of the borehole. Technically measurement quality looks good, so it is possible that the 14 m drawdown has caused this fracture flow rate to decrease so much that the flow rate was below the detection limit during the measurement run conducted in pumped conditions. Pumping rate was difficult to determine accurately but the order of magnitude was 200 ml/min. Sum of fracture flows in pumped conditions was 174 ml/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 the measurement section. When the probe is moved along the borehole it carries water within the measurement section and therefore the results don't necessarily represent the borehole water conditions at the measured depth. The main objective of these measurements is to monitor conditions in the 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\_BH05.8 and IG\_BH05.9. The highest measured electrical conductivity value was measured at the bottom of the borehole (0.38 S/m). The electrical conductivity value is

quite invariant throughout the borehole. The value is only slightly lower at top of the borehole.

## **6.5 Summary of results**

Three planned measurement runs were conducted in borehole IG\_BH05, one in unpumped conditions and two while borehole was pumped to obtain 13 m and 14 m draw-downs in water level. Total of eleven water flowing fractures were found and total flow from fractures into borehole was 174 ml/min with the 14 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 depth matching between different measurement runs. Pressure measurements and water level measurements were successful. There was small variation in water level during the flow logging run 1 as the water level in borehole had not stabilized after drilling before starting the flow logging. Balance between inflows and outflows was good so change in water level most probably did not affect the results.

Fracture with the largest transmissivity was found at depth of 93.3 m ( $7.00 \cdot 10^{-8} \text{ m}^2/\text{s}$ ).

Electrical conductivity of water was measured in connection with flow logging. The highest electrical conductivity values (0.38 S/m) were found at bottom of the borehole.

## 7 NONCONFORMITIES

The dummy probe was very dirty both times it was lifted out of the borehole. After the flow logging run 1 the PFL probe was the dirtiest (*Figure 7-1*). Nevertheless, no sign of distortion of measurement results were observed. Inflow and outflow balance was fairly good and flow measurement details, such as quality of created heat pulse and cooling transient after heat pulse, looked normal. Impurities at flow sensor thermistors would cause distortion to these values.



**Figure 7-1.** PFL probe upped rubber disks after flow logging.

During the second flow logging cooling transient after heat pulse and the heat pulse related to flow measurement started to look abnormal. Normally the temperature descends smoothly after heating period. This is a property that can be checked from data, but it is not reported. This indicated that there were impurities attached to flow sensor thermistors. During flow logging run 2 the dirt had created kind of coating to the probe.

It is not possible to take a photo inside the flow sensor but *Figure 7-2* shows the electrical conductivity sensor which is right above the flow sensor. The EC-electrode was dirty and the dirt had to be brushed out, flushing with water was not enough. Sum of detected fracture flows was 1297 ml/h and pumping rate was 14400 ml/h. The most obvious reasons for difference could be that all flowing fractures were not found or flow rates of found fractures were not measured correctly. For not detecting a flowing fracture above base level is not likely as flow channel would have to be plugged entirely. After flow logging the flow channel was checked and it was not lugged. Small flows that can be detected

with PFL probe would flow through very small opening in the flow channel. Getting incorrect flow rate values due to dirt in flow sensor is more likely as flow measurement technique is very sensitive for impurities at measurement thermistors. Therefore, it was assumed that all flowing fracture locations have been detected based on measurement runs 1 and 2 and run 3 could be started.



**Figure 7-2.** Dirt coating at PFL probe after flow logging run 2.

Teams meeting between NWMO, Golder and Posiva Solutions was arranged August 15<sup>th</sup>, 2021, 9:15-10:00 (Toronto time). Quality of measurement run 2 results was discussed and options for continuing the measurements were evaluated. Posiva Solutions' opinion was that the dirt in borehole that had attached to probe is causing incorrect flow measurement results (flow rate) but most probably it has not affected *finding* flowing fractures in the borehole. Flowing fractures had been found in borehole, but the flow rate results were unreasonable as at one fracture flow was the same in pumped and in unpumped conditions



(flow should be larger in pumped conditions) and sum of flows did not match with pumping rate.

Two options were discussed: Conducting run 2 again in sequences starting from top of the borehole. This way dirtier (presumably) lower part of the borehole would be measured last. Another option was to continue with run 3 (also starting at top part of the borehole) and measured depth zones where fractures had been detected during runs 1 and 2. If sum of flows obtained during run 3 matches with pumping rate with accuracy of  $\pm 10\%$  it is assumed that all flowing fractures have been found. The second option was chosen.

The flow logging run 3 was conducted in depth intervals as presented in Table 5-1. The bottom of the borehole was measured last to avoid the assumably the dirtiest part of the borehole. No abnormalities were observed during the measurement run and the probe was not as dirty as after previous runs. Sum of flows is 10465 ml/h and average pumping rate was 11700 ml/h (0.195 l/min). Difference between pumping rate and sum of flows is 1235 ml/h (12% of sum of flow). This is slightly over accuracy limit (10%) and additional measurements were conducted to find if some fracture zones were not detected during run 2. A 12% difference can be caused by varying conditions in the borehole, and it is possible that matching results will not be obtained even after an additional measurement. Additional measurement will be measuring flow along the borehole to find if flow along the borehole changes in depth zones where fractures were not detected.

Flow along the borehole measurements were conducted at depths presented in Table 5-1. The aim was to measure flow along the borehole at start and end of borehole intervals where fractures had not been detected. If flow along the borehole is the same at both depths this proves that there are no flowing fractures between these depths. The flow results at all the depths contained quite large variation which makes it difficult to interpret flow rates reliably. Based on the results the flow changed at some of the intervals where fractures had not been found, but variation in flow results was so large that this result is highly unreliable and has not been reported. Also, the highest measured flow along the borehole value was smaller than sum of flows measured during run 3. Flow along the casing pipe was also measured but for some reason the flow rate was smaller than below the casing pipe at the beginning of borehole. The reason for this can be that PFL probes rubber disks leaked at casing pipe.

As the reason for the difference between sum of flows and pumping rate was still unclear, Golder measured the flow along the borehole at top of borehole using their heat pulse flow meter. This measurement was part of their measurement programme. This result matched with sum of fracture flows obtained with PFL. Based on all these results Posiva Solutions concluded that there is no uncertainty whether all fracture flows above detection limit have been found and there is no need to conduct more PFL measurements.

Flow sensor calibration was checked after measurements in Finland. This was done to check if impurities in borehole had caused permanent changes to flow sensor. Flow sensor had been flushed with water at site, but thorough cleaning was not done before calibration check. Based on the check no changes were observed so the calibration done before field work was still valid.

## 8 SUMMARY

Difference flow and other related measurements were performed in borehole IG\_BH05 in August 2021 at the Ignace investigation site. Three planned measurement runs were conducted and one additional flow along the borehole measurement run. The first run was conducted with a 5 m long measurement section in unpumped conditions. The second run also with a 5 m long section but conducted in pumped conditions with c. 13 m drawdown in borehole water level. In the third run those borehole sections, where fractures were found were measured with a 0.5 m long measurement section with a 14 m drawdown. Fracture locations were determined based on this measurement run.

The locations of the water-conducting fractures were obtained with the resolution of 0.1 m. The transmissivity and hydraulic head of these fractures were calculated from the flow and pressure results. Hydraulic conductivity of borehole sections were also calculated based on fracture transmissivities. Altogether eleven fractures were found along the 919.4 m borehole length. The upper most fracture was found at the depth of 93.3 m and lowest at the depth of 857.1 m. The highest detected transmissivity was  $7.00 \cdot 10^{-8} \text{ m}^2/\text{s}$  and lowest  $1.49 \cdot 10^{-9} \text{ m}^2/\text{s}$ . Base level of the 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 (0.38 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 hydraulic head values have been presented in plots and tables.

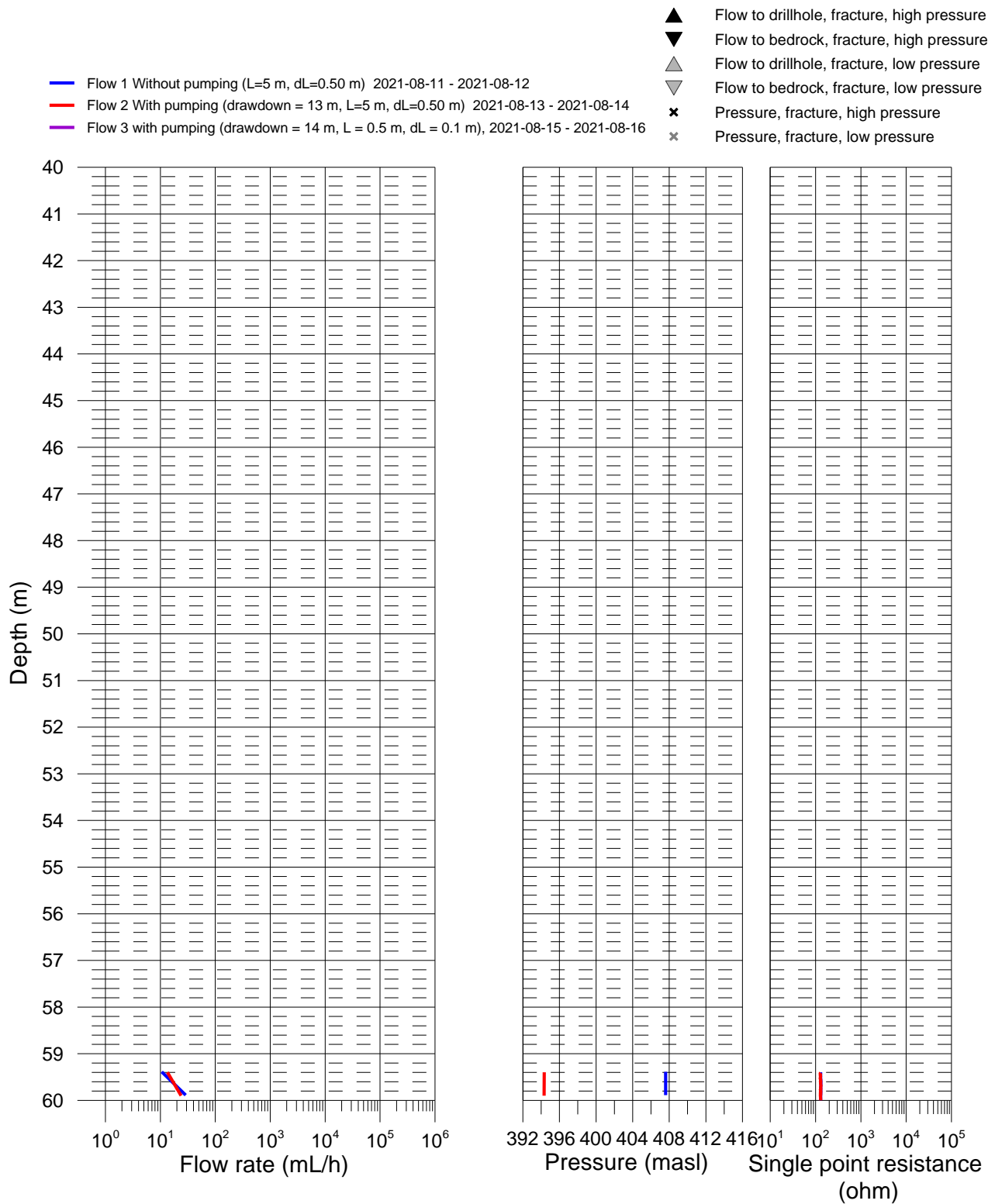
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**Lake, L.W., Fanchi, J.R., Mitchell, R.F., Arnold, K., Clegg, J.D., Holstein, E.D., and Warner, H.R., 2007.** Petroleum Engineering Handbook, Volume II: Drilling Engineering. Society of Petroleum Engineers. 2007. pp. 90-95. ISBN 978-1-55563-114-7

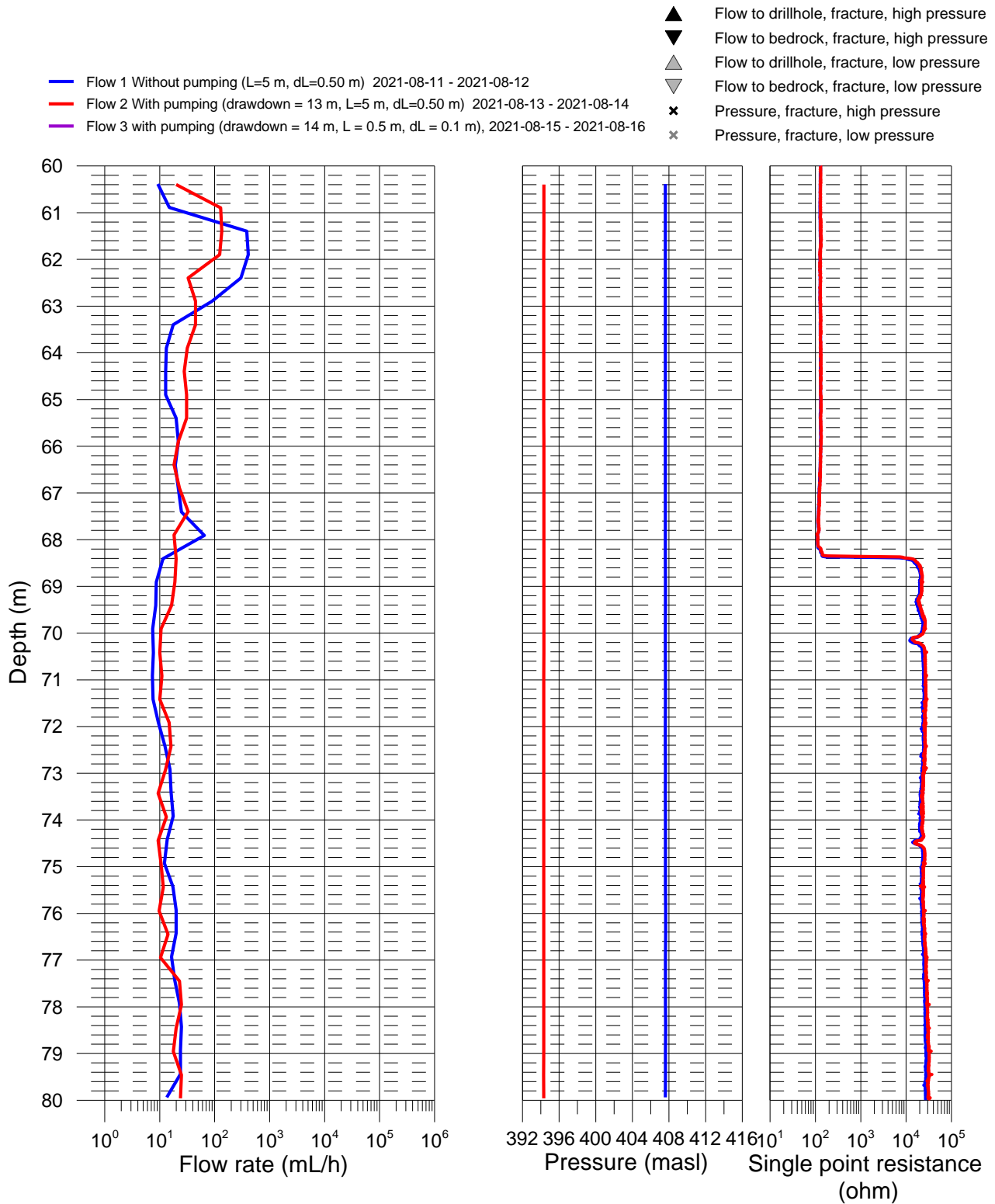
# Ignace, borehole IG\_BH05

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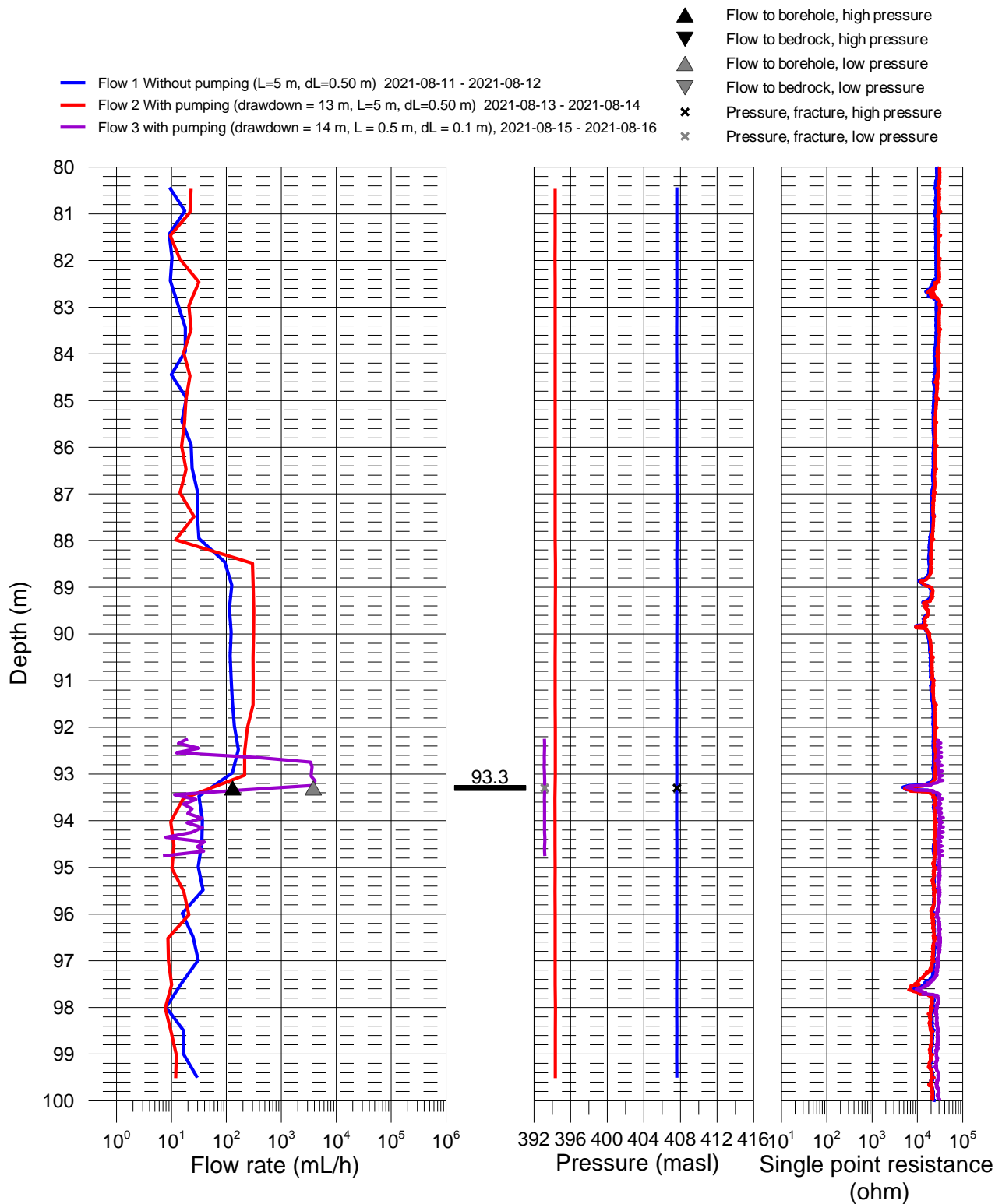


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Flow rate, pressure and single point resistance

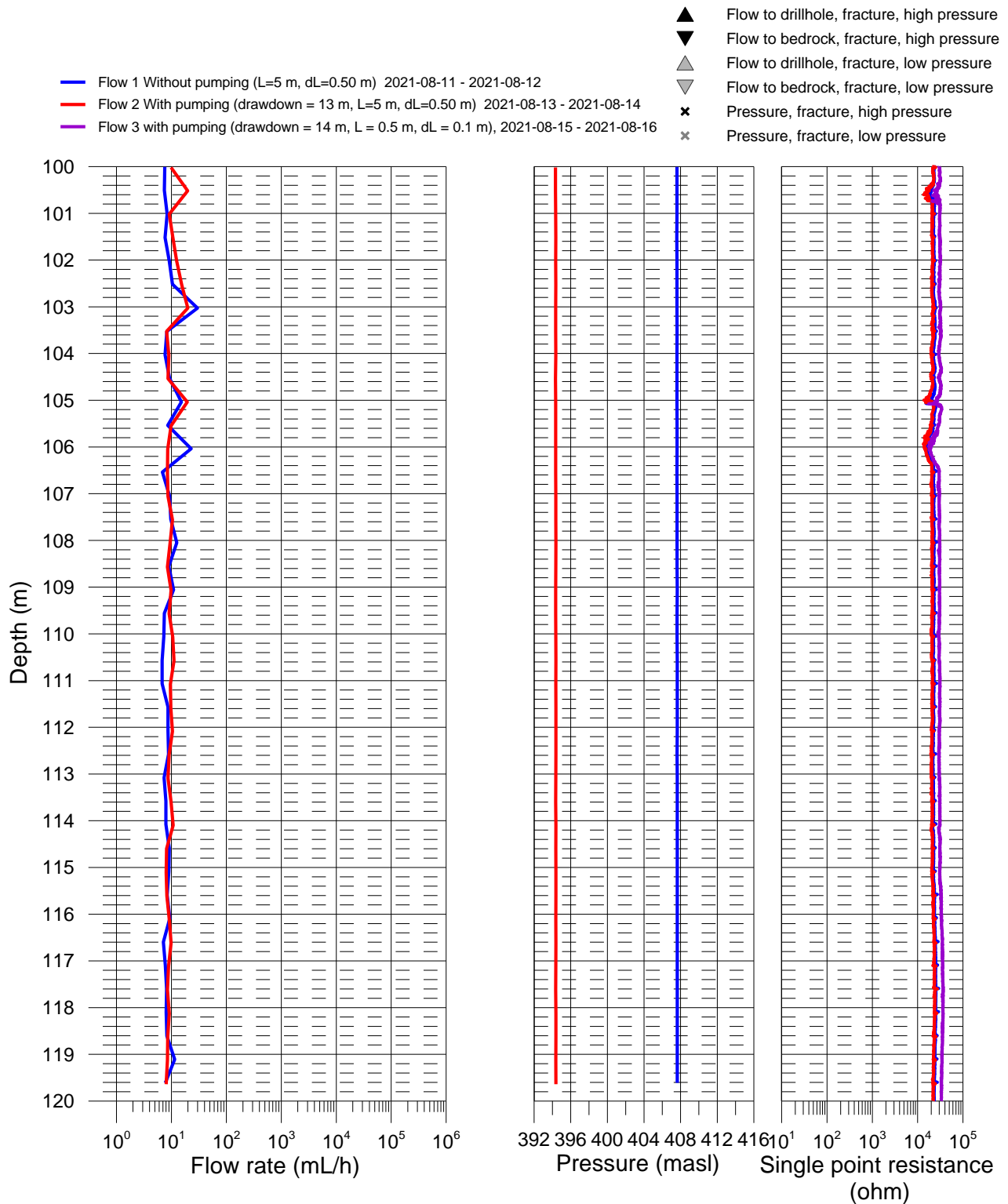


## Ignace, borehole IG\_BH05

## Flow rate, pressure and single point resistance

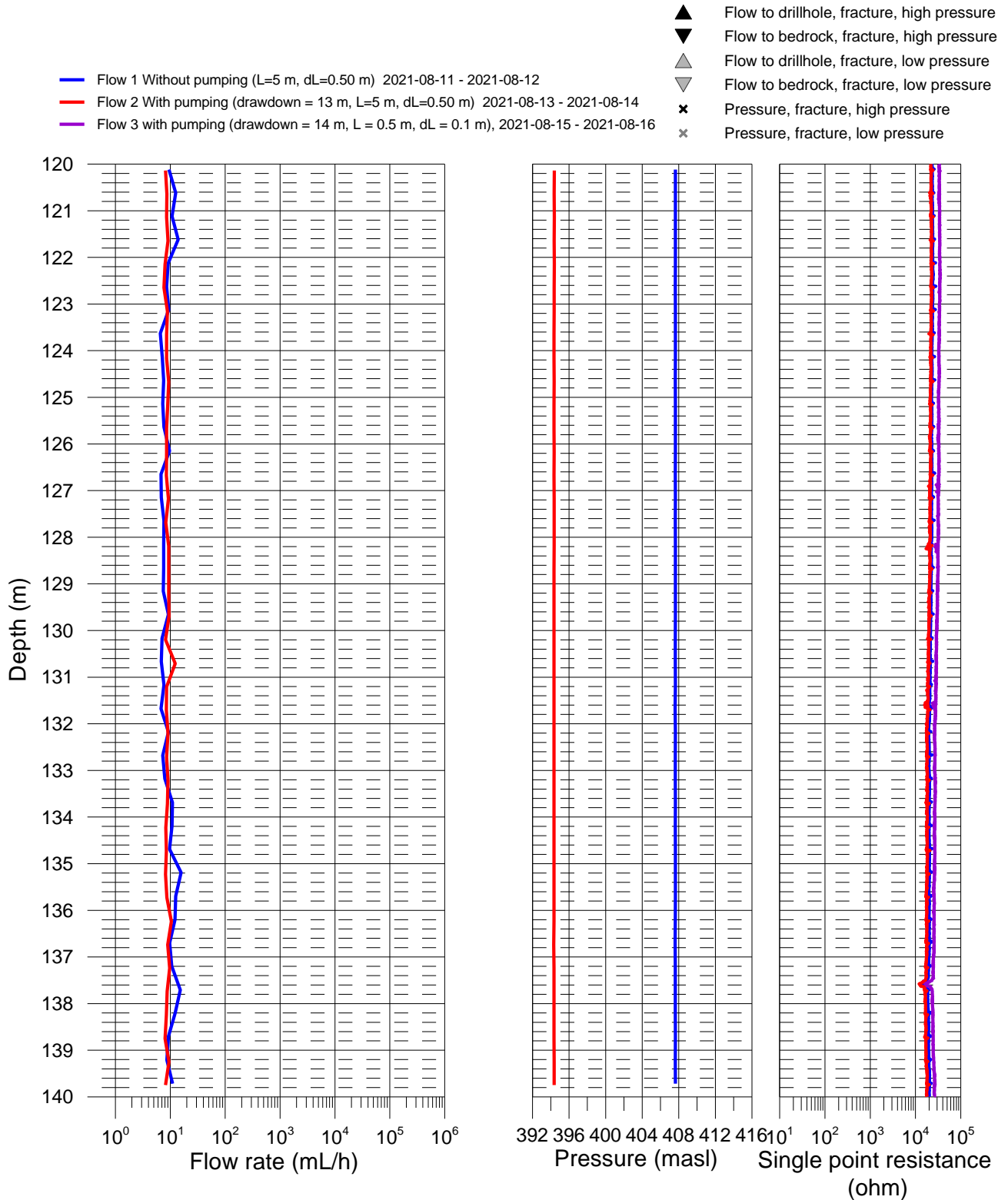


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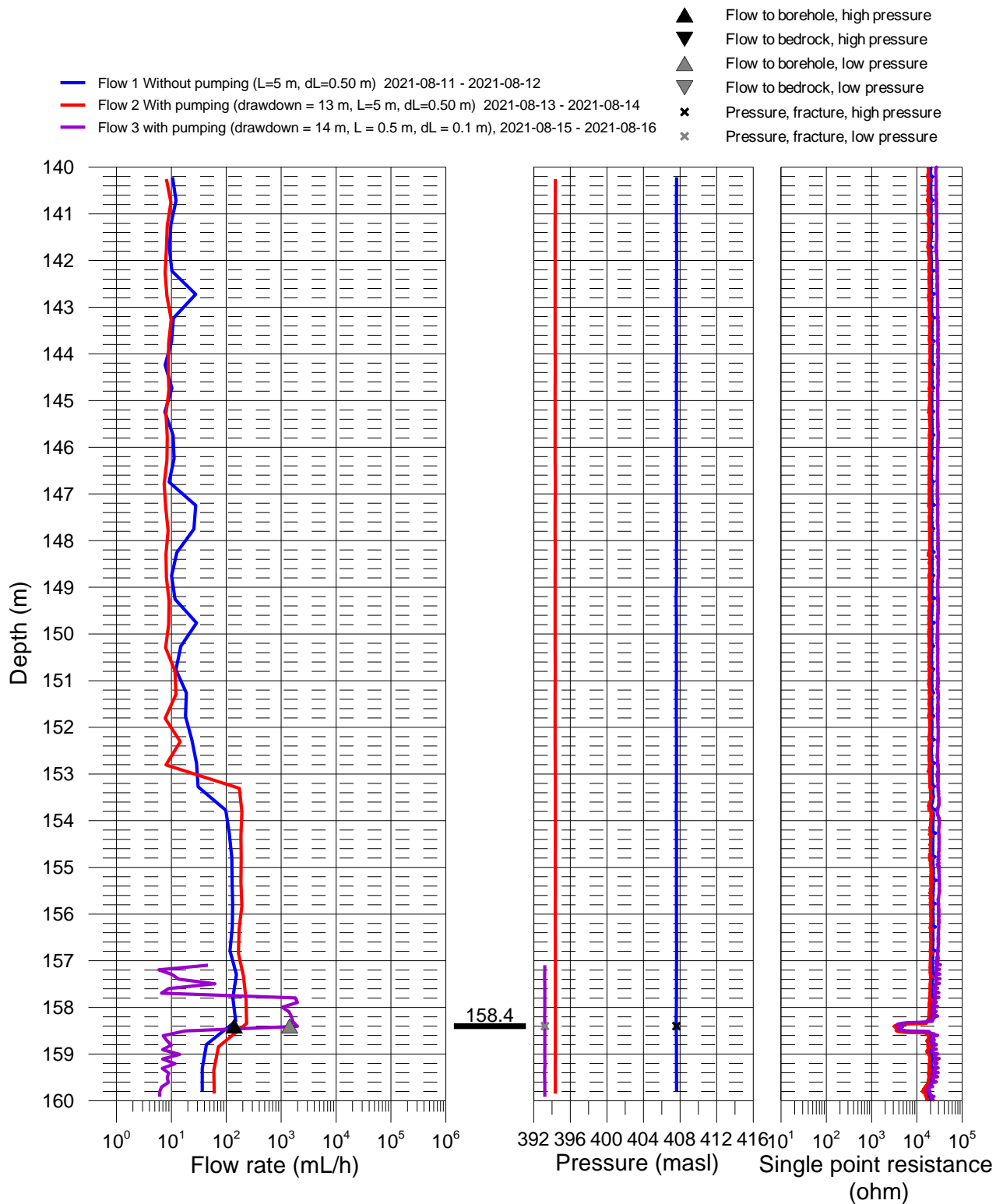


