

MAINTENANCE AND MONITORING OF BOREHOLES

As a specialised wireline logging company **Robertson Geo** offers a variety of probes which are routinely deployed to provide data to assist owners with cost and time effective maintenance of boreholes.



Robertson Geo has a fleet of service logging vehicles fully customised and comprehensively equipped with subsurface data acquisition and surface winch deployment equipment; ready to go whatever the location or application.

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Boreholes are drilled for many reasons, for the purposes of this discussion they can be divided into either temporary or permanent, the latter meaning they have a working life.

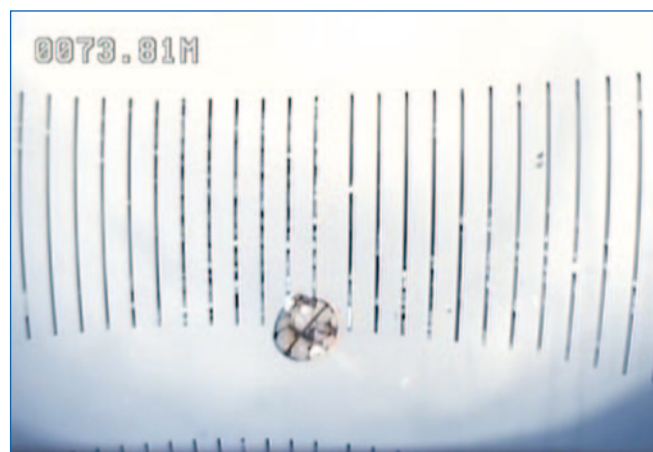
Temporary boreholes, for geotechnical or mineral exploration are drilled to extract specific information, after which they are often filled in and abandoned, although in some cases they may be cased and have instrumentation installed for continuous measures of water level as an example. Oil and natural gas boreholes with their sophisticated designs and techniques are a specialist area; it is the permanent groundwater filled boreholes, which have a working life and by necessity are monitored and maintained, that will be discussed here.

The starting point for the borehole inspections is invariably a visual image. Downhole cameras provide indisputable evidence of borehole condition. Downward and side-facing cameras and more recently fish-eye cameras such as Robertson's RGeo-Eye® provide depth referenced video images of the borehole/casing condition. For boreholes up to 12" diameter optical and acoustic televiwers offer an alternative high resolution unwrapped oriented image of the borehole wall. Where the water is cloudy or opaque only the acoustic televiwer will work as it provides a pseudo-colour image based on high frequency sound rather than light. Images obtained by these means form an integral part of the historical record of the borehole which cannot be achieved by any other means.

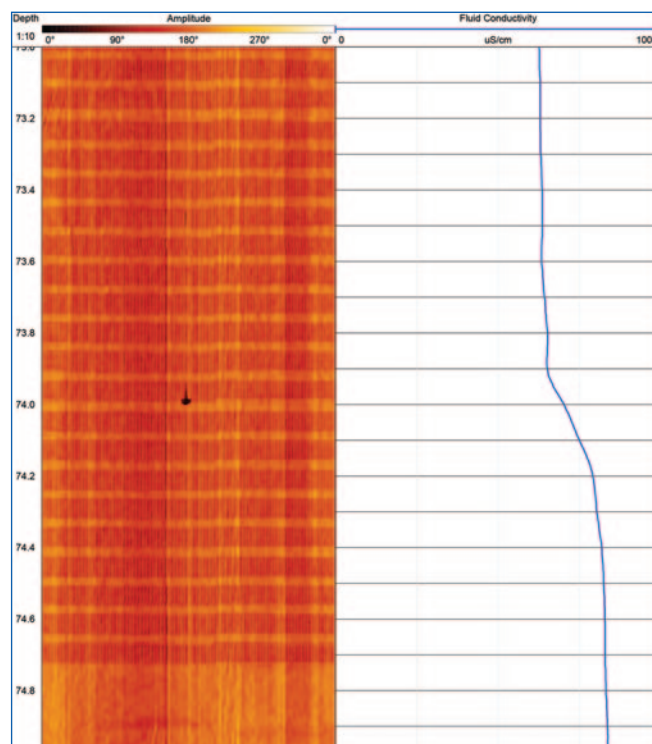
In conjunction with a visual image, caliper logs are also routinely employed to provide millimetrically accurate diameter measurement to quantify borehole breakout and casing anomalies. The Robertson Geo 3-Arm Caliper gives a single diameter and the Borehole Geometry probe uses two pairs of arms which can provide additional information on any ovalisation present.

In many boreholes solid casing is grouted in to isolate sections of the borehole column to ensure not only stability but to avoid intrusion by surface water contaminants. Cement bond logs from a Full Waveform Sonic probe are traditionally used to investigate the condition of grouting around steel casing, the interpretation of which is well established from the oil industry. However, where solid PVC casing is grouted in, the cement bond log will still give results which can give indications of loss of casing integrity.

For boreholes that are open or with perforated casing it is often important to investigate the characteristics of

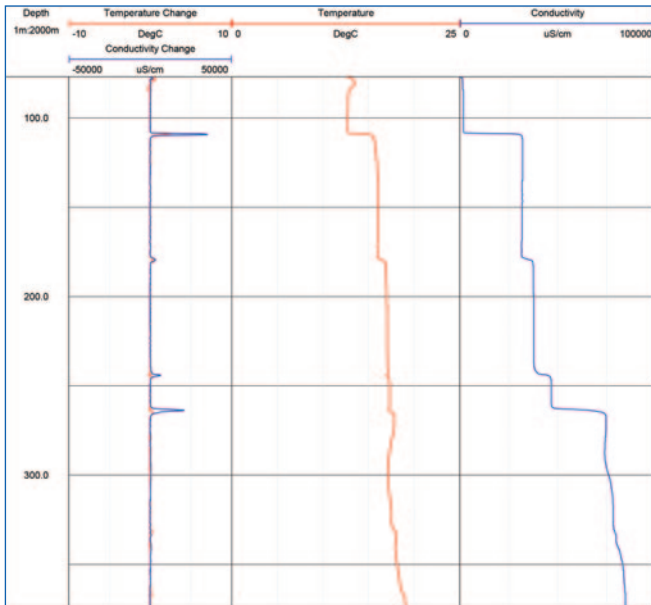


Downhole camera image showing break in perforated PVC casing.



Acoustic televiwer image of same break in perforated PVC casing.

the water column. For pumped boreholes, advantage can be taken when the pump and filters are removed for routine maintenance whereby the water column can settle allowing measurements of the static conditions. A Temperature/Conductivity probe gives highly sensitive logs which can exhibit step changes in temperature or fluid conductivity indicating potential inflow and outflow regions. As boreholes can effectively connect different



Temperature conductivity log showing step changes with depth.