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## Flow rate, pressure and single point resistance

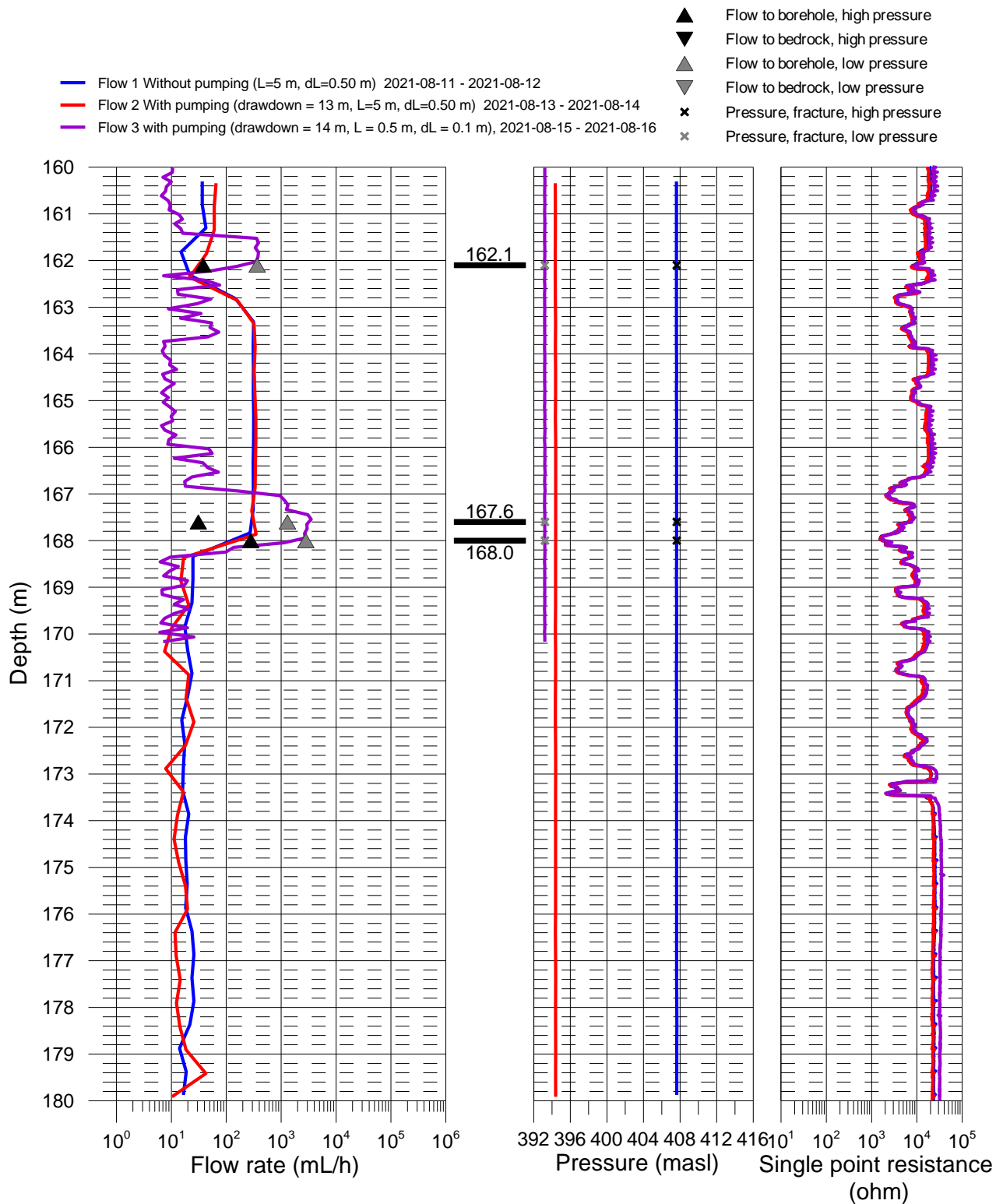


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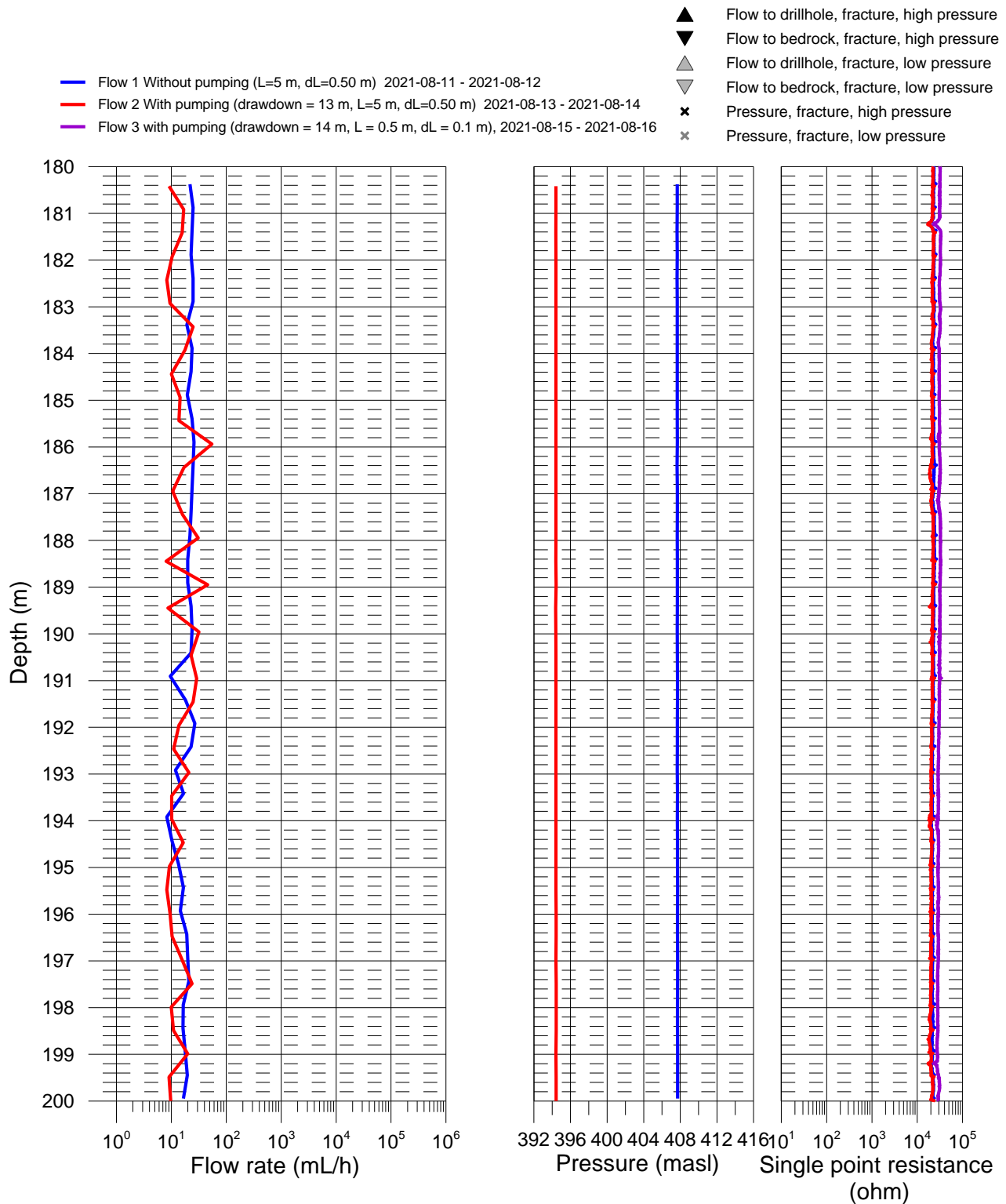


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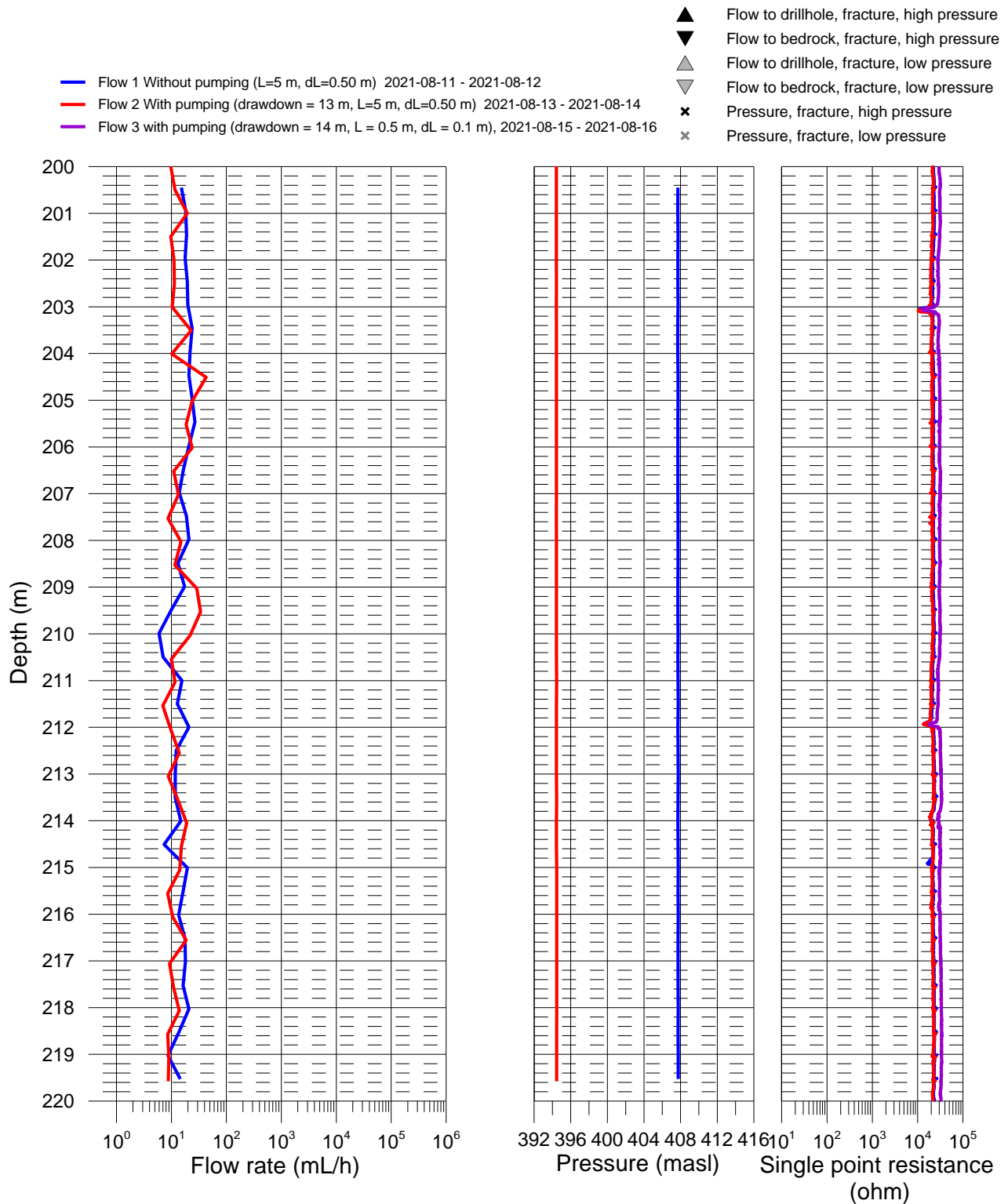
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# Ignace, borehole IG\_BH05 Flow rate, pressure and single point resistance



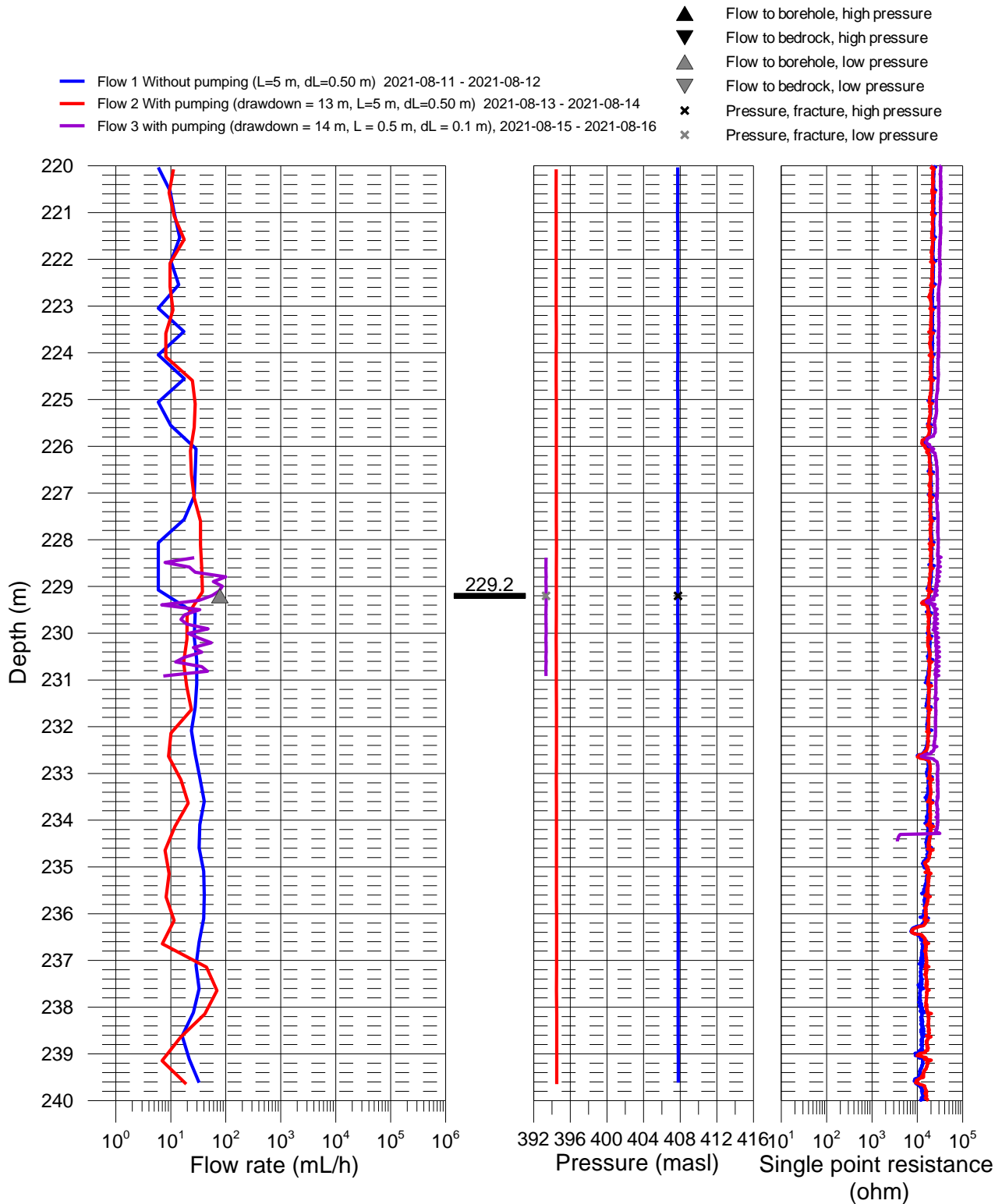
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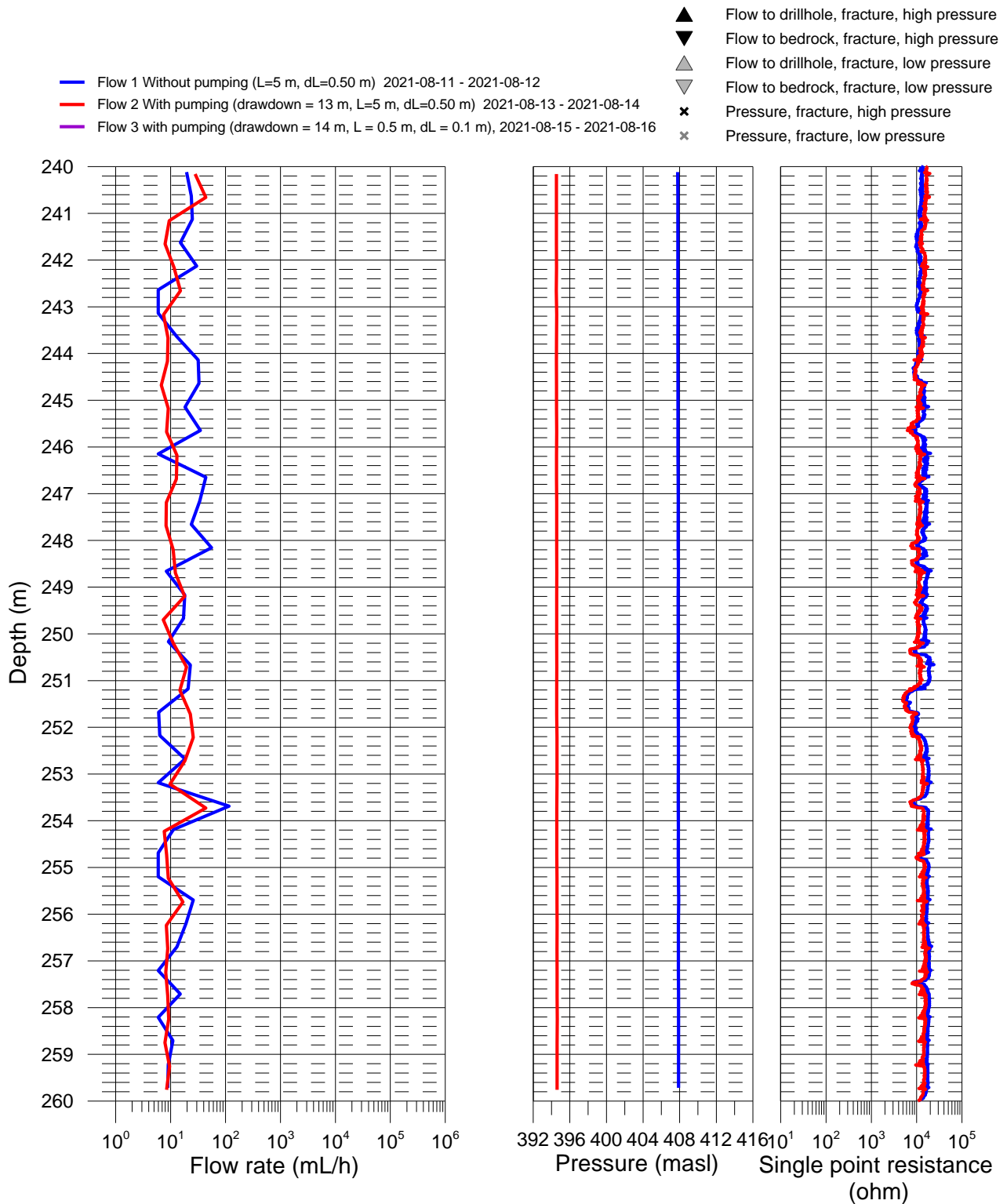


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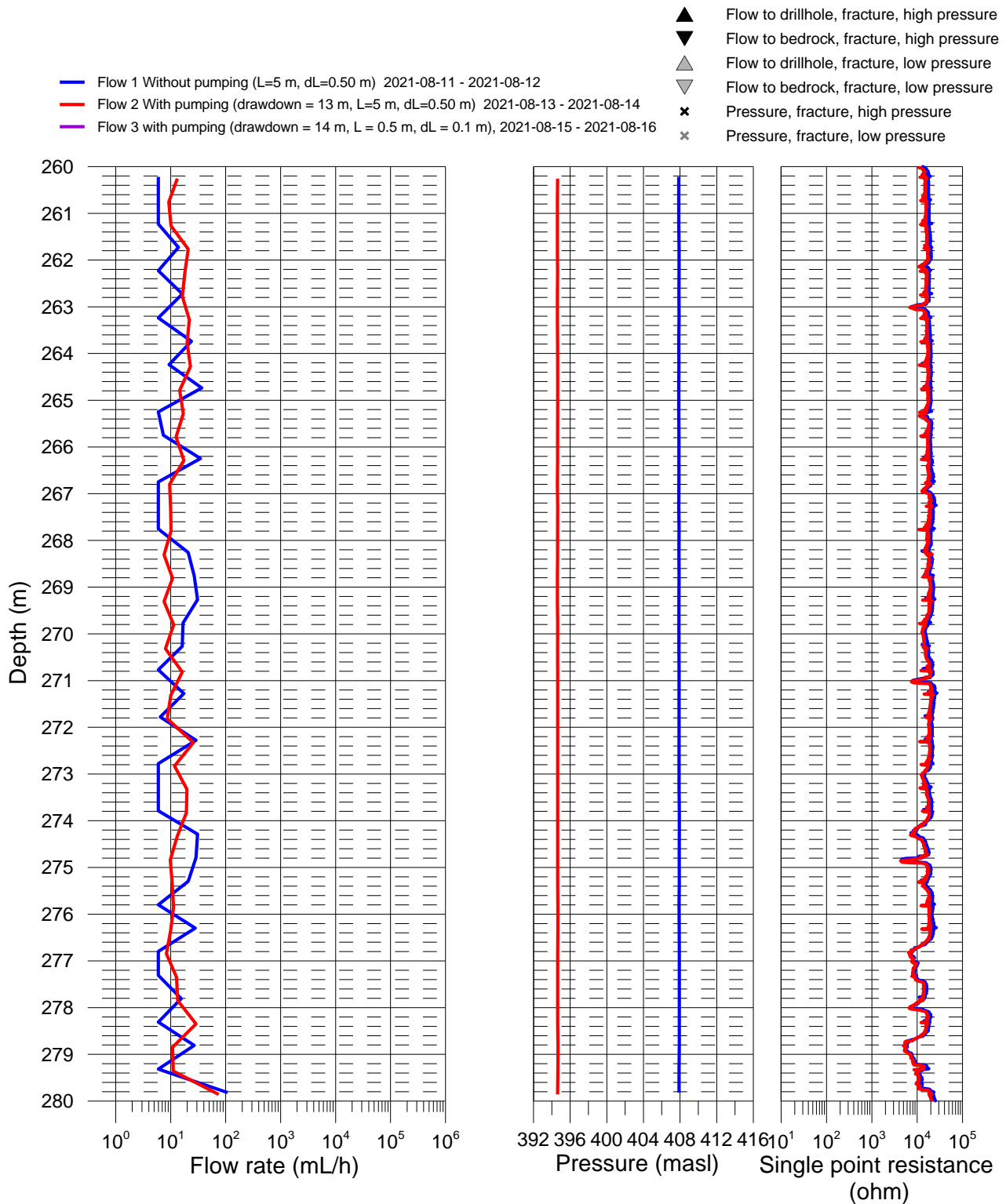
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Flow rate, pressure and single point resistance

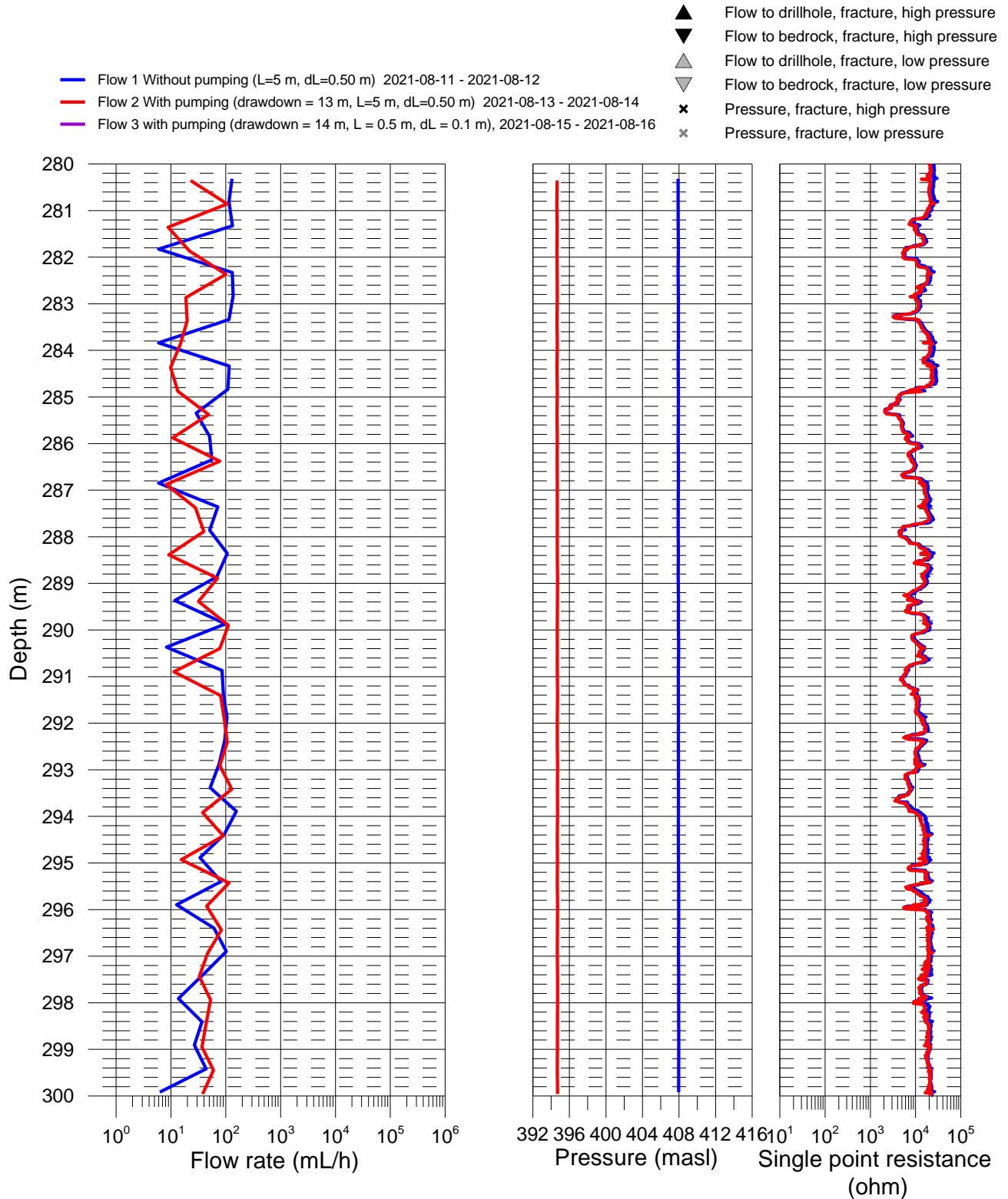


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Flow rate, pressure and single point resistance



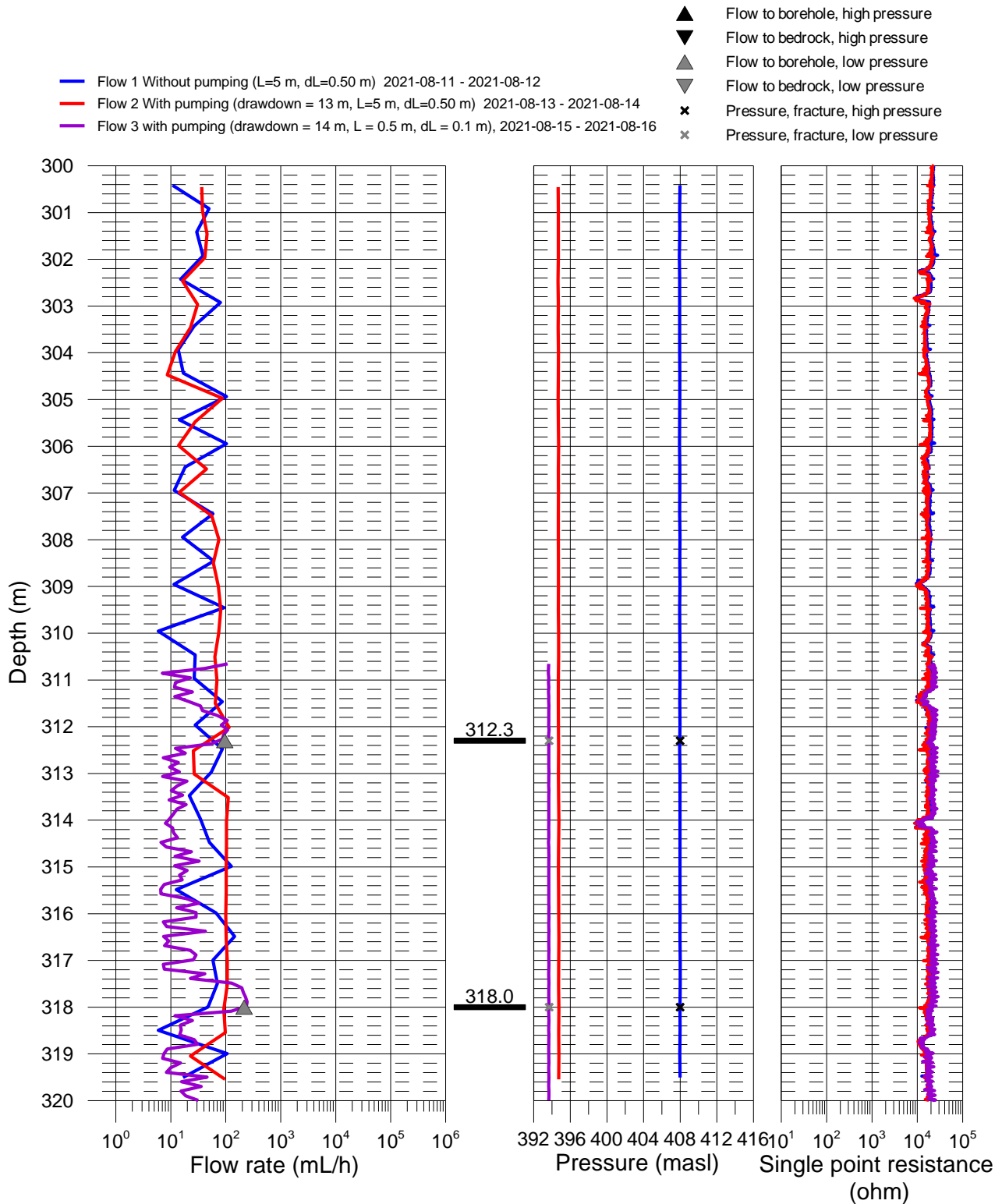
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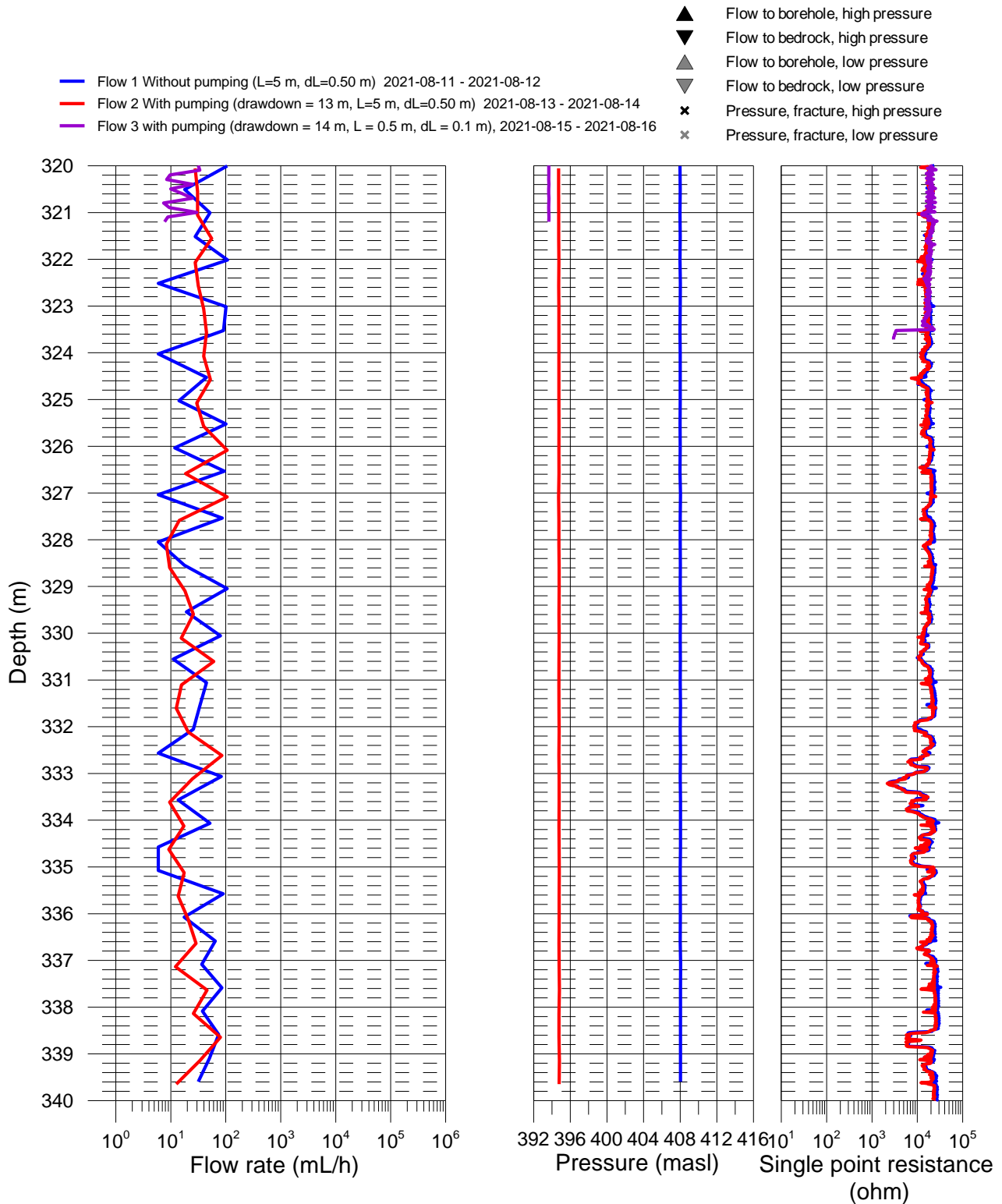
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## Flow rate, pressure and single point resistance

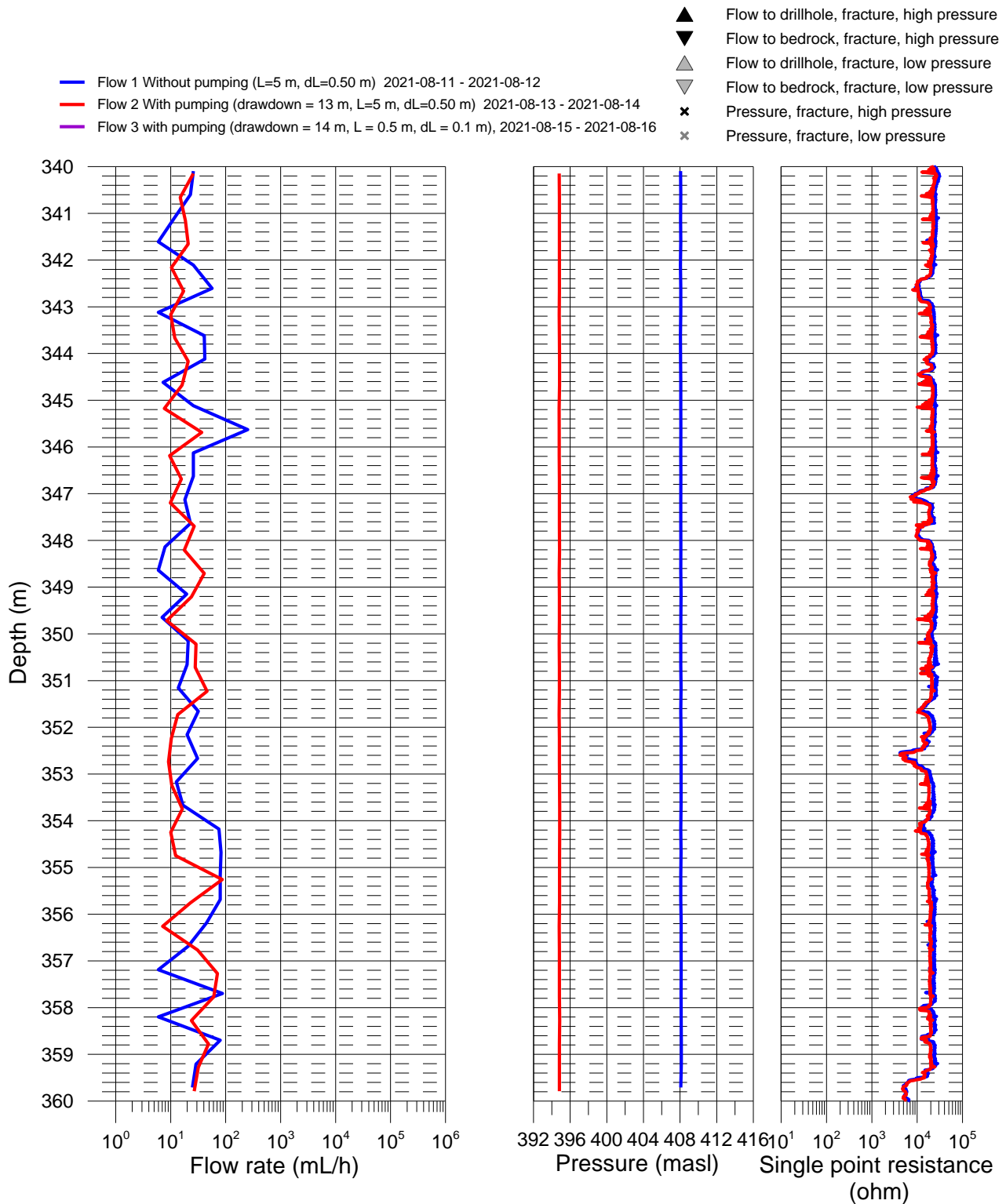


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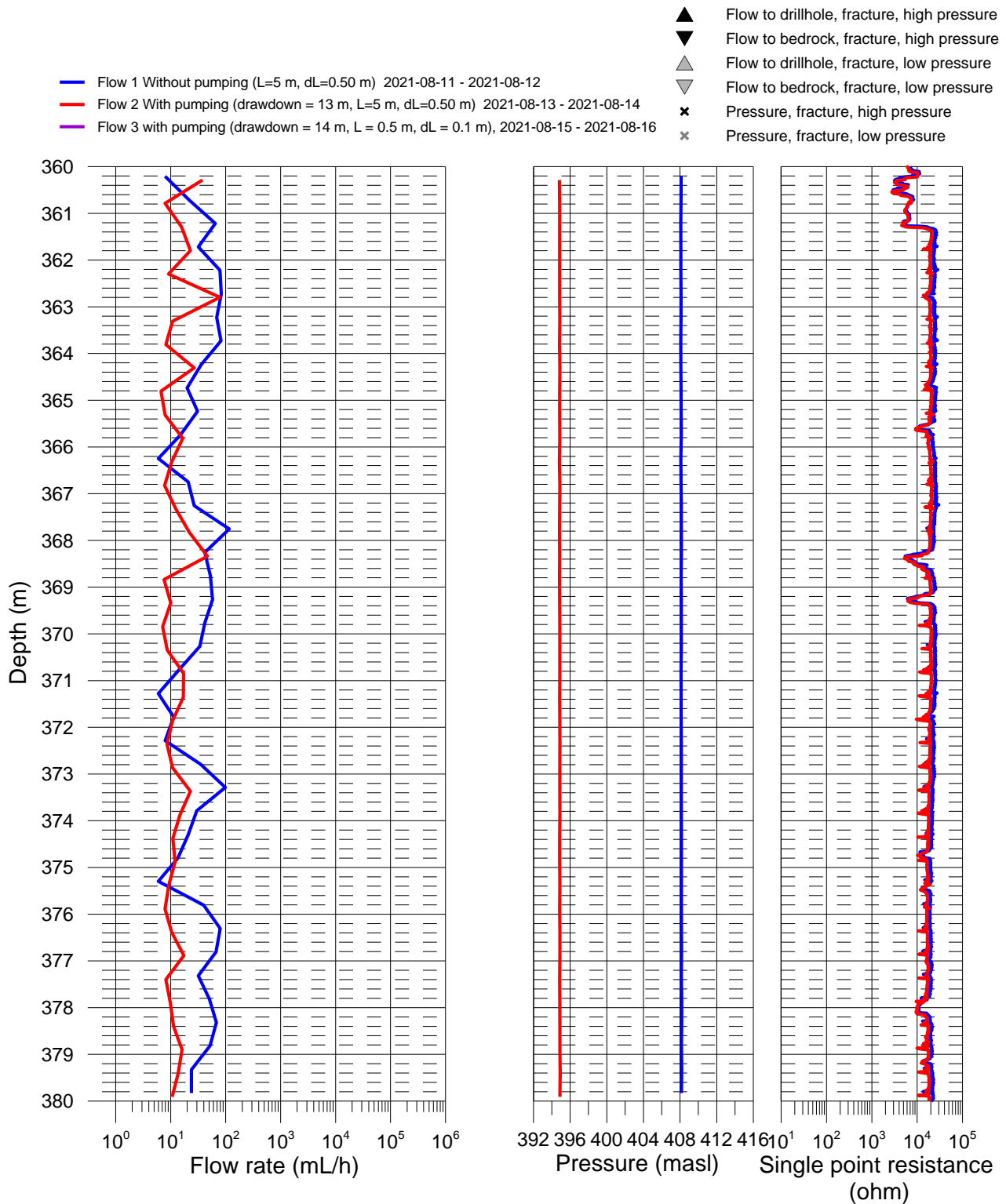
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Ignace, borehole IG\_BH05  
Flow rate, pressure and single point resistance



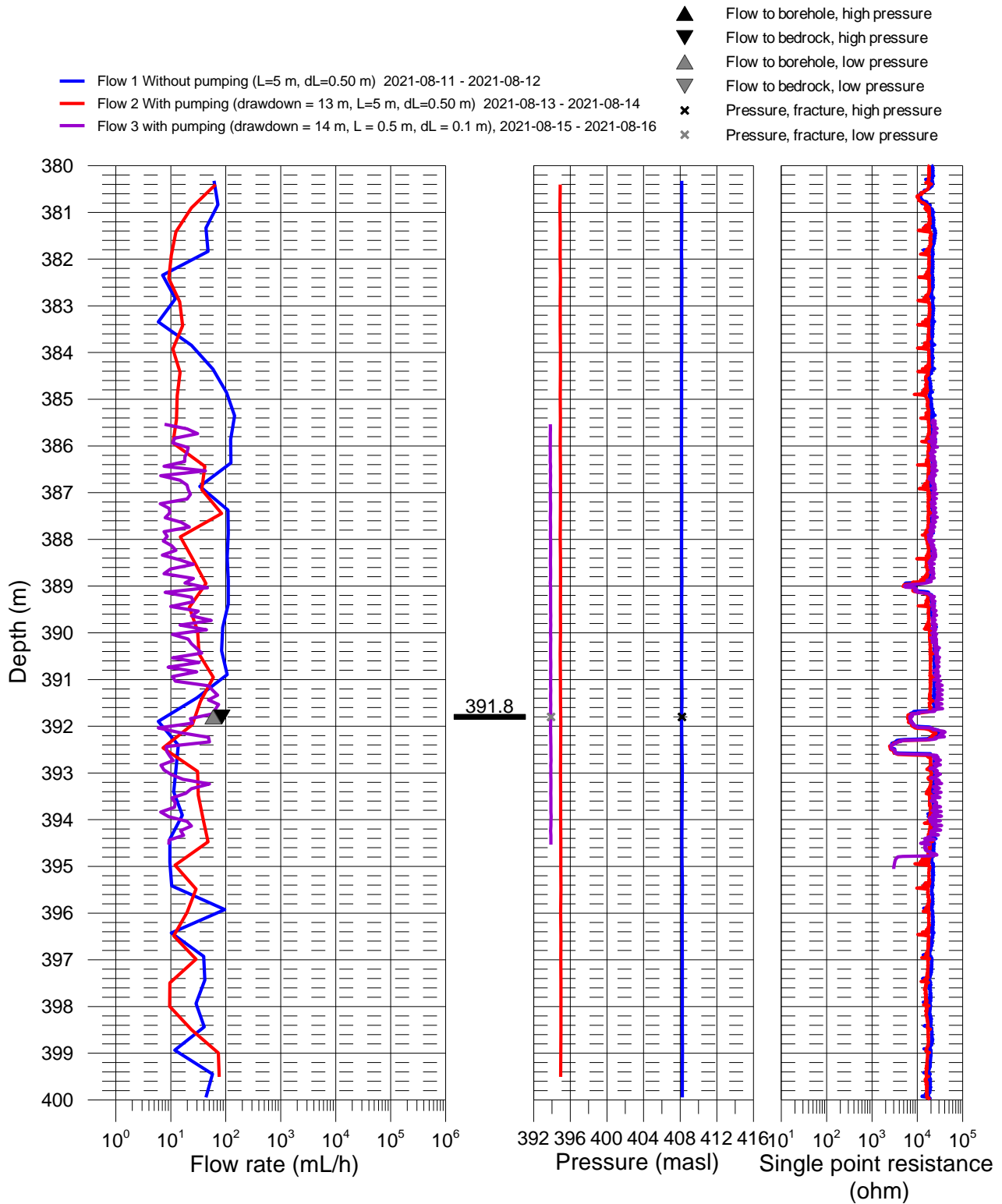
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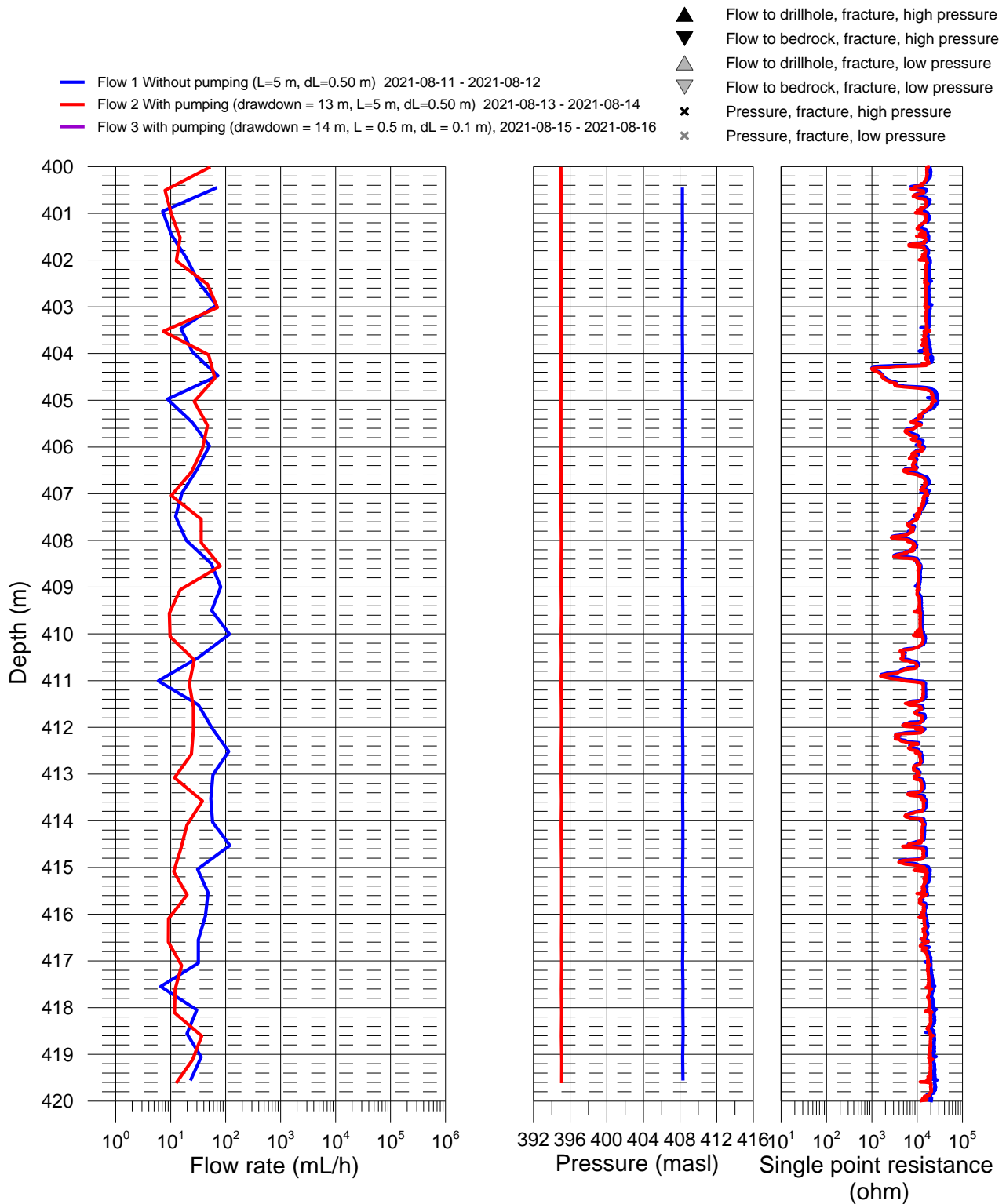


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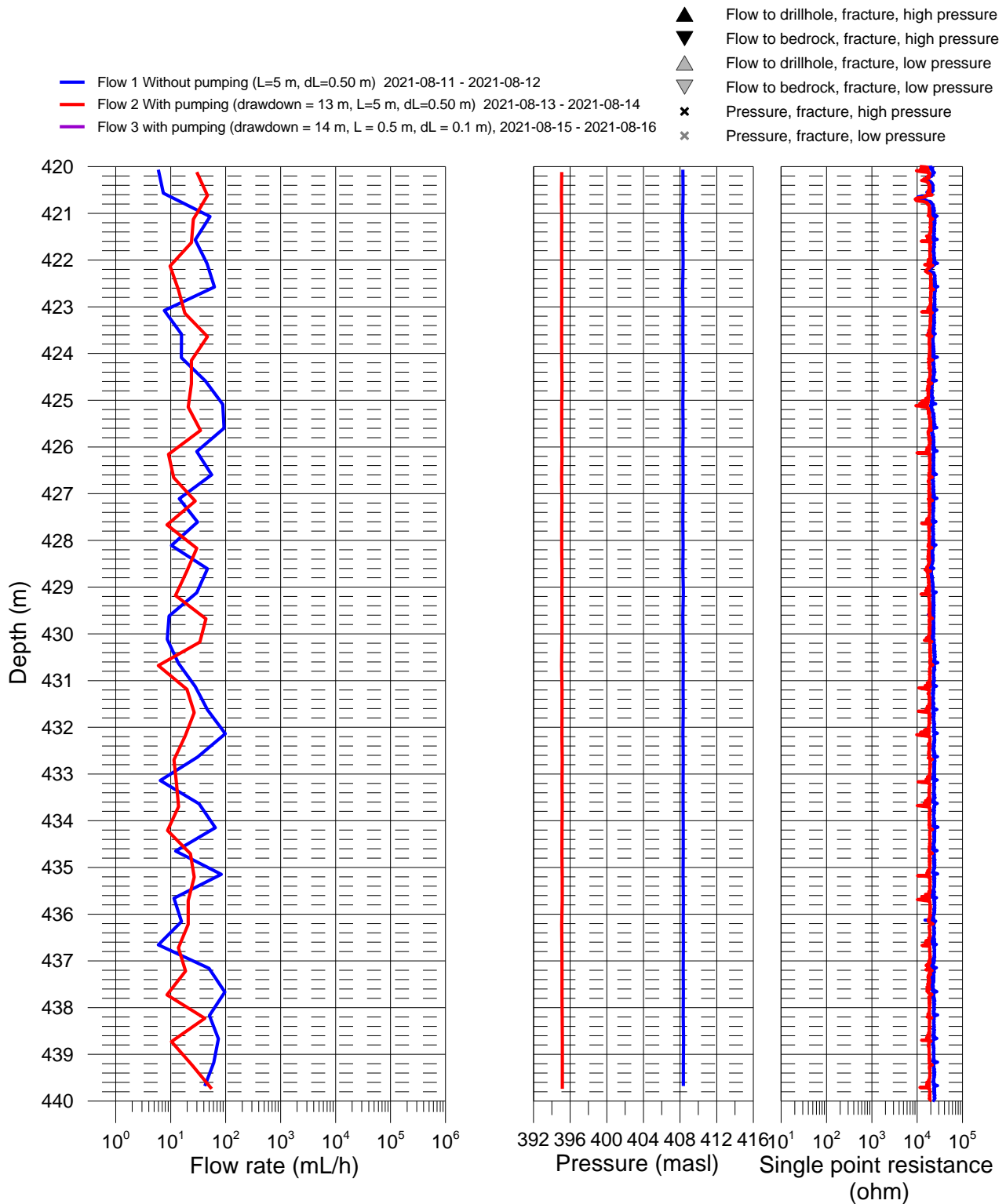
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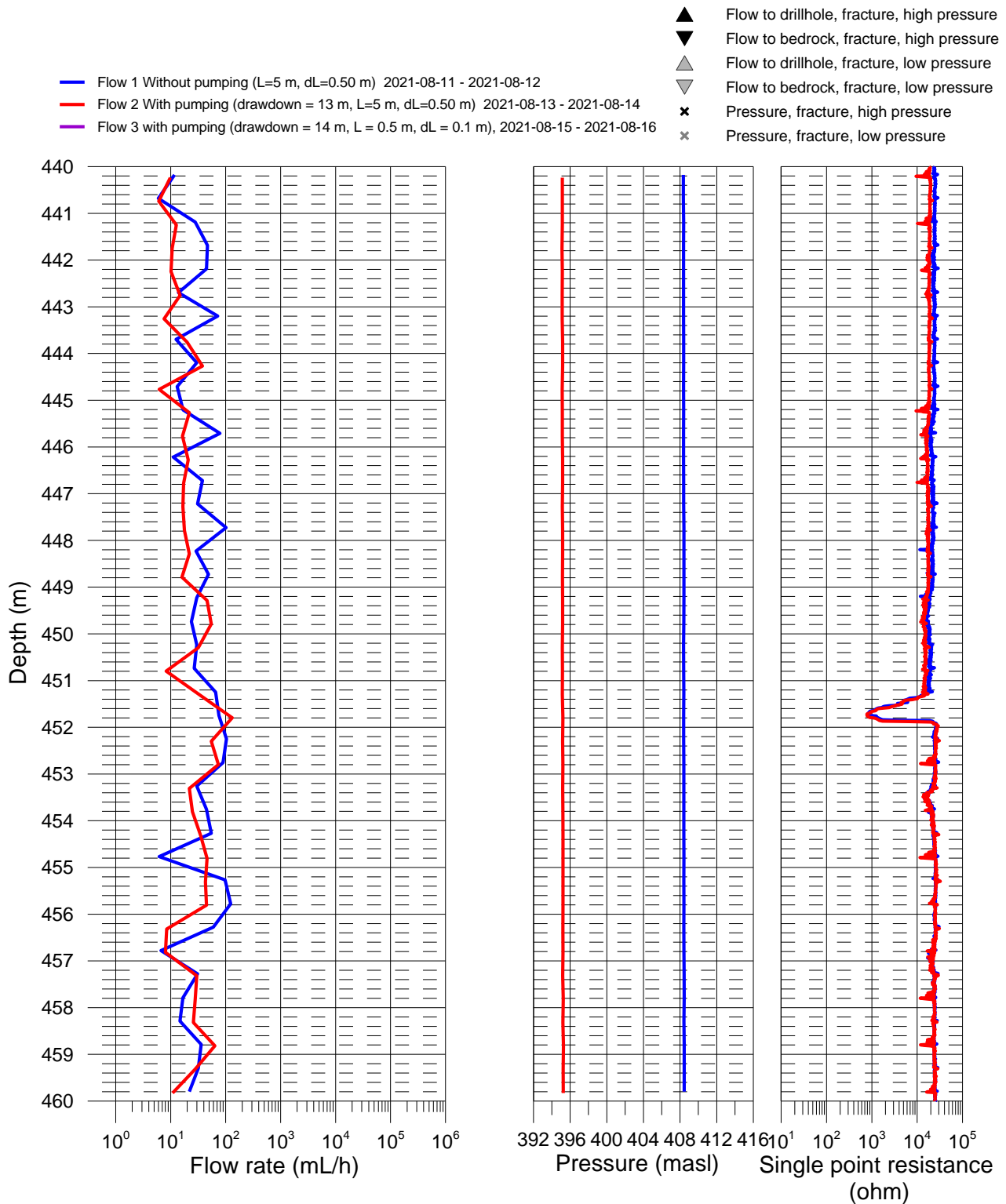
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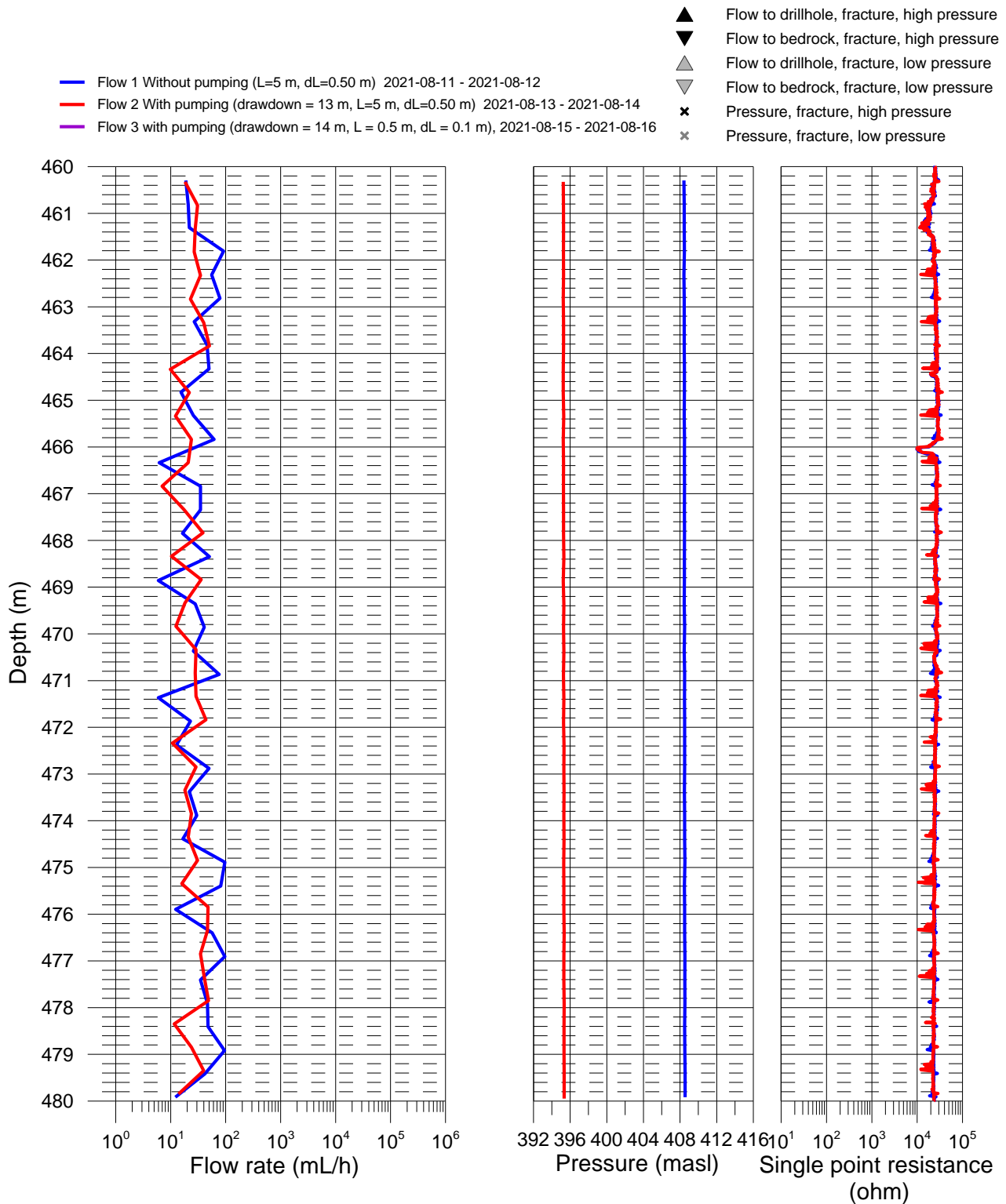
Ignace, borehole IG\_BH05  
Flow rate, pressure and single point resistance



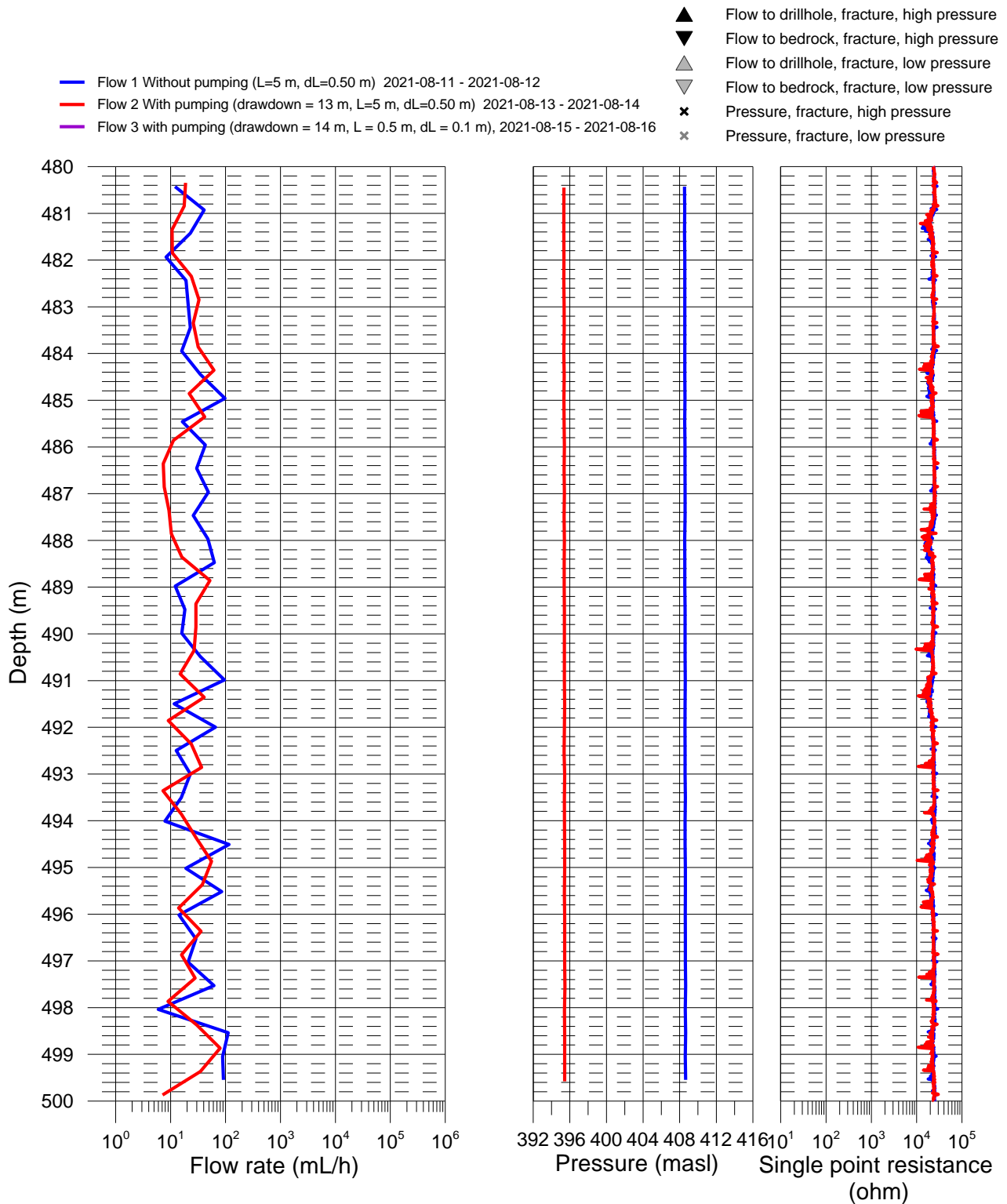
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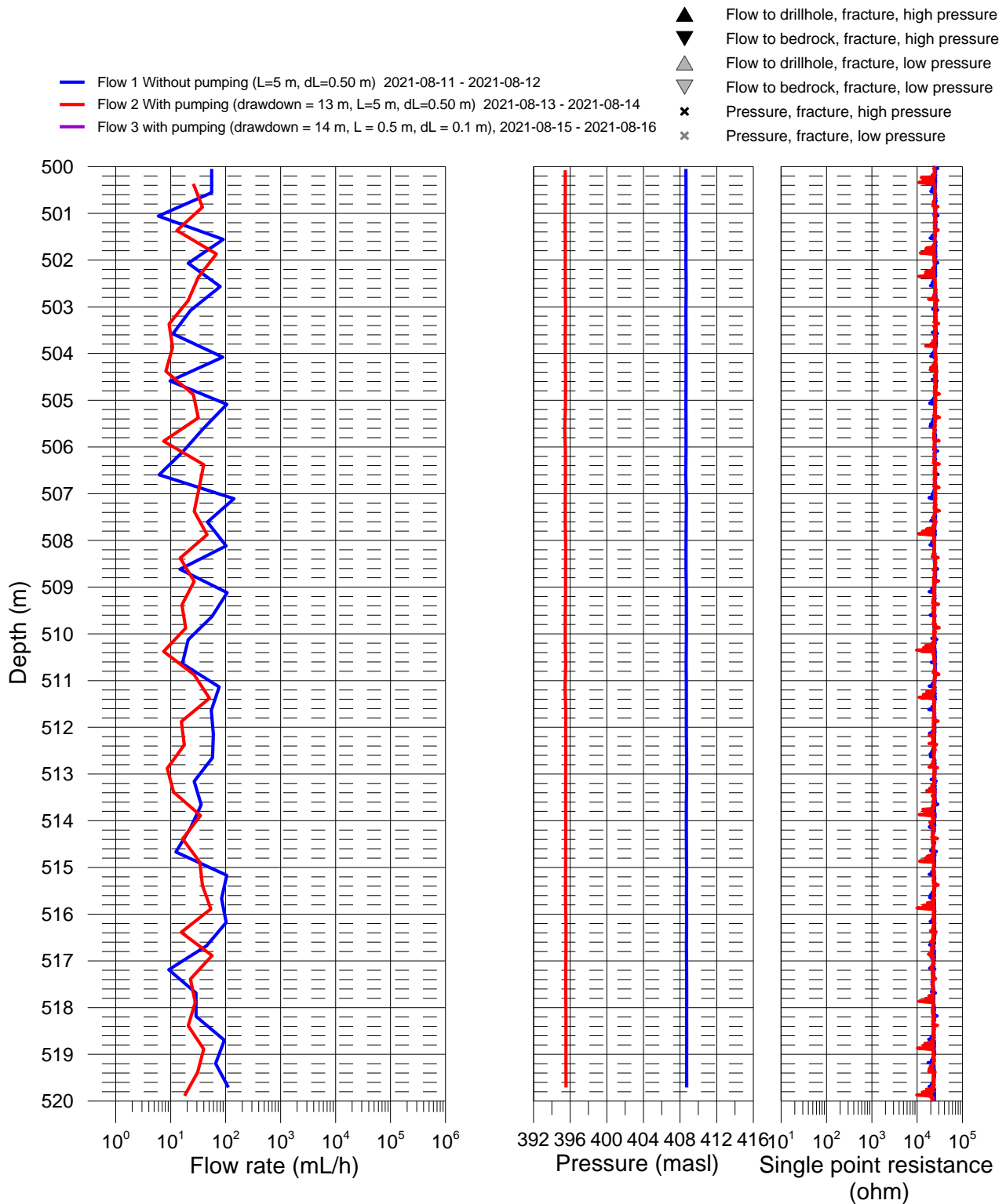
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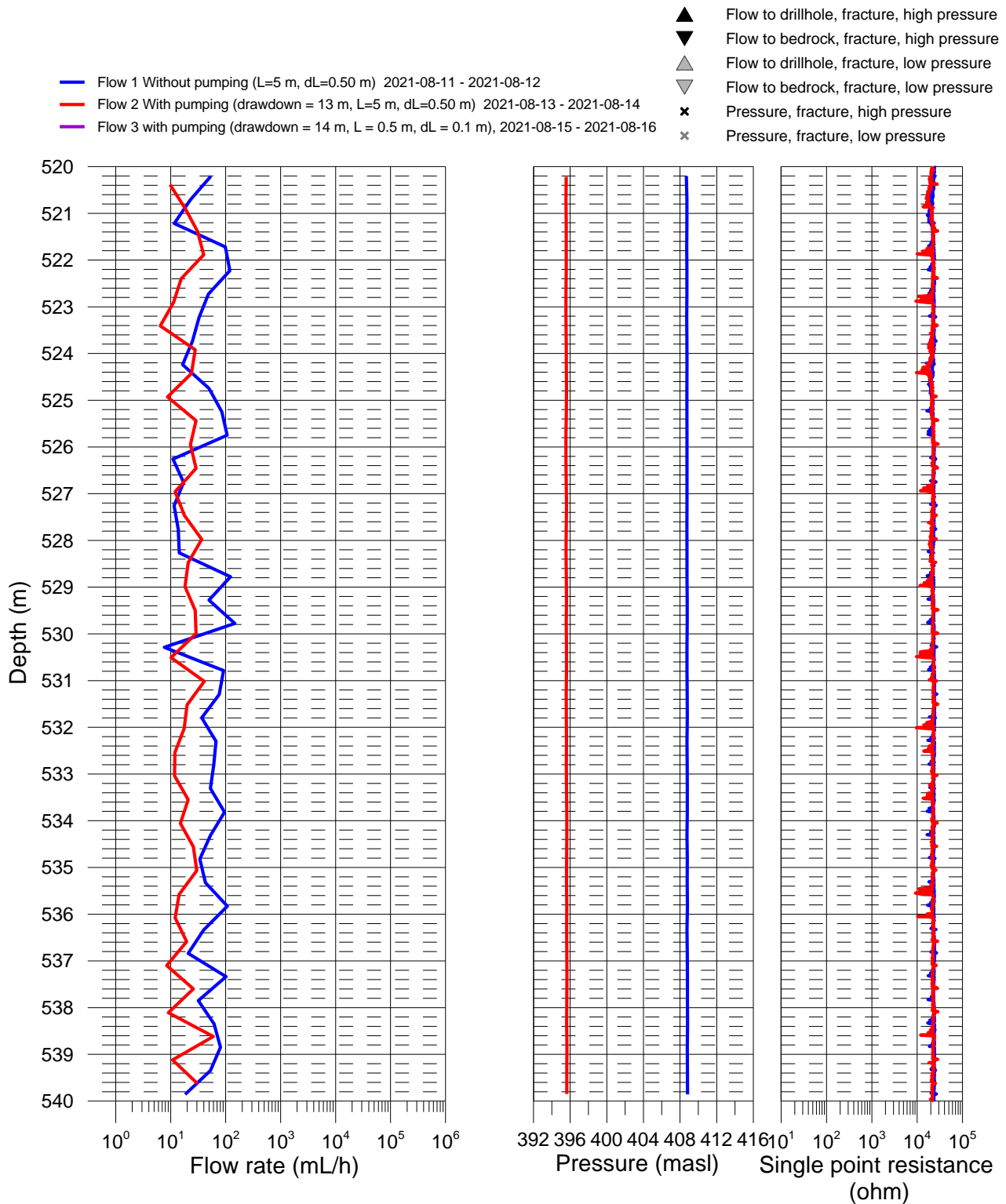
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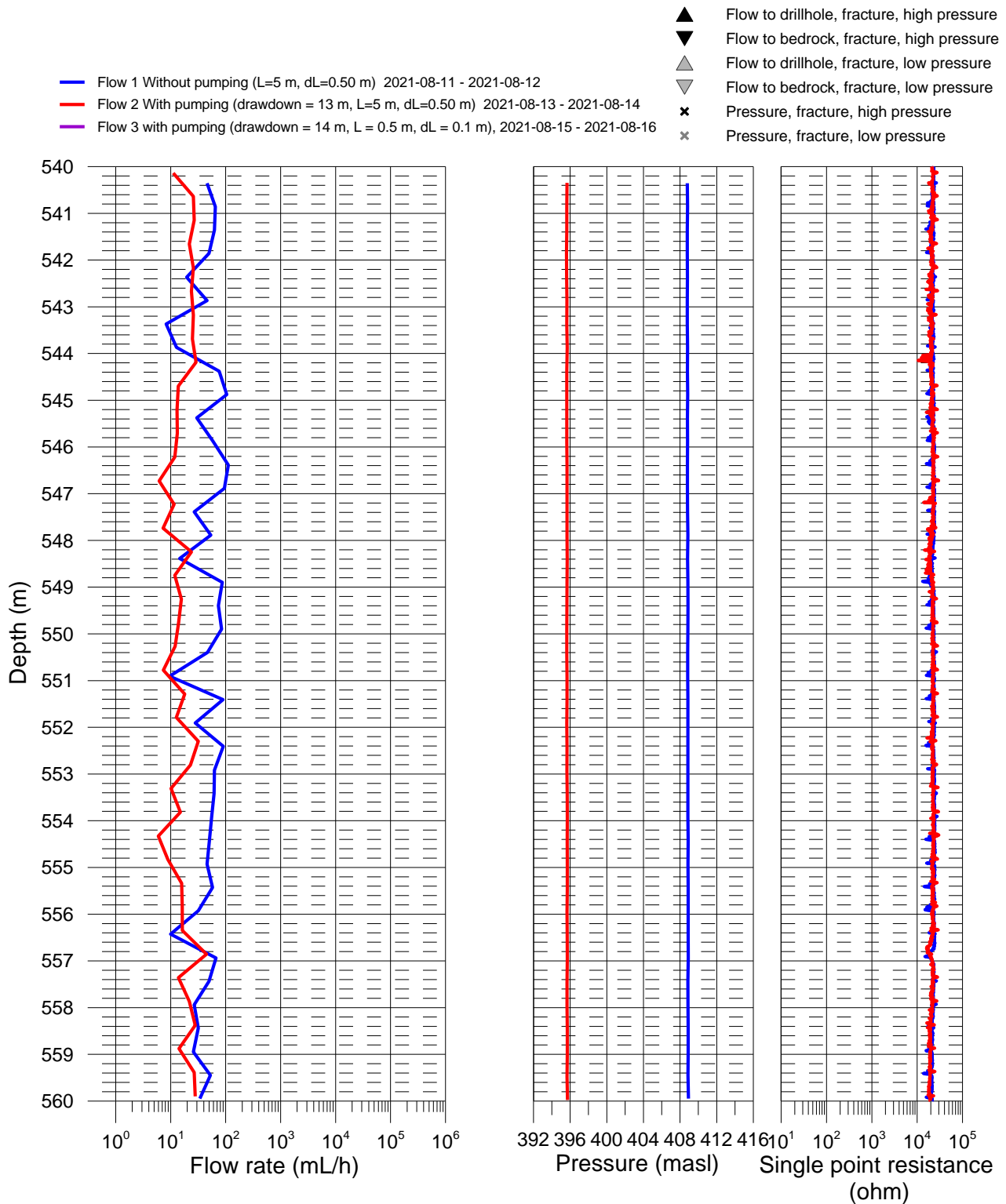


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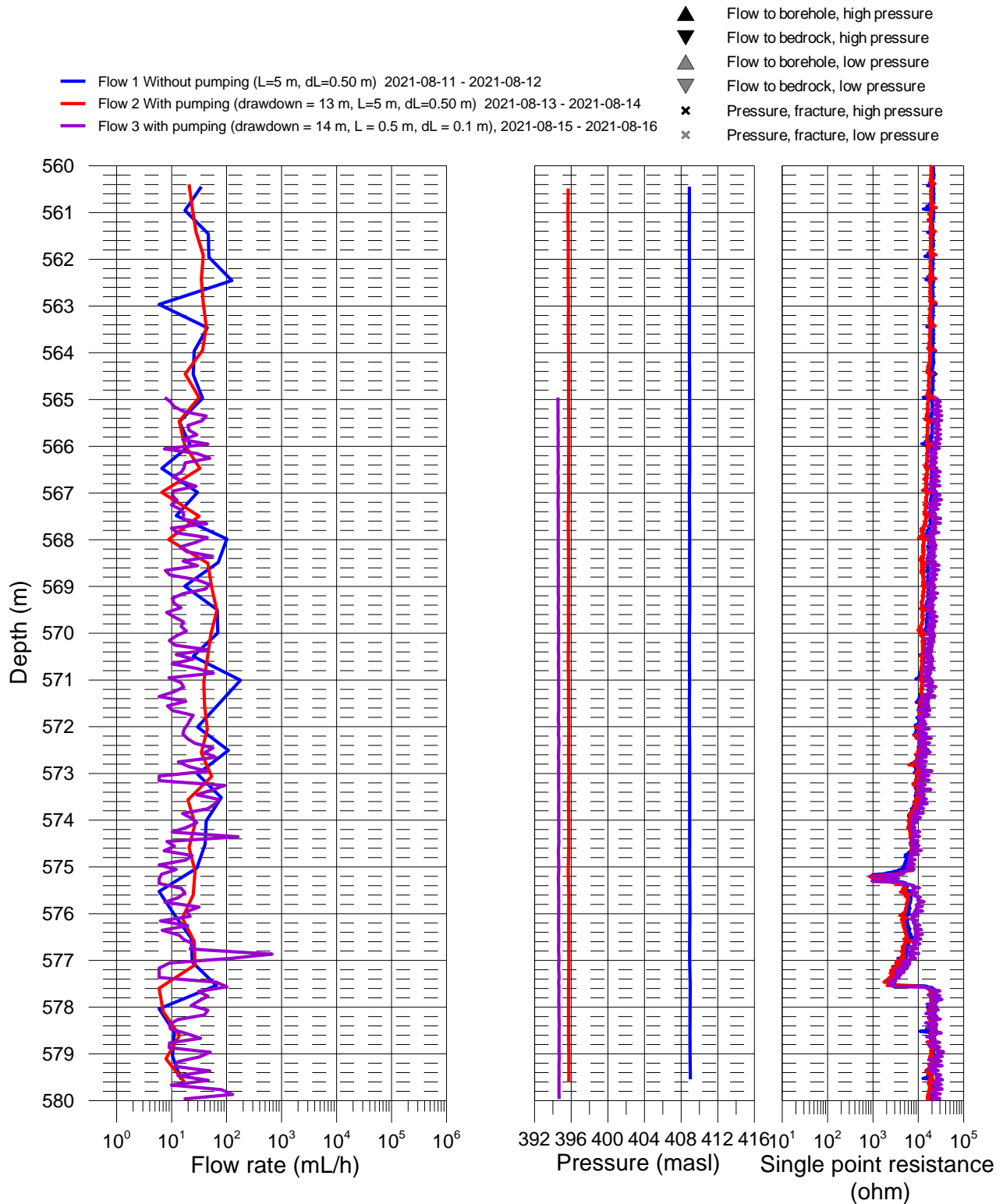


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Flow rate, pressure and single point resistance



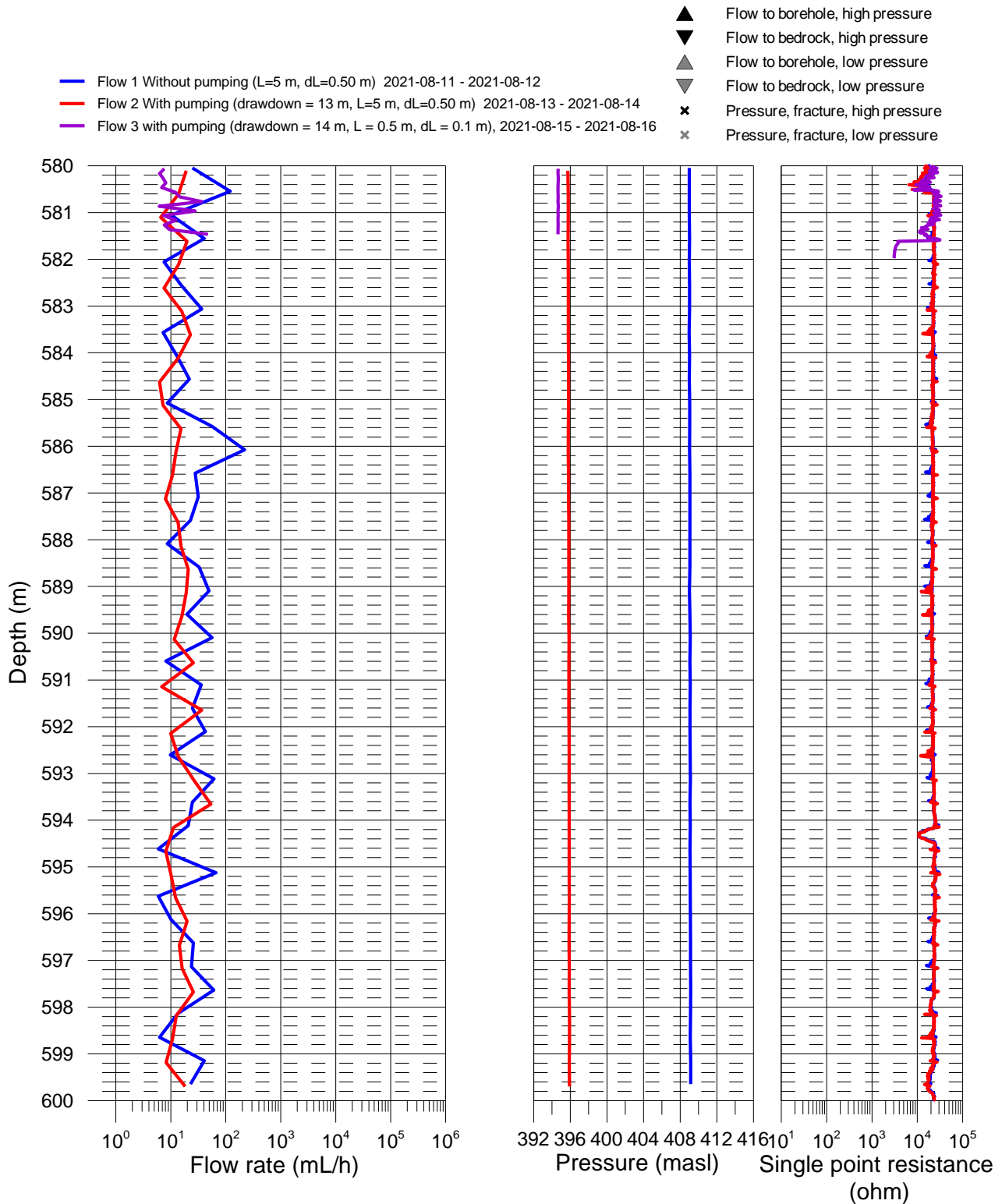
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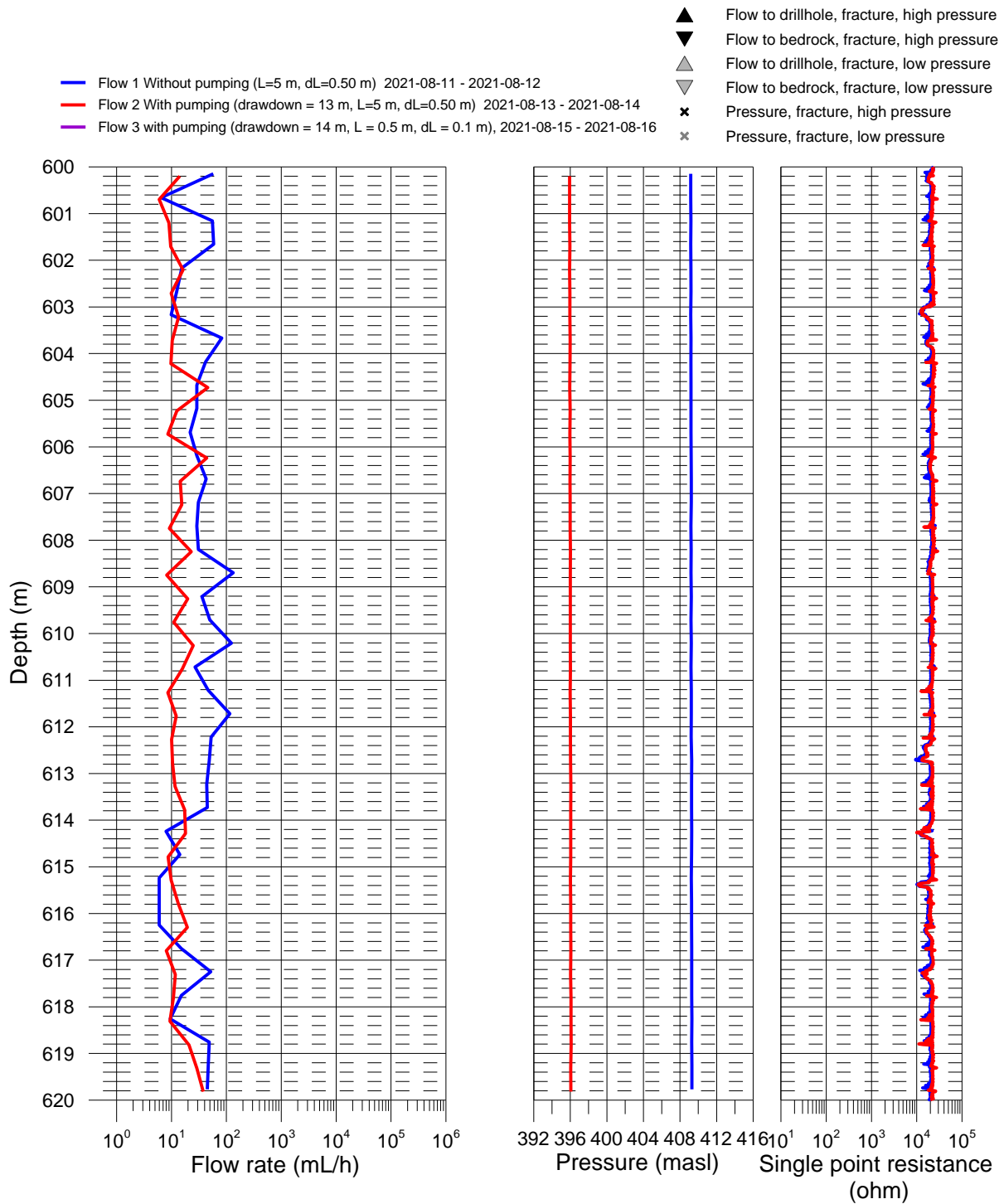
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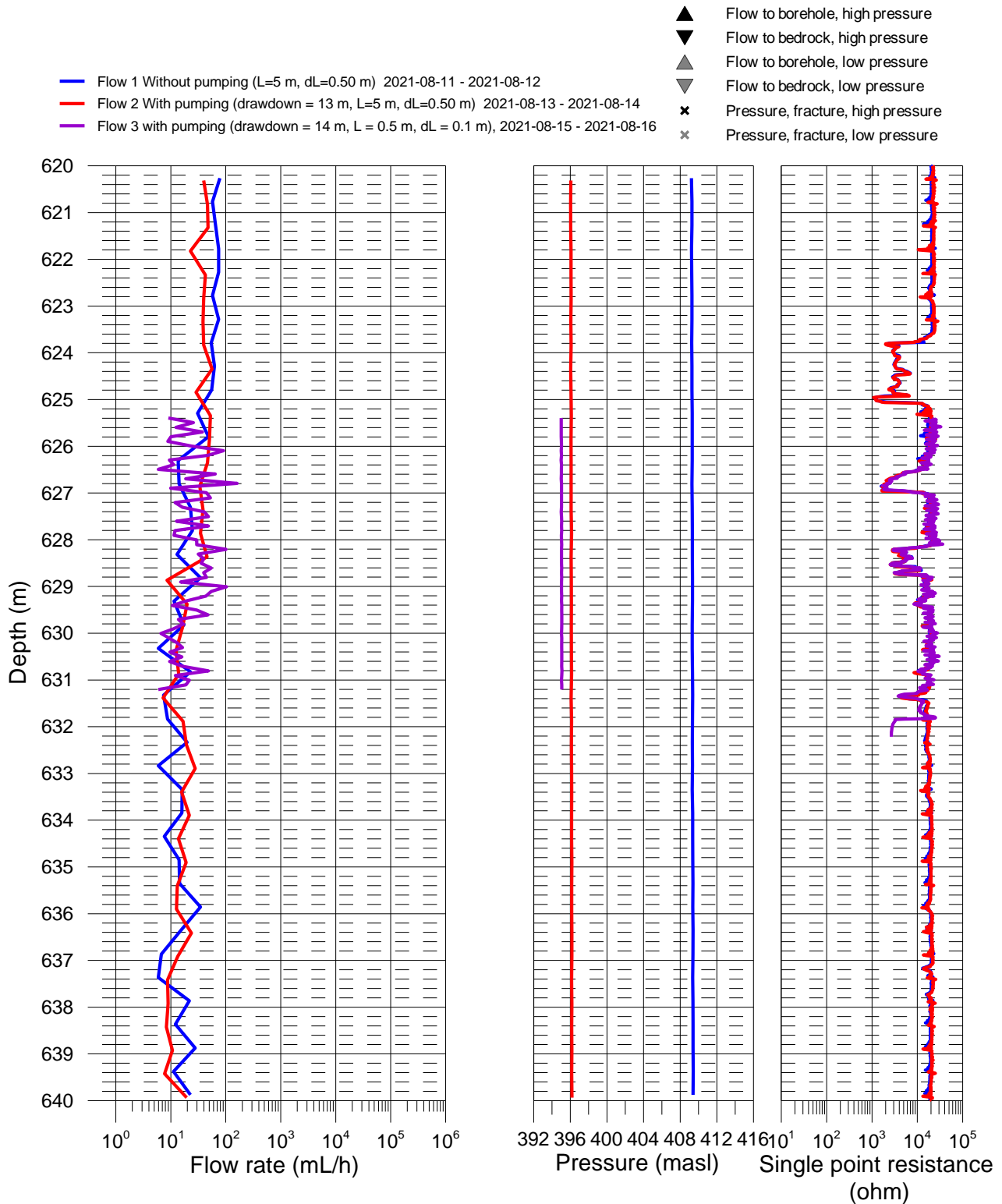
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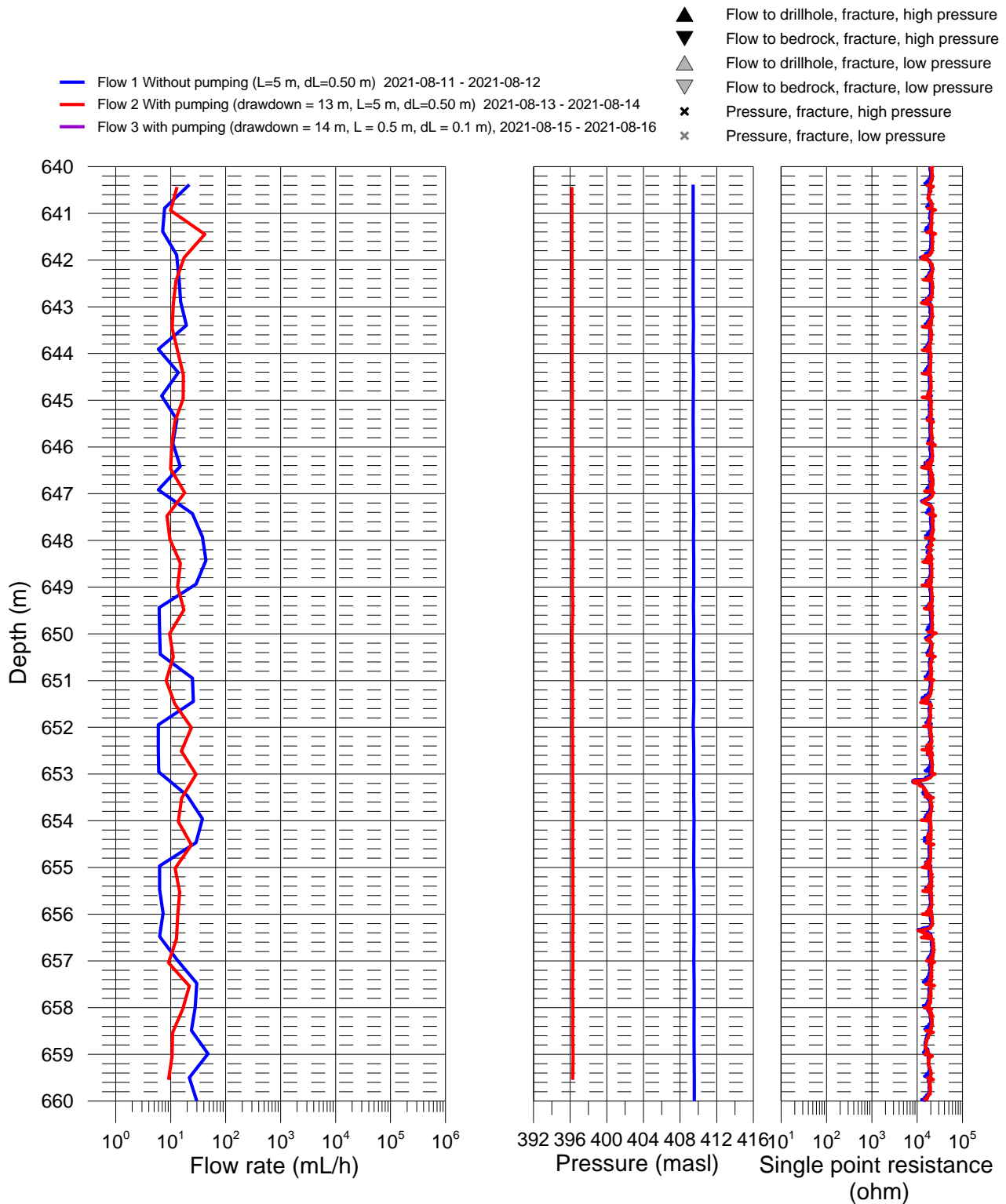


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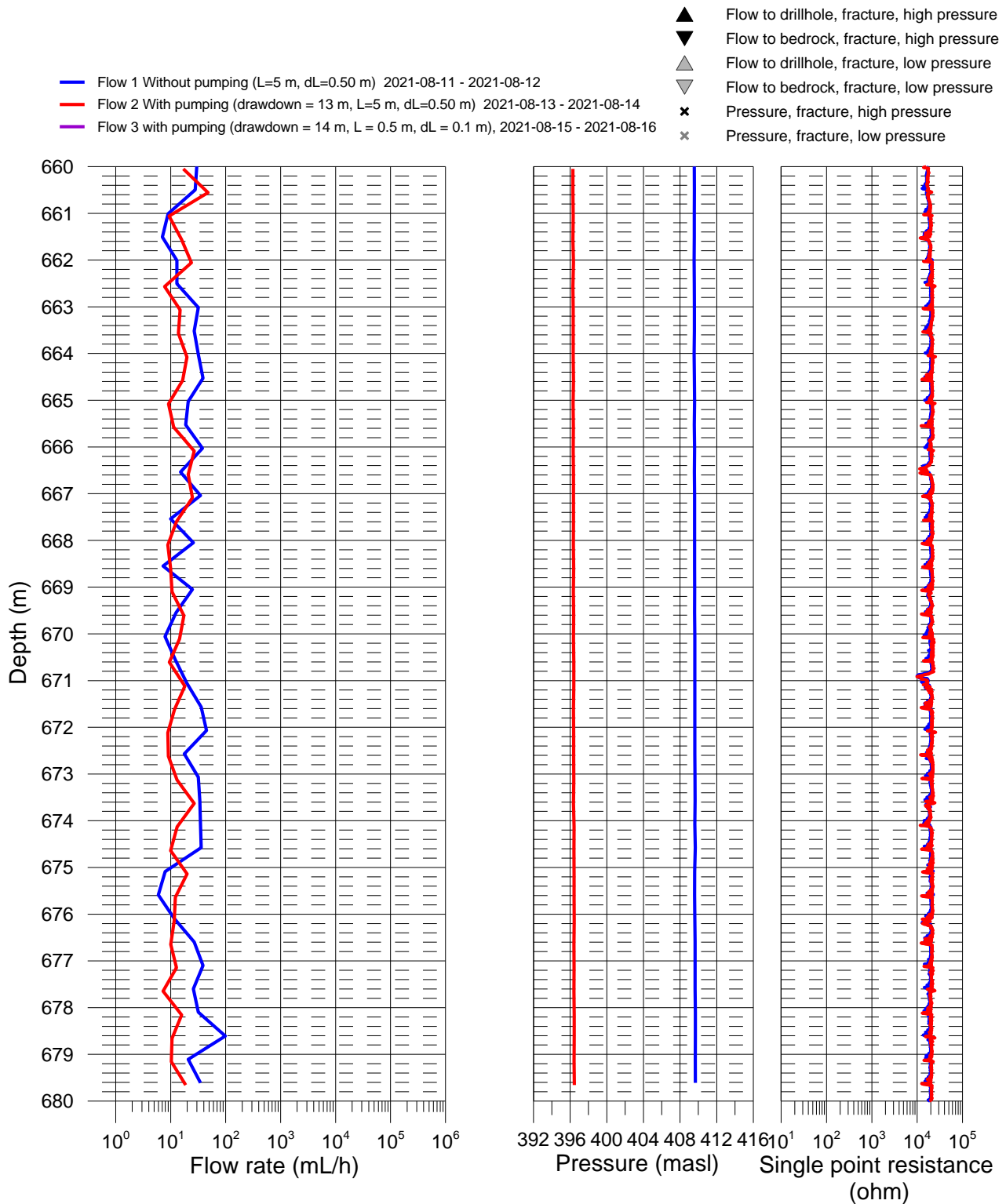
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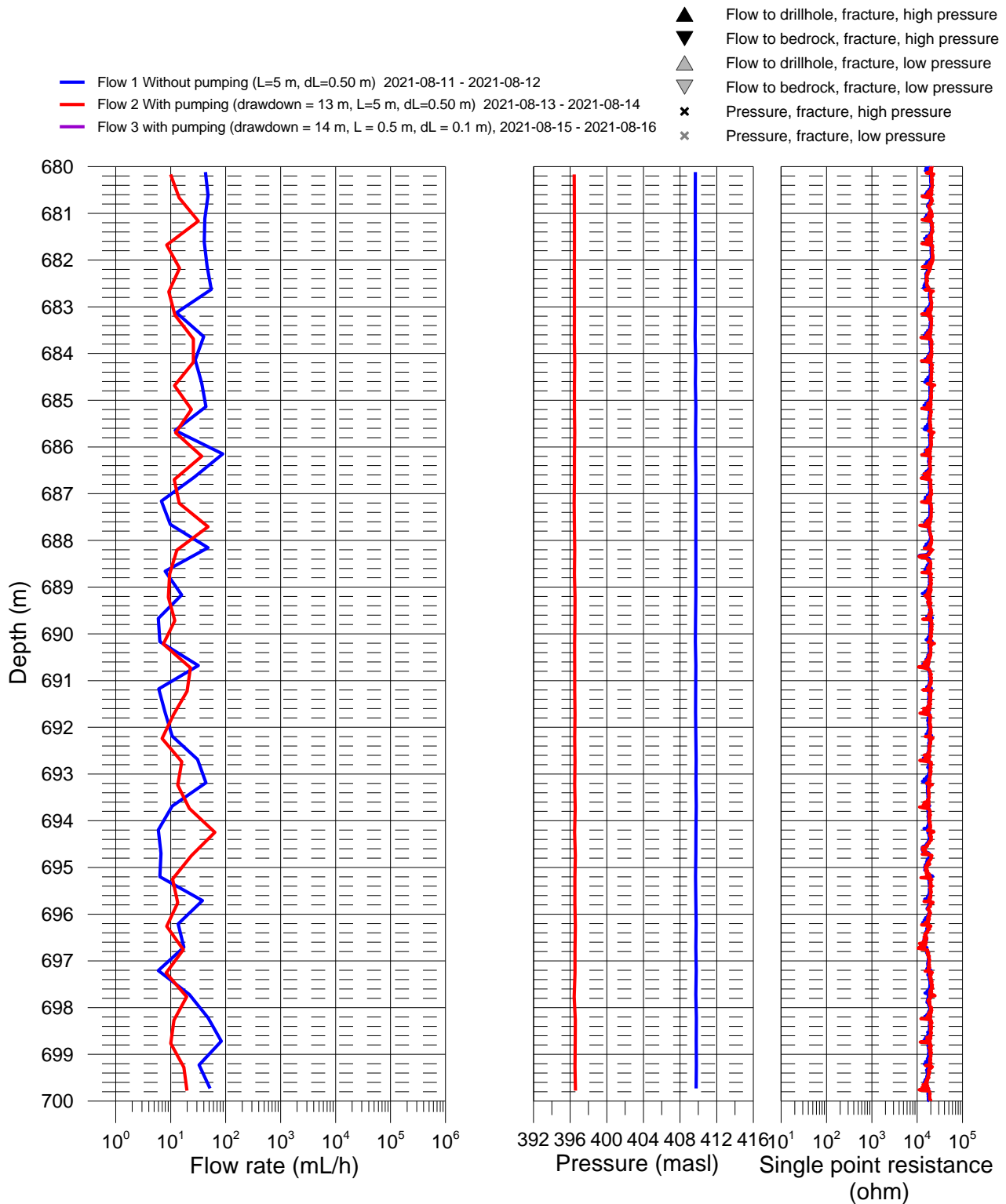
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Flow rate, pressure and single point resistance



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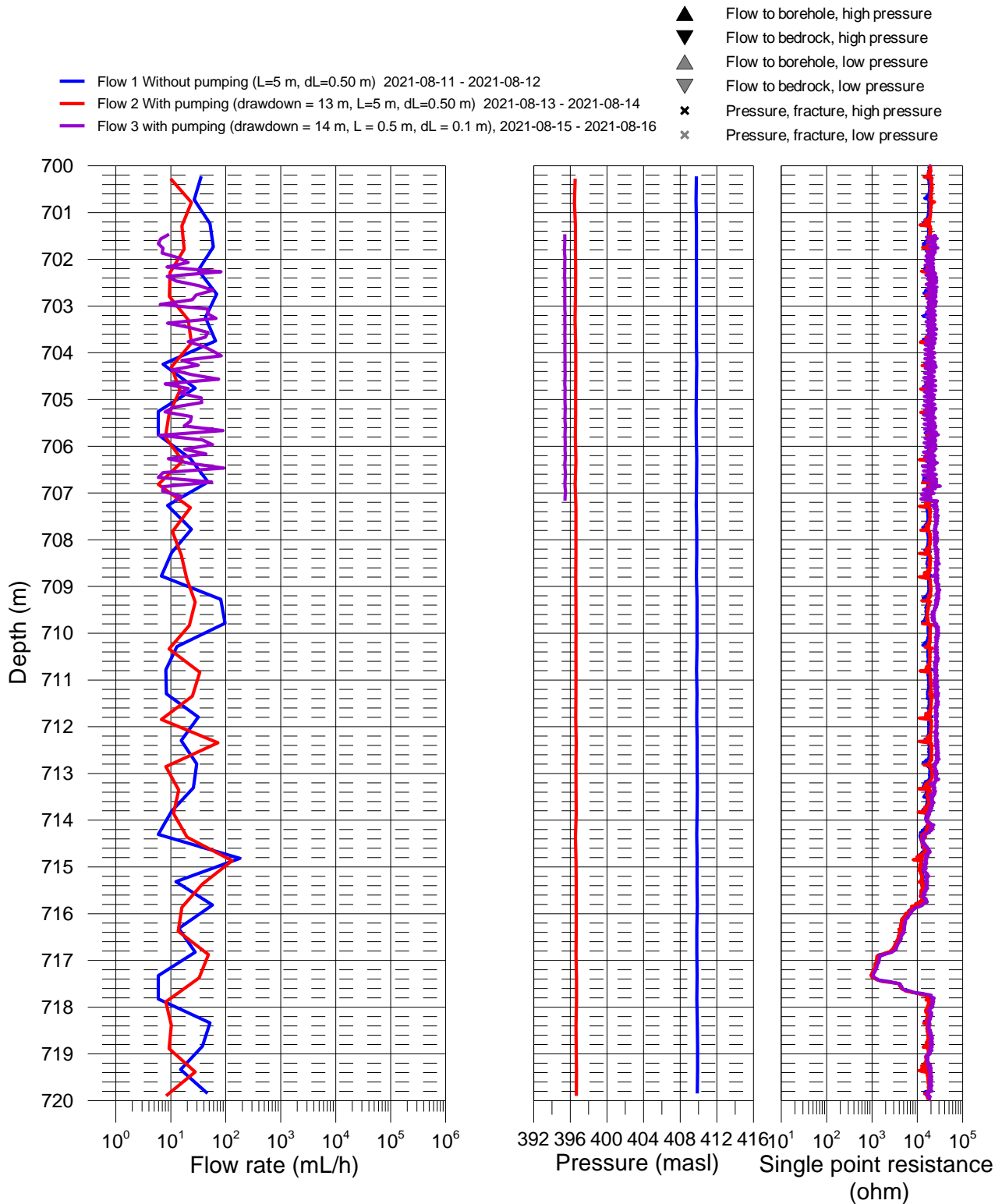
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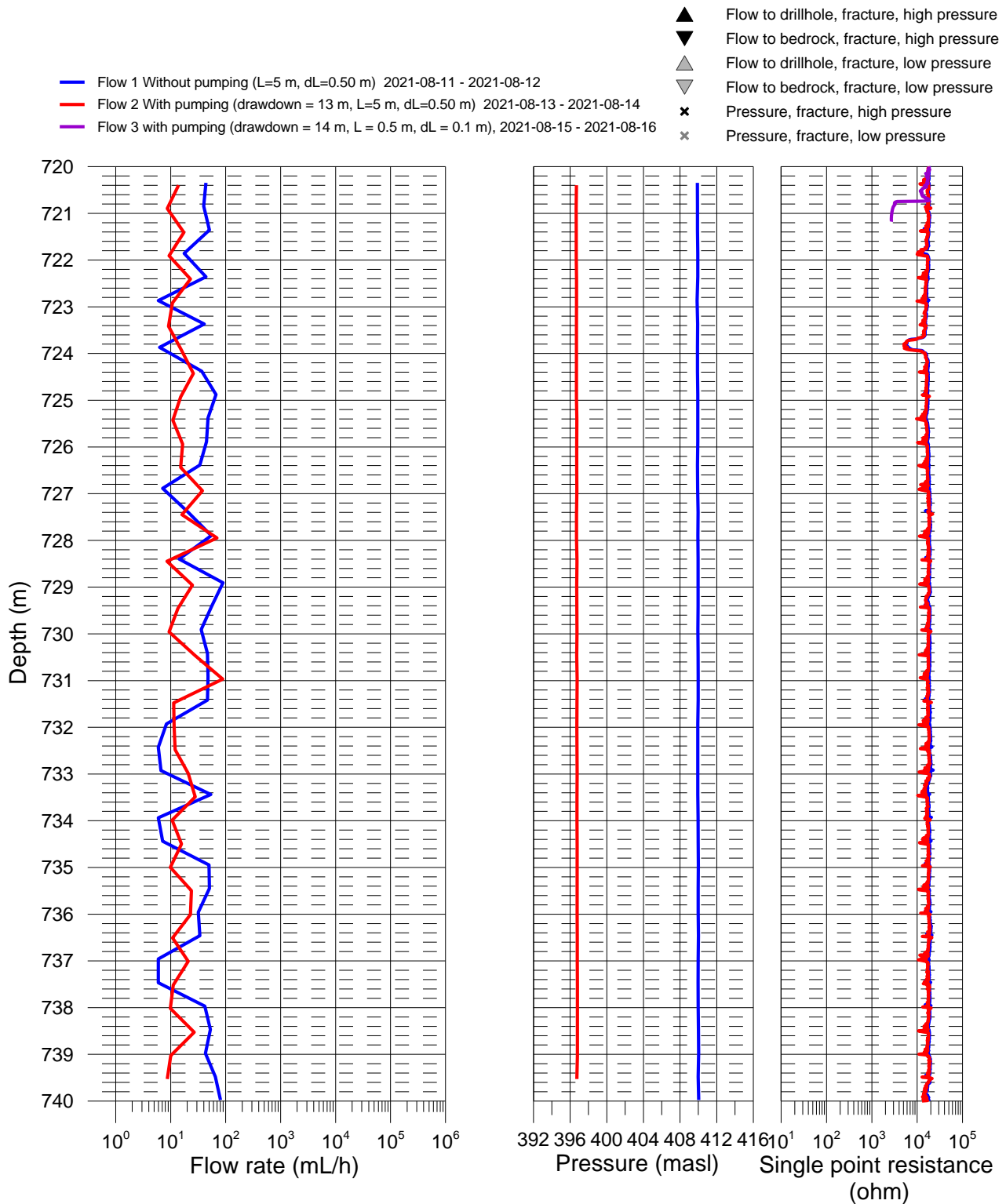


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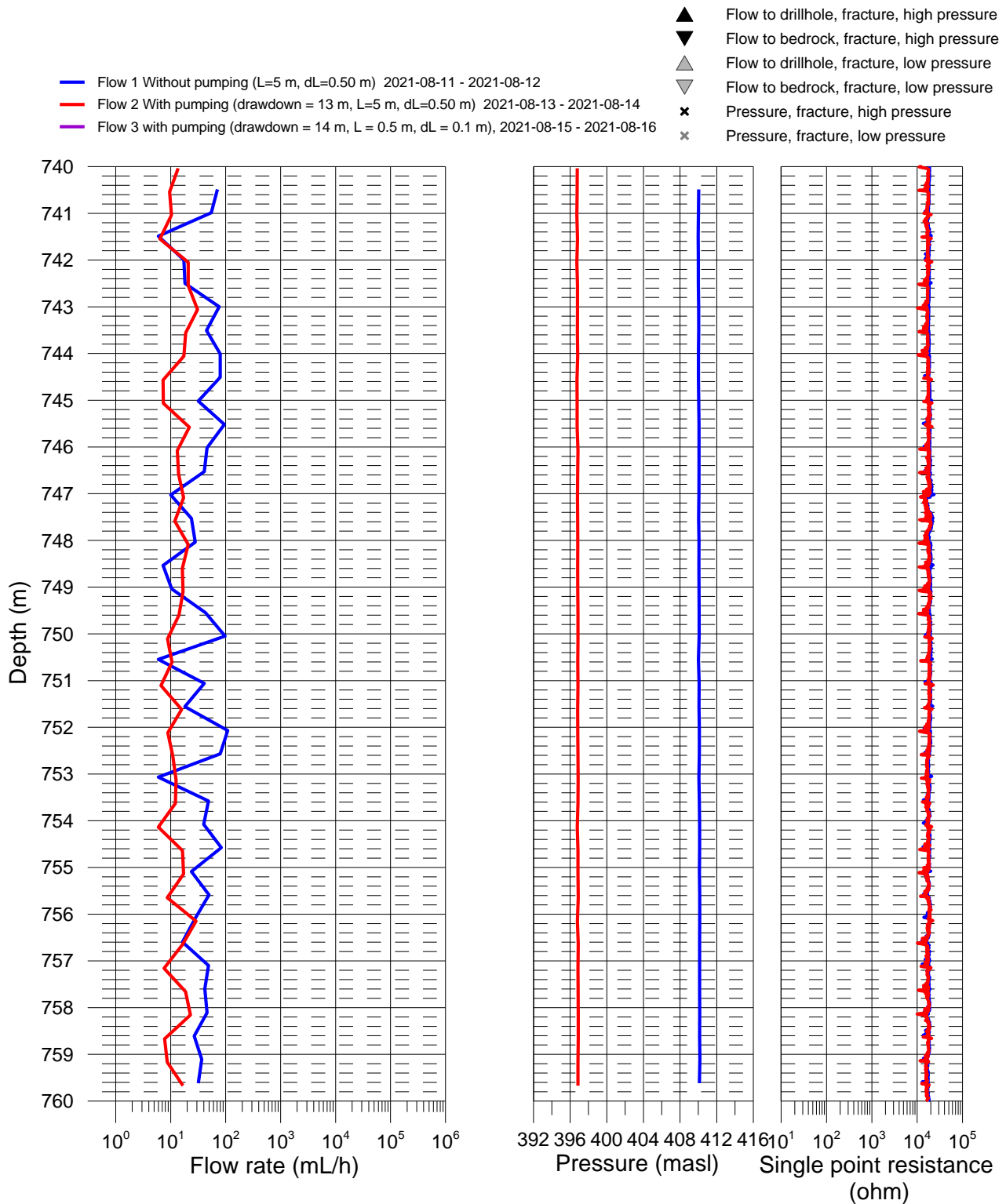
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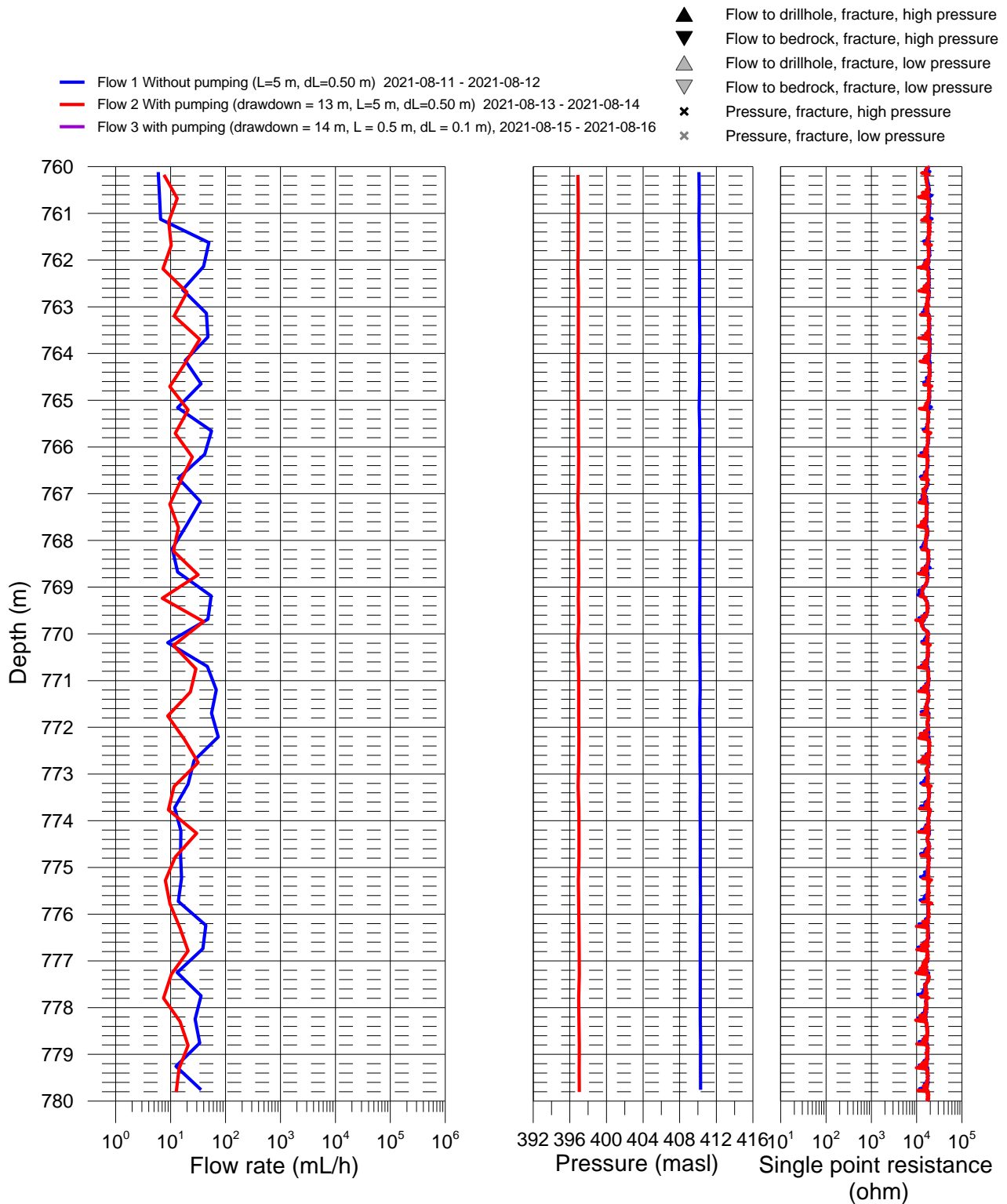
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Flow rate, pressure and single point resistance

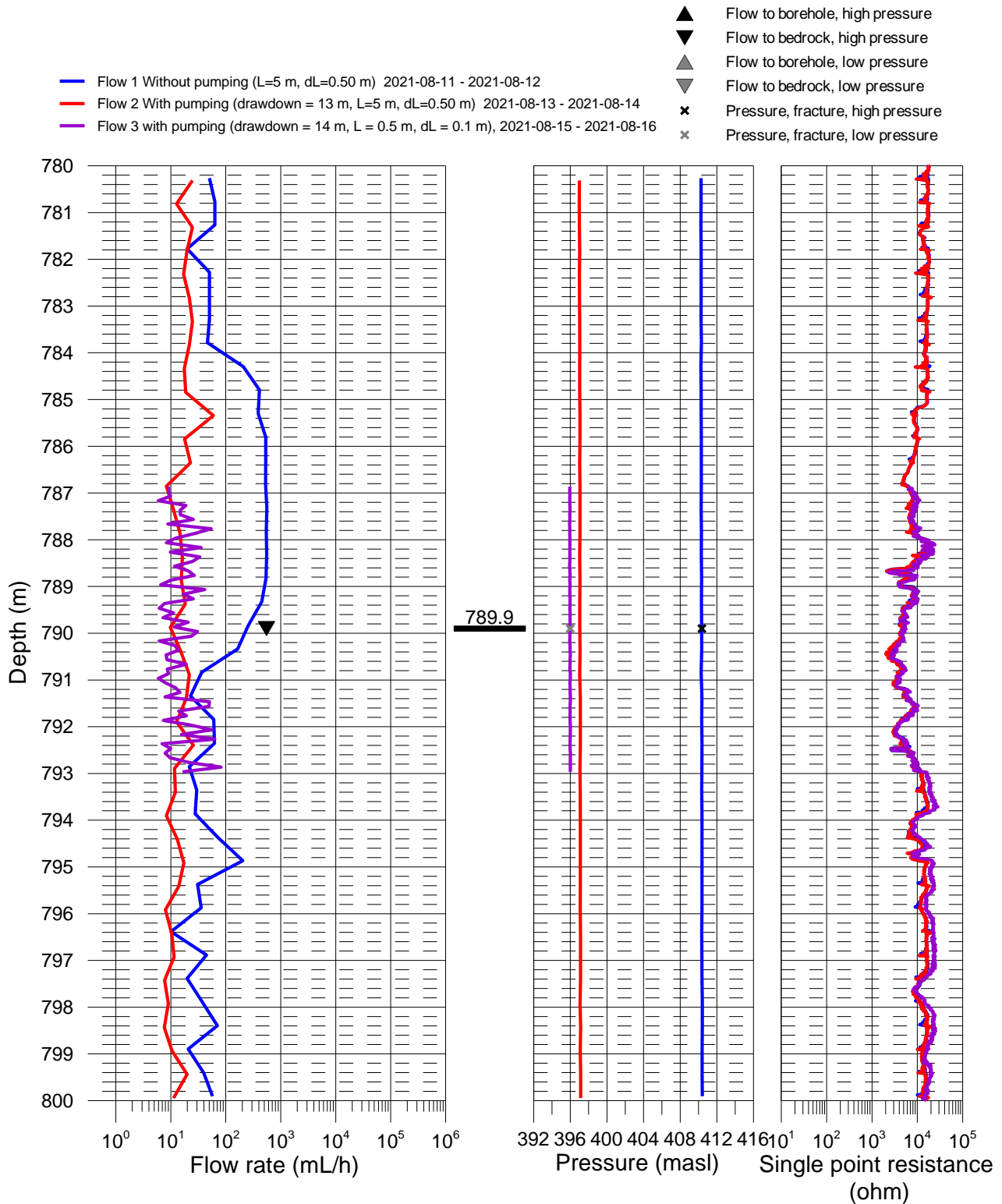


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Flow rate, pressure and single point resistance

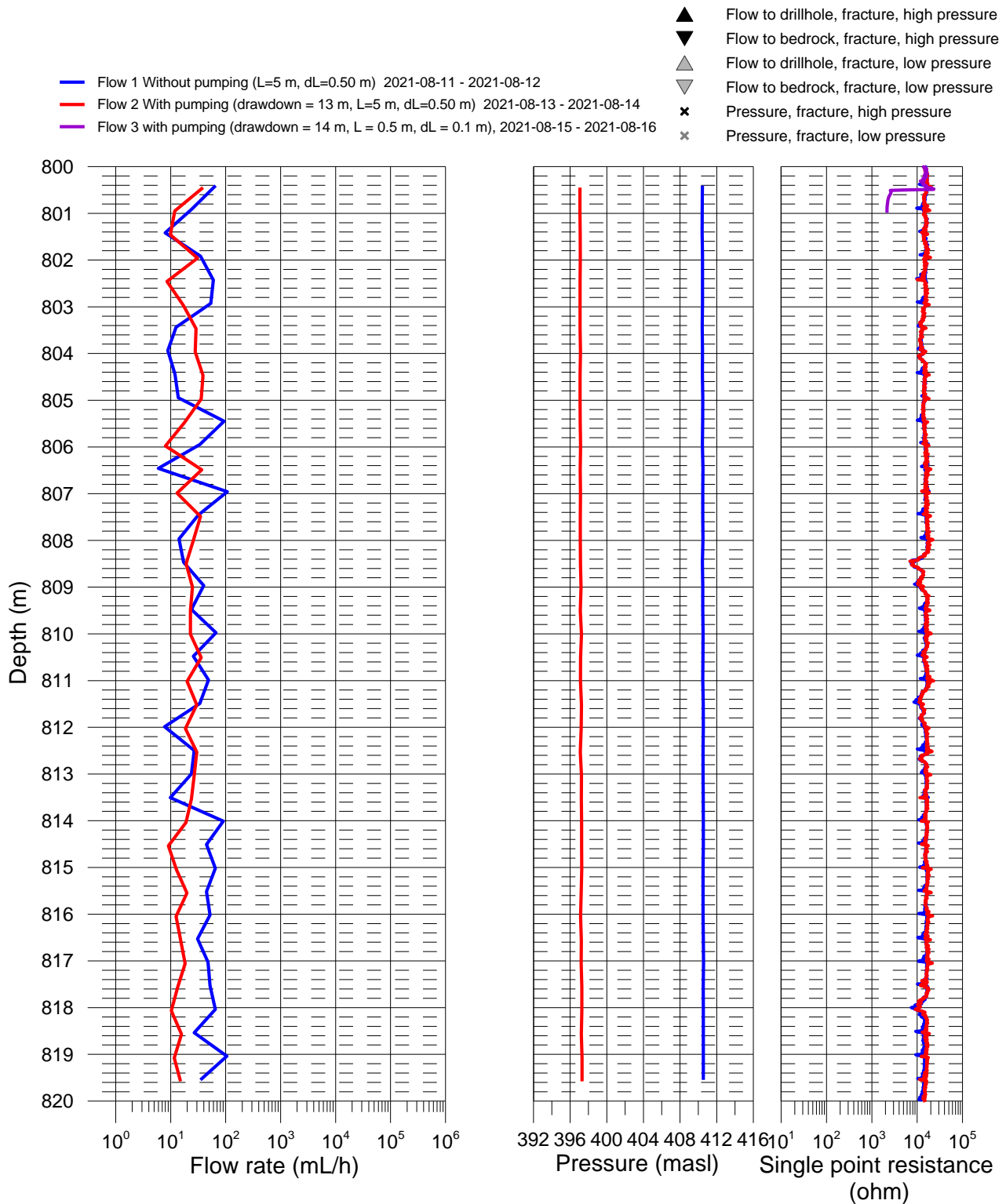


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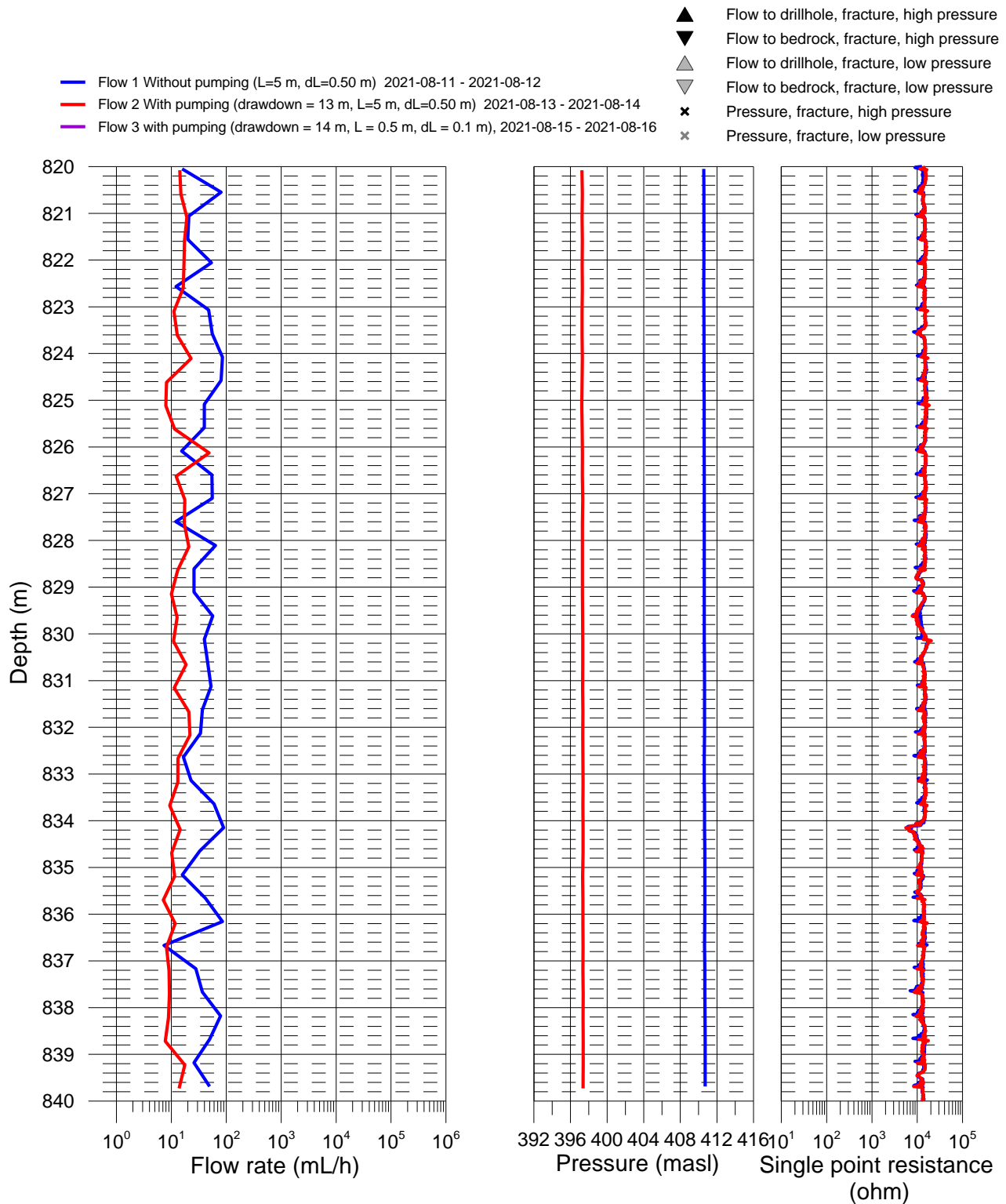
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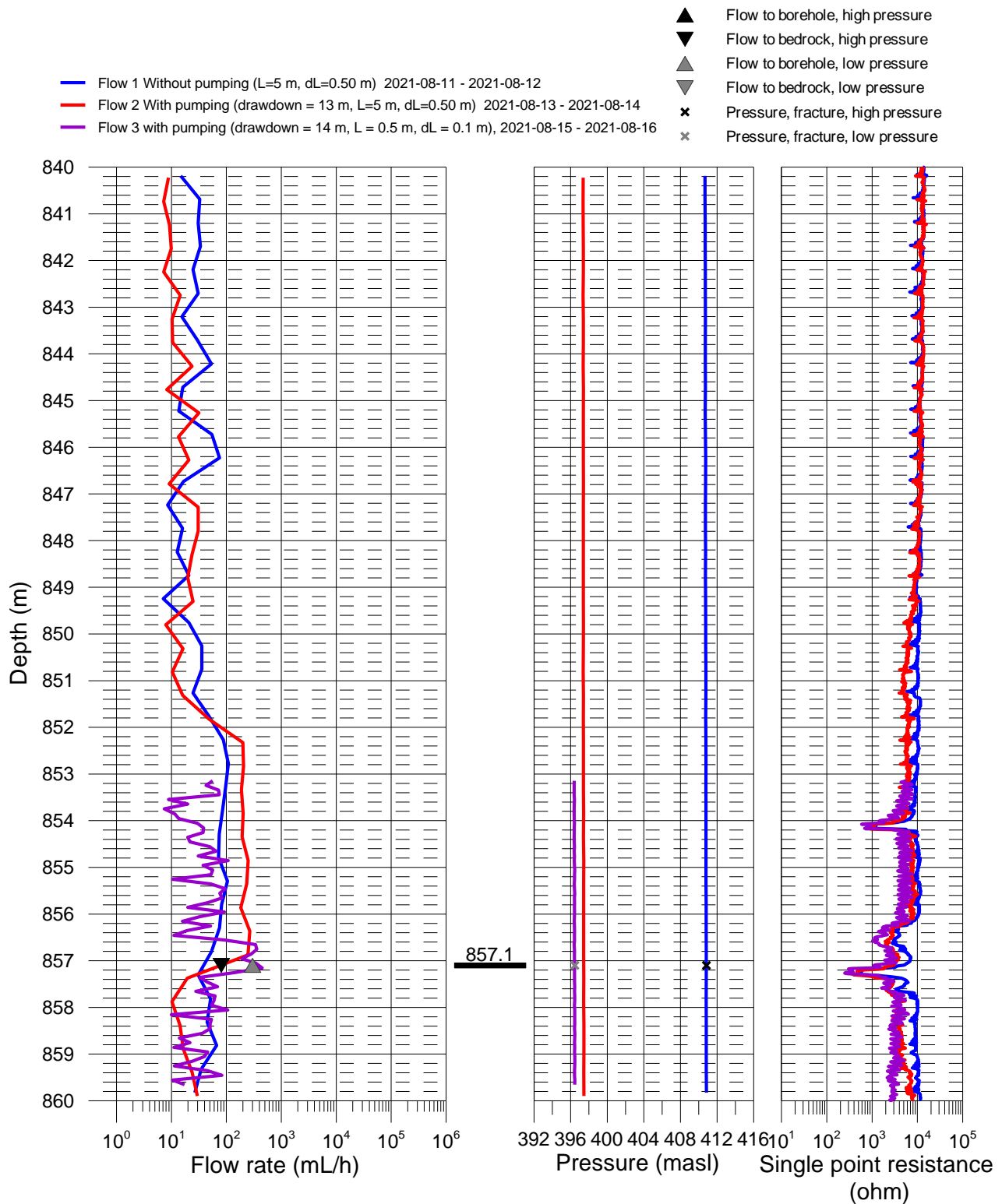
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Flow rate, pressure and single point resistance



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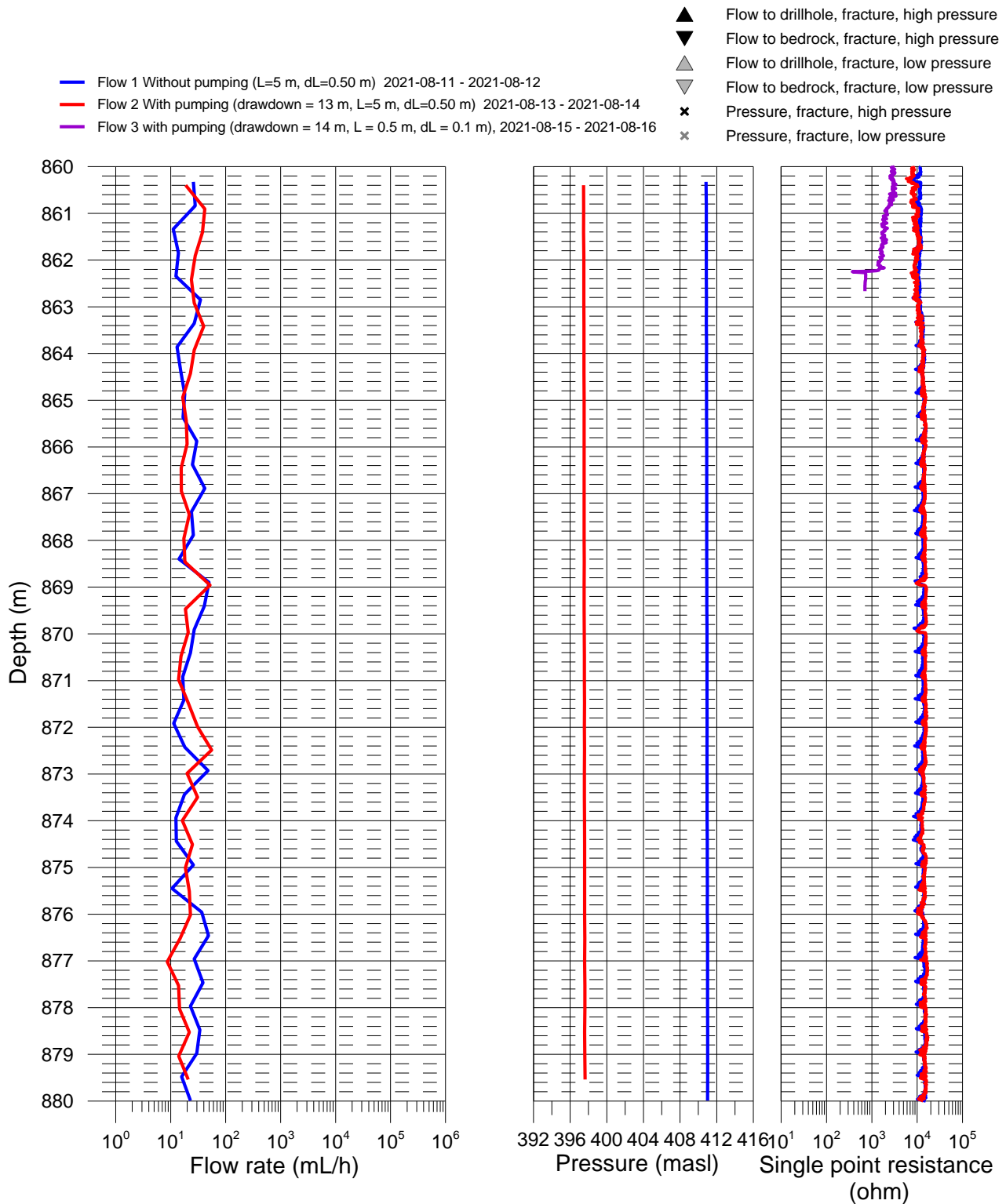


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Flow rate, pressure and single point resistance

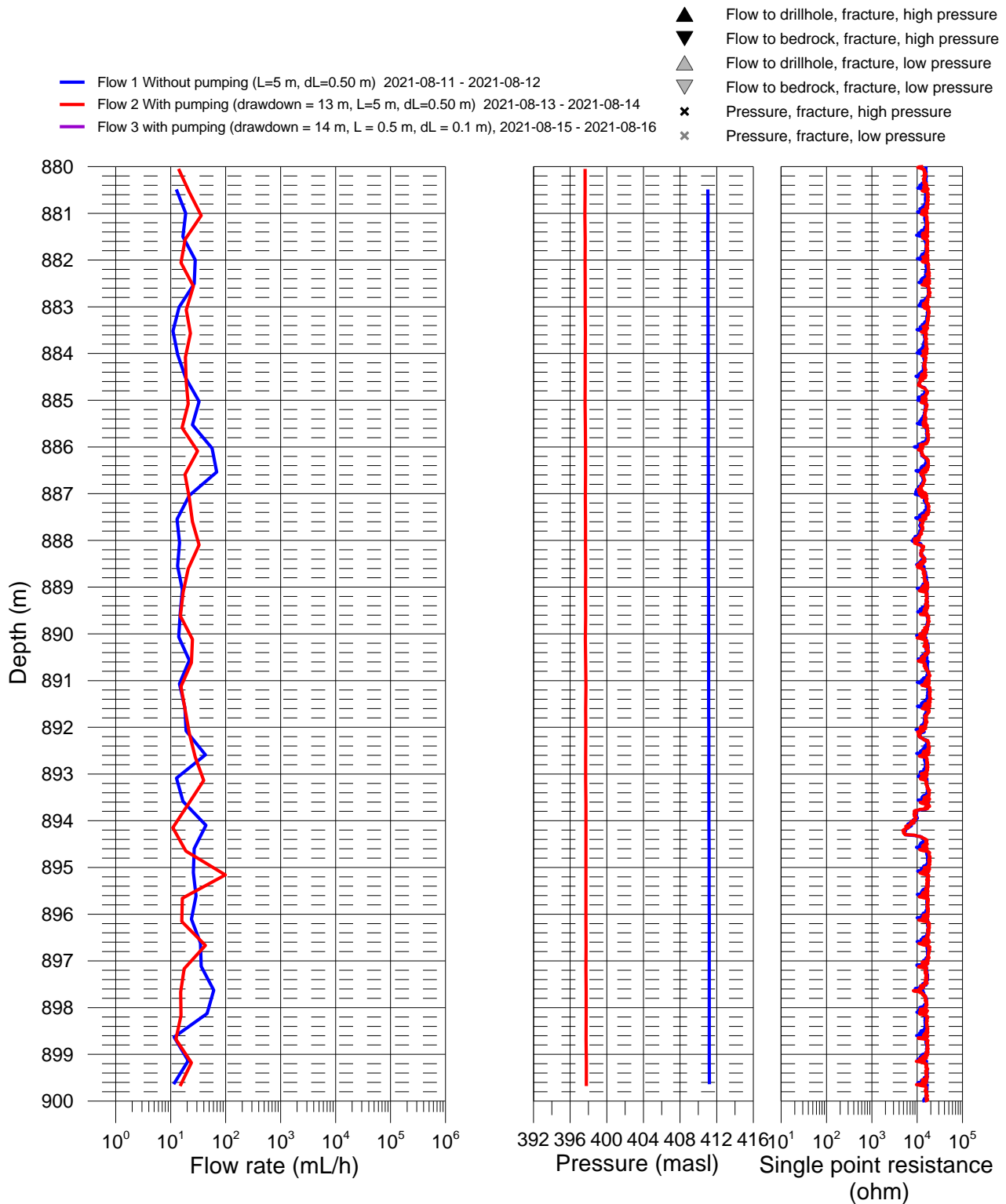




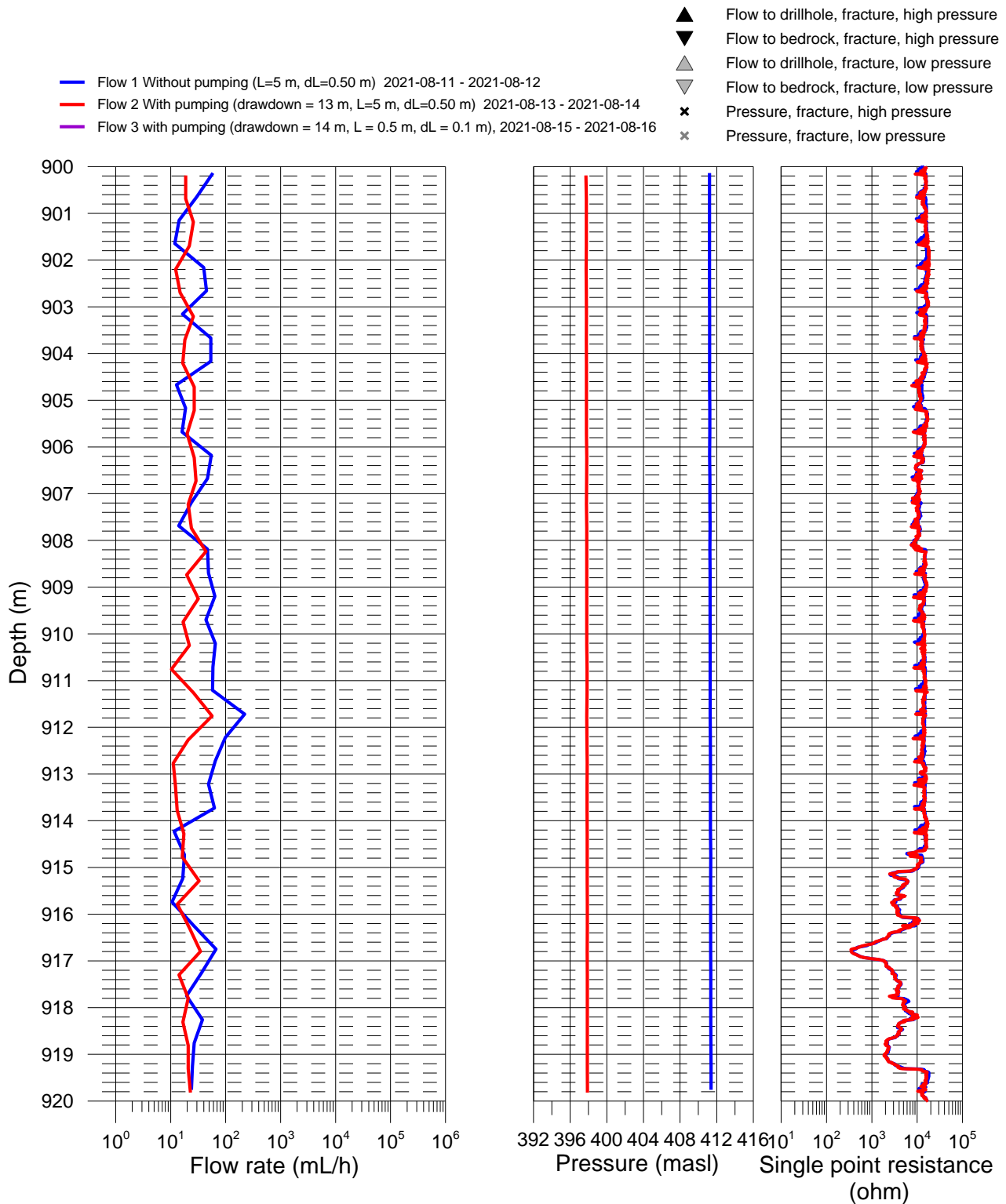
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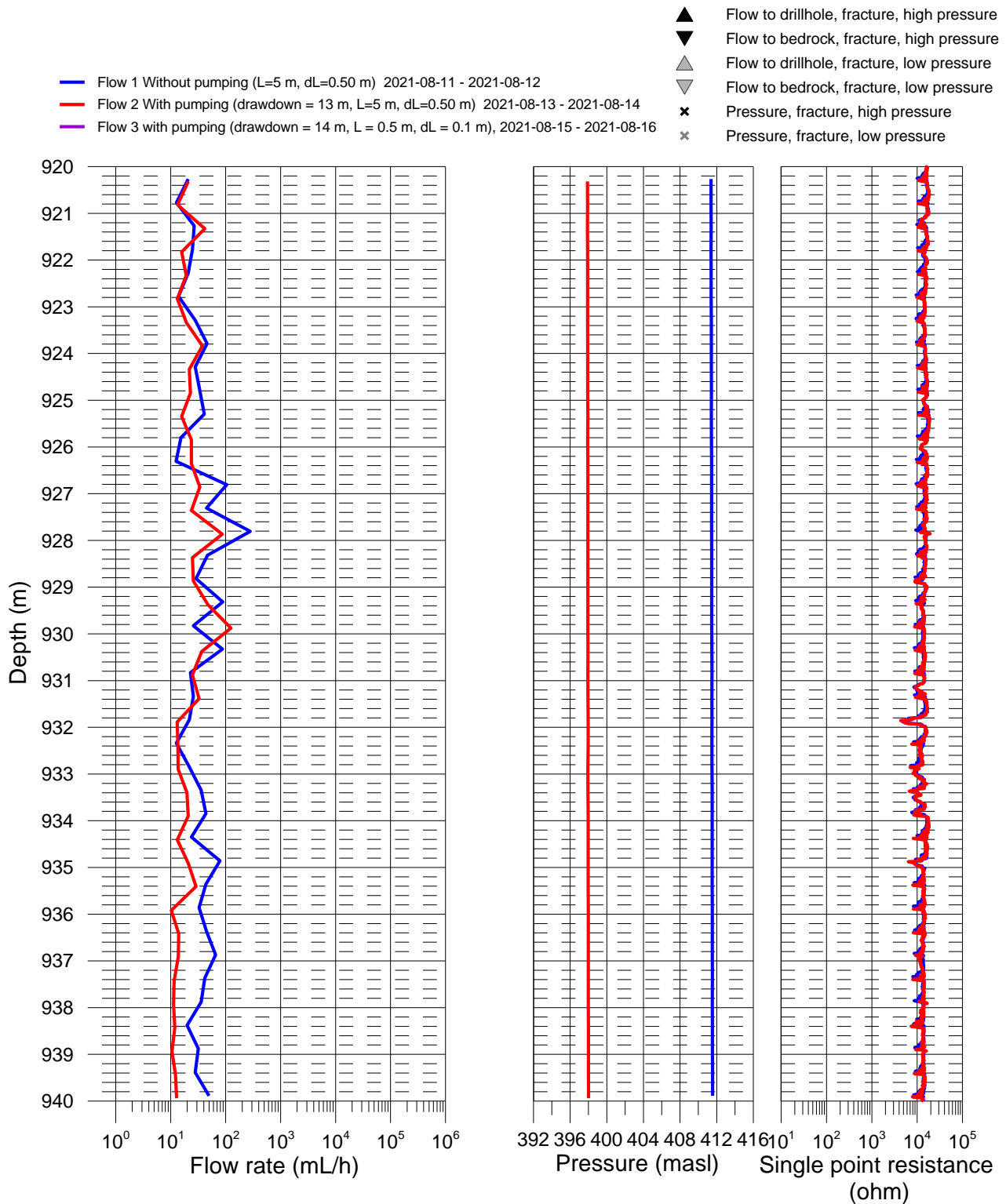
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Flow rate, pressure and single point resistance



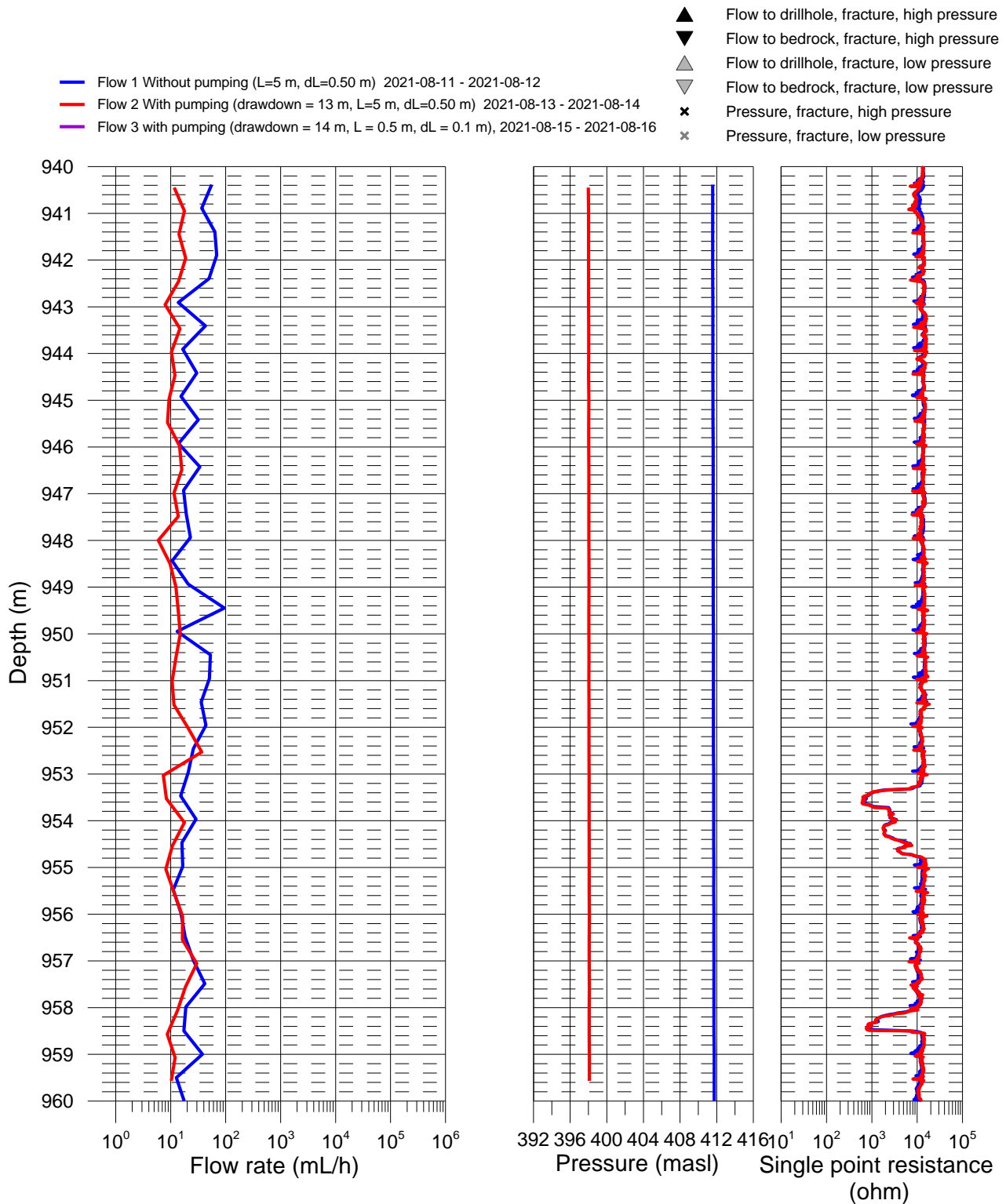
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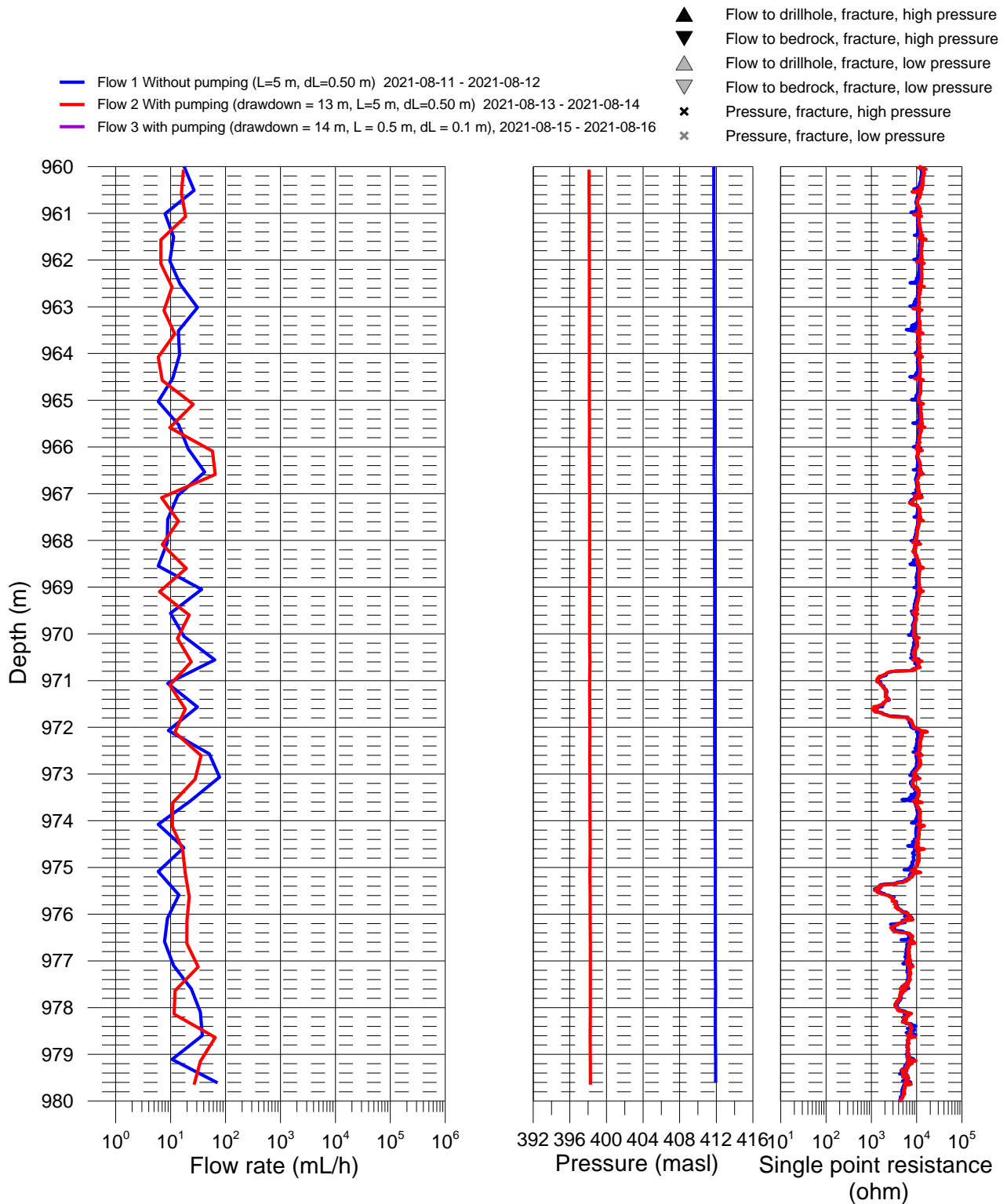
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Ignace, borehole IG\_BH05  
Flow rate, pressure and single point resistance

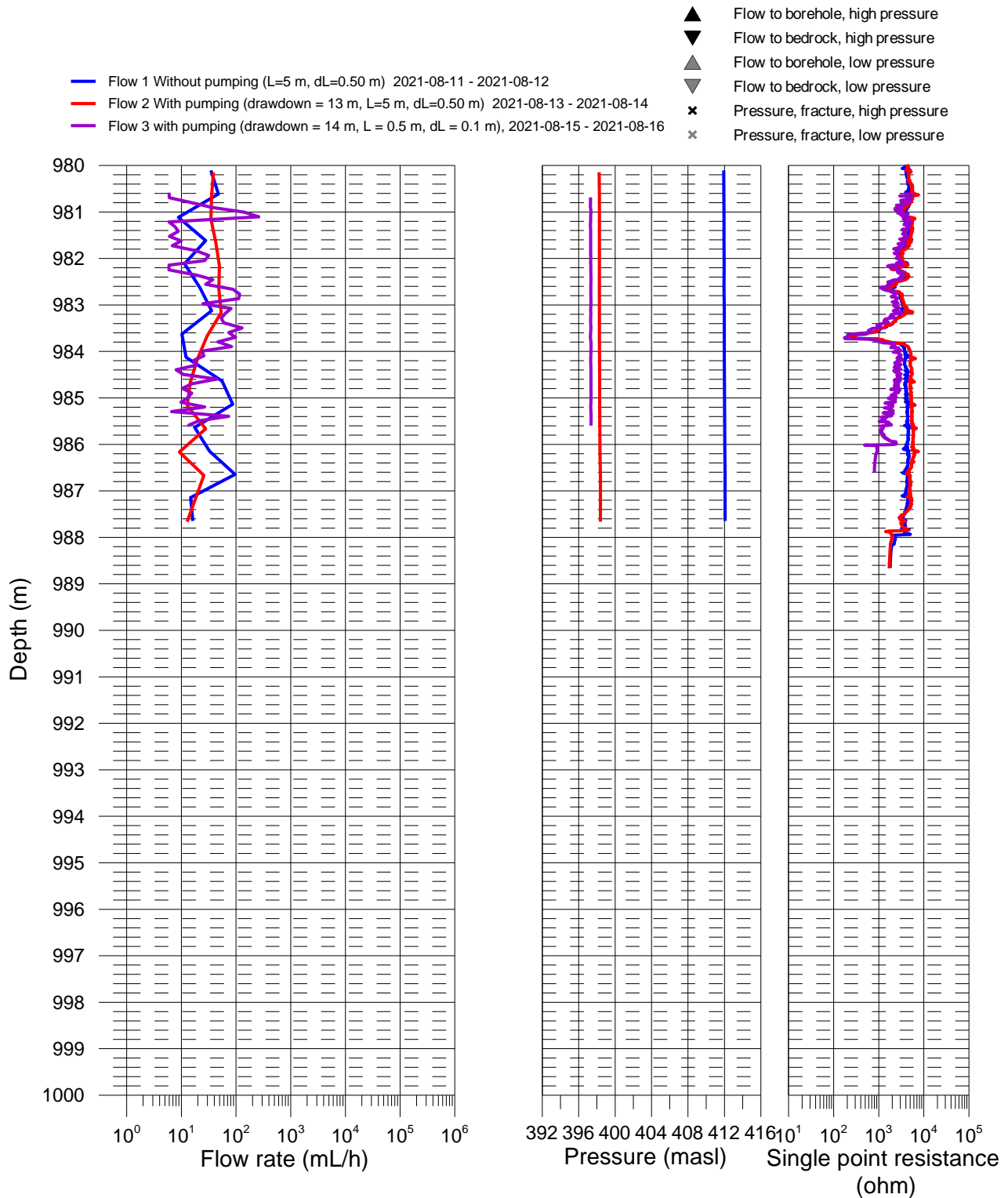


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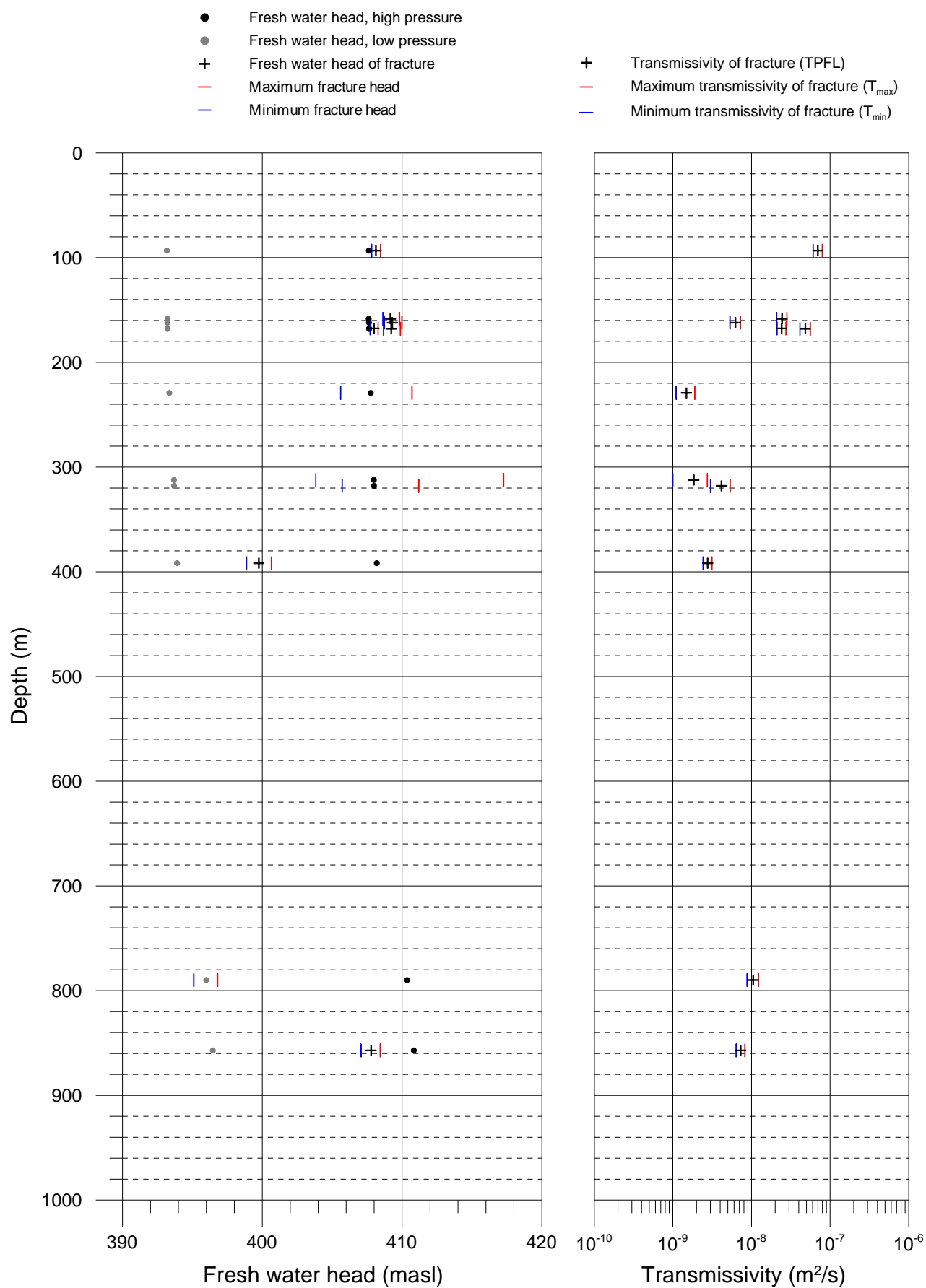


# Ignace, borehole IG\_BH05

## Flow rate, pressure and single point resistance



Ignace, borehole IG\_BH05  
Transmissivity and head of detected fractures





## Ignace, borehole IG\_BH05

### Table of transmissivity and head of detected fractures

Description of columns:

**Length (m)** = Distance from the reference to the fracture (m)

**FW Head<sub>H</sub> (masl)** = Fresh water head in the drillhole (meter above sea level), higher drillhole pressure

**Flow<sub>H</sub> (mL/h)** = Flow rate of the fracture, higher drillhole pressure

**FW Head<sub>L</sub> (masl)** = Fresh water head in the drillhole (meter above sea level), lower drillhole pressure

**Flow<sub>L</sub> (mL/h)** = Flow rate of the fracture, lower drillhole pressure

**T<sub>PFL</sub> (m<sup>2</sup>/s)** = Transmissivity of the fracture

**FW Head of fracture (masl)** = Fresh water head of the fracture

**T<sub>max</sub> (m<sup>2</sup>/s)** = Upper limit for T<sub>PFL</sub> based on uncertainty in flow and pressure measurements

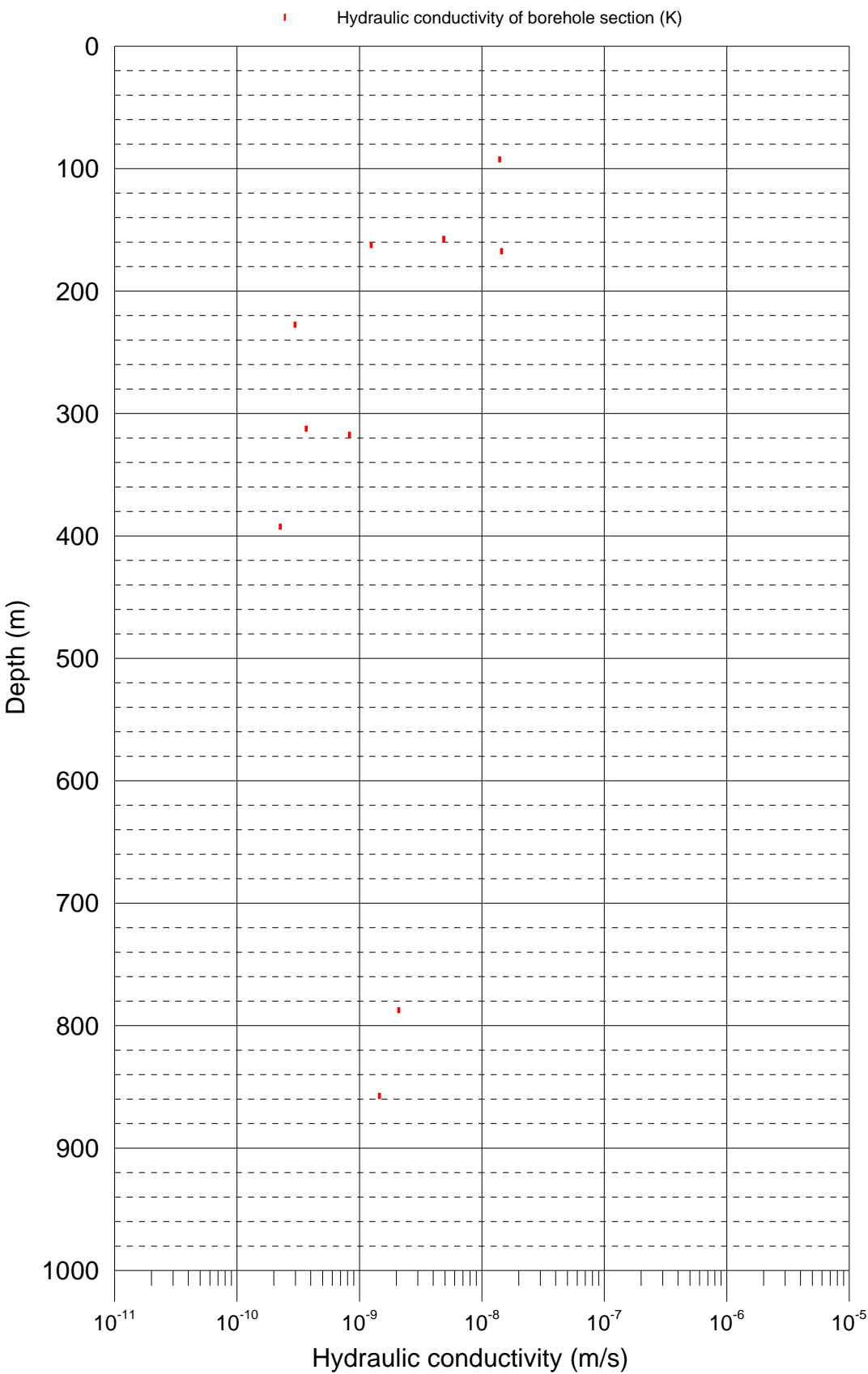
**T<sub>min</sub> (m<sup>2</sup>/s)** = Lower limit for T<sub>PFL</sub> based on uncertainty in flow and pressure measurements

**FW HeadOff<sub>max</sub> (masl)** = Upper limit for FW head of fracture based on uncertainty in flow and pressure measurements

**FW HeadOff<sub>min</sub> (masl)** = Lower limit for FW head of fracture based on uncertainty in flow and pressure measurements

| Length<br>(m) | FW<br>Head <sub>H</sub><br>(masl) | Flow <sub>H</sub><br>(mL/h) | FW<br>Head <sub>L</sub><br>(masl) | Flow <sub>L</sub><br>(mL/h) | T <sub>PFL</sub><br>(m <sup>2</sup> /s) | FW<br>Head of<br>fracture<br>(masl) | T <sub>max</sub><br>(m <sup>2</sup> /s) | T <sub>min</sub> (m <sup>2</sup> /s) | FW<br>HeadOff <sub>max</sub><br>(masl) | FW<br>HeadOff <sub>min</sub><br>(masl) |
|---------------|-----------------------------------|-----------------------------|-----------------------------------|-----------------------------|---|-------------------------------------|---|--------------------------------------|--|--|
| 93.3          | 407.62                            | 130                         | 393.17                            | 3810                        | 7.00E-08                                | 408.13                              | 7.97E-08                                | 6.08E-08                             | 408.47                                 | 407.82                                 |
| 158.4         | 407.61                            | 139                         | 393.22                            | 1420                        | 2.45E-08                                | 409.17                              | 2.82E-08                                | 2.09E-08                             | 409.82                                 | 408.63                                 |
| 162.1         | 407.63                            | 38                          | 393.21                            | 366                         | 6.25E-09                                | 409.30                              | 7.22E-09                                | 5.33E-09                             | 409.98                                 | 408.73                                 |
| 167.6         | 407.64                            | 31                          | 393.23                            | 1300                        | 2.42E-08                                | 407.99                              | 2.75E-08                                | 2.11E-08                             | 408.28                                 | 407.72                                 |
| 168.0         | 407.64                            | 279                         | 393.22                            | 2820                        | 4.84E-08                                | 409.22                              | 5.59E-08                                | 4.14E-08                             | 409.88                                 | 408.67                                 |
| 229.2         | 407.76                            | ±10                         | 393.35                            | 78                          | 1.49E-09                                | -                                   | 1.90E-09                                | 1.10E-09                             | 410.71                                 | 405.61                                 |
| 312.3         | 407.98                            | ±30                         | 393.68                            | 96                          | 1.84E-09                                | -                                   | 2.74E-09                                | 9.98E-10                             | 417.26                                 | 403.83                                 |
| 318.0         | 407.99                            | ±30                         | 393.69                            | 216                         | 4.15E-09                                | -                                   | 5.35E-09                                | 3.02E-09                             | 411.20                                 | 405.71                                 |
| 391.8         | 408.19                            | -85                         | 393.9                             | 59                          | 2.77E-09                                | 399.75                              | 3.13E-09                                | 2.42E-09                             | 400.66                                 | 398.88                                 |
| 789.9         | 410.36                            | -549                        | 395.99                            | ±20                         | 1.05E-08                                | -                                   | 1.23E-08                                | 8.78E-09                             | 396.80                                 | 395.10                                 |
| 857.1         | 410.84                            | -81                         | 396.46                            | 300                         | 7.28E-09                                | 407.78                              | 8.24E-09                                | 6.37E-09                             | 408.44                                 | 407.07                                 |

Ignace, borehole IG\_BH05  
Hydraulic conductivity (K) of 5 m sections



## Ignace, borehole IG\_BH05

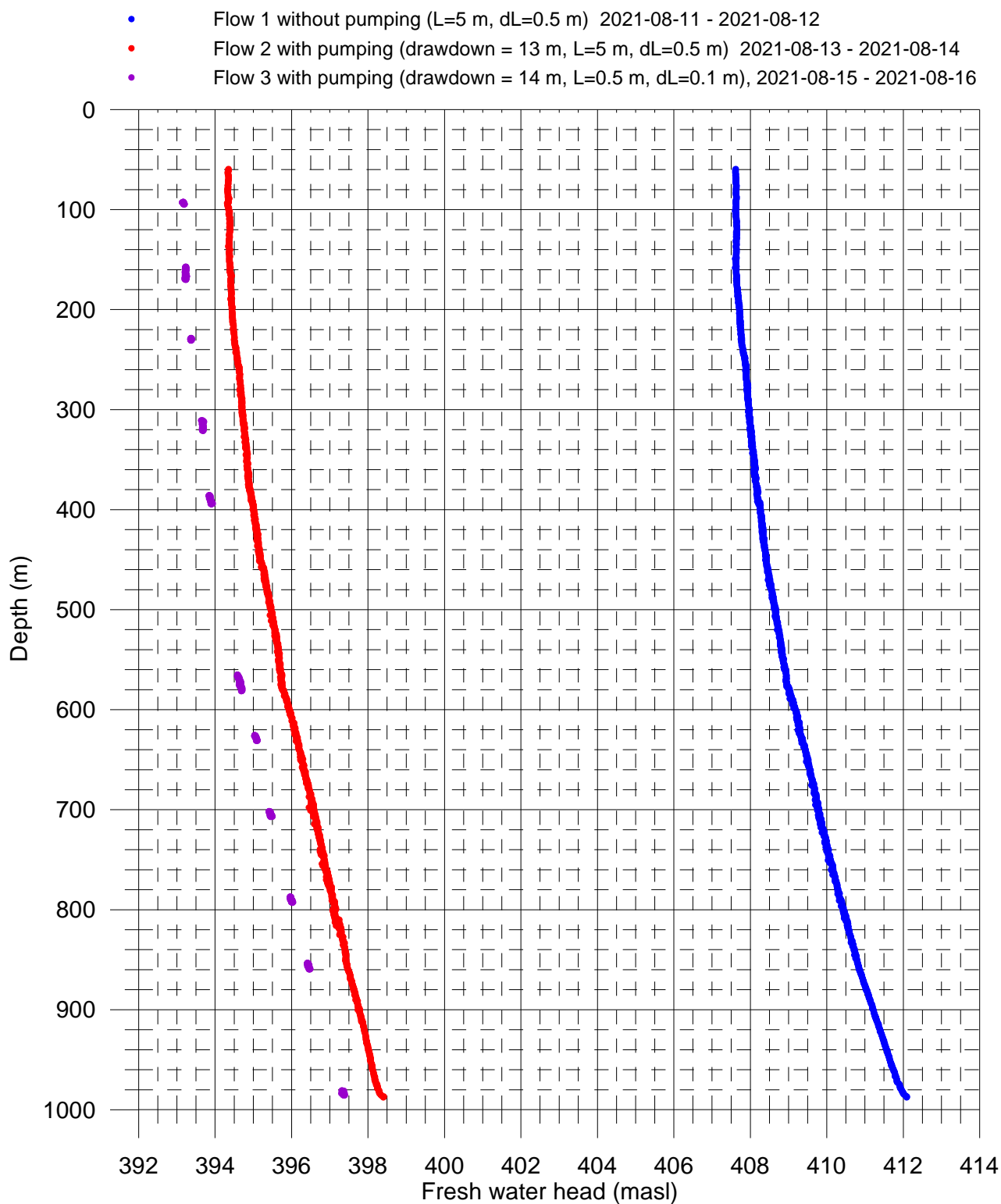
## Table of hydraulic conductivity of 5 m sections

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 (m<sup>2</sup>/s)** = Calculated transmissivity of the section**L (m)** = Length of borehole section**K (m/s)** = Calculated hydraulic conductivity of the section

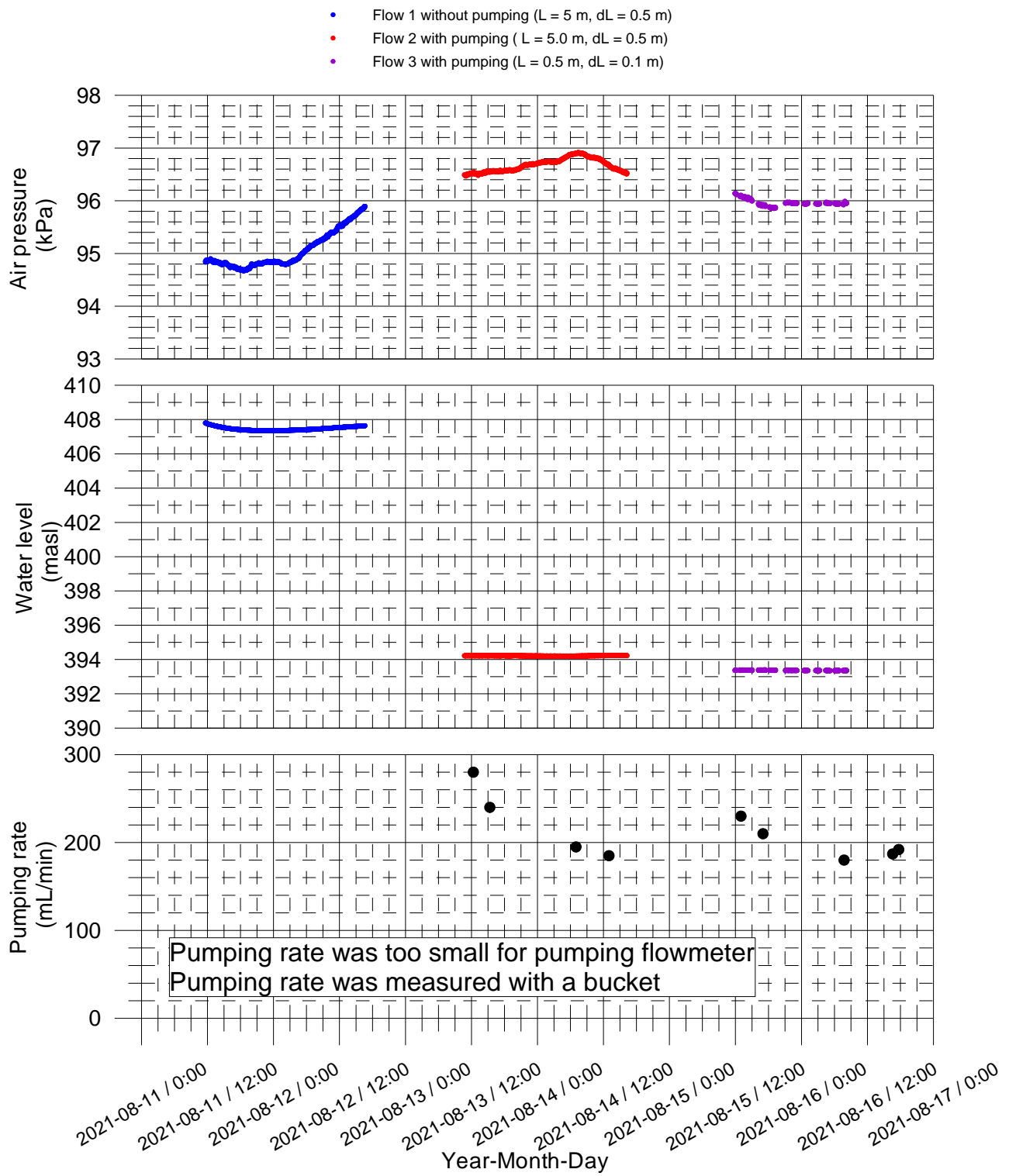
| <b>Sec Up<br/>(m)</b> | <b>Sec<br/>Low<br/>(m)</b> | <b>Tsum (m<sup>2</sup>/s)</b> | <b>L<br/>(m)</b> | <b>K (m/s)</b> | <b>Comment</b>     |
|-----------------------|----------------------------|-------------------------------|------------------|----------------|--------------------|
| 60                    | 90                         |                               |                  |                | No fractures found |
| 90                    | 95                         | 7.00E-08                      | 5                | 1.40E-08       |                    |
| 95                    | 155                        |                               |                  |                | No fractures found |
| 155                   | 160                        | 2.45E-08                      | 5                | 4.90E-09       |                    |
| 160                   | 165                        | 6.25E-09                      | 5                | 1.25E-09       |                    |
| 165                   | 170                        | 7.27E-08                      | 5                | 1.45E-08       |                    |
| 170                   | 225                        |                               |                  |                | No fractures found |
| 225                   | 230                        | 1.49E-09                      | 5                | 2.98E-10       |                    |
| 230                   | 310                        |                               |                  |                | No fractures found |
| 310                   | 315                        | 1.84E-09                      | 5                | 3.68E-10       |                    |
| 315                   | 320                        | 4.15E-09                      | 5                | 8.30E-10       |                    |
| 320                   | 390                        |                               |                  |                | No fractures found |
| 390                   | 395                        | 1.13E-09                      | 5                | 2.26E-10       |                    |
| 395                   | 785                        |                               |                  |                | No fractures found |
| 785                   | 790                        | 1.05E-08                      | 5                | 2.10E-09       |                    |
| 790                   | 855                        |                               |                  |                |                    |
| 855                   | 860                        | 7.28E-09                      | 5                | 1.46E-09       |                    |
| 860                   | 990                        |                               |                  |                | No fractures found |

### Ignace, borehole IG\_BH05 Fresh water head in the borehole



## Ignace, borehole IG\_BH05

Air pressure, water level in the borehole and pumping rate during flow logging

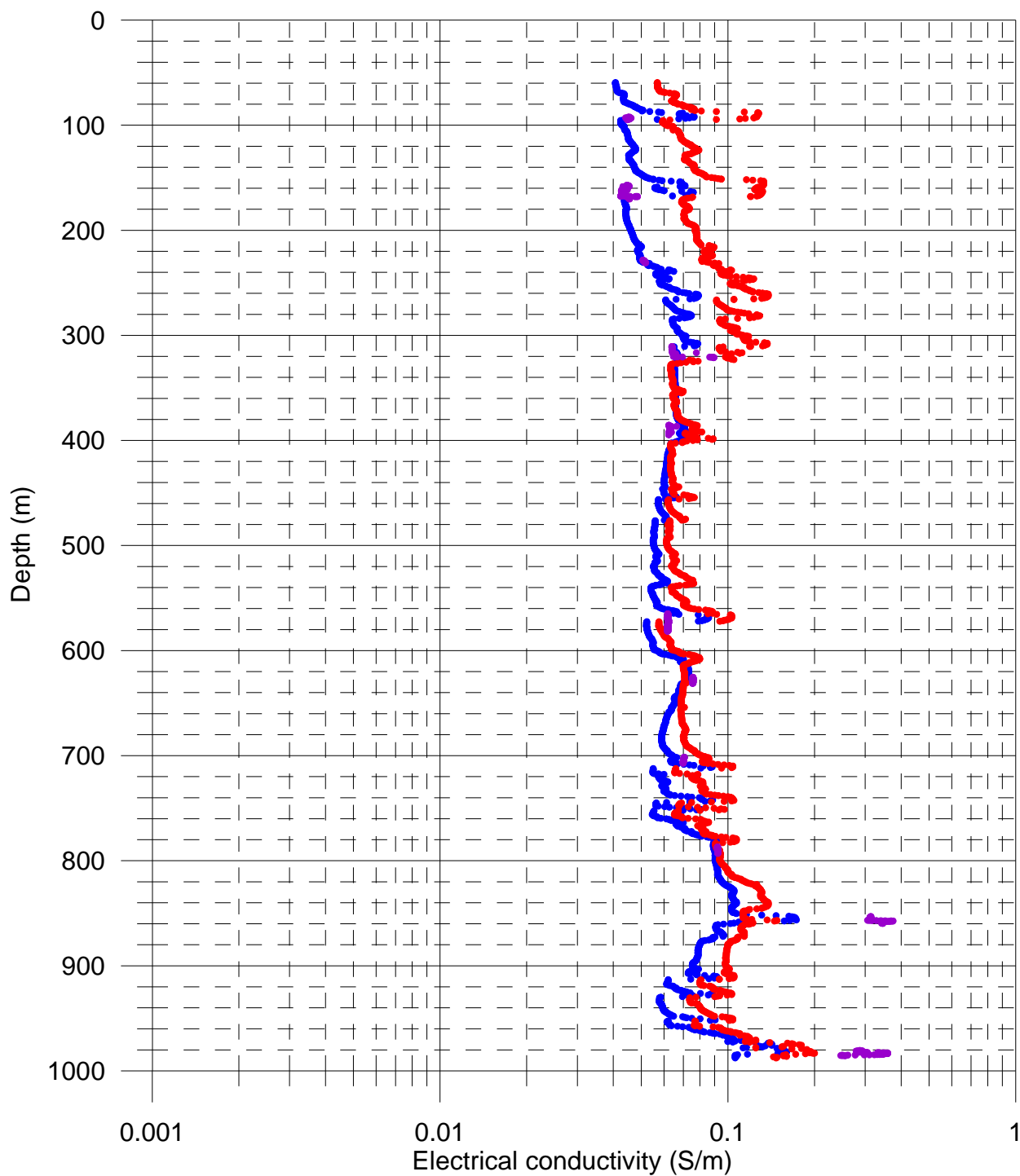


## Ignace, borehole IG\_BH05

### 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.

- Flow 1 without pumping during flow logging, 2021-08-11 - 2021-08-12
- Flow 2 with pumping during flow logging, 2021-08-13 - 2021-08-14
- Flow 3 with pumping during flow logging, 2021-08-15 - 2021-08-16



Ignace, borehole IG\_BH05  
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.



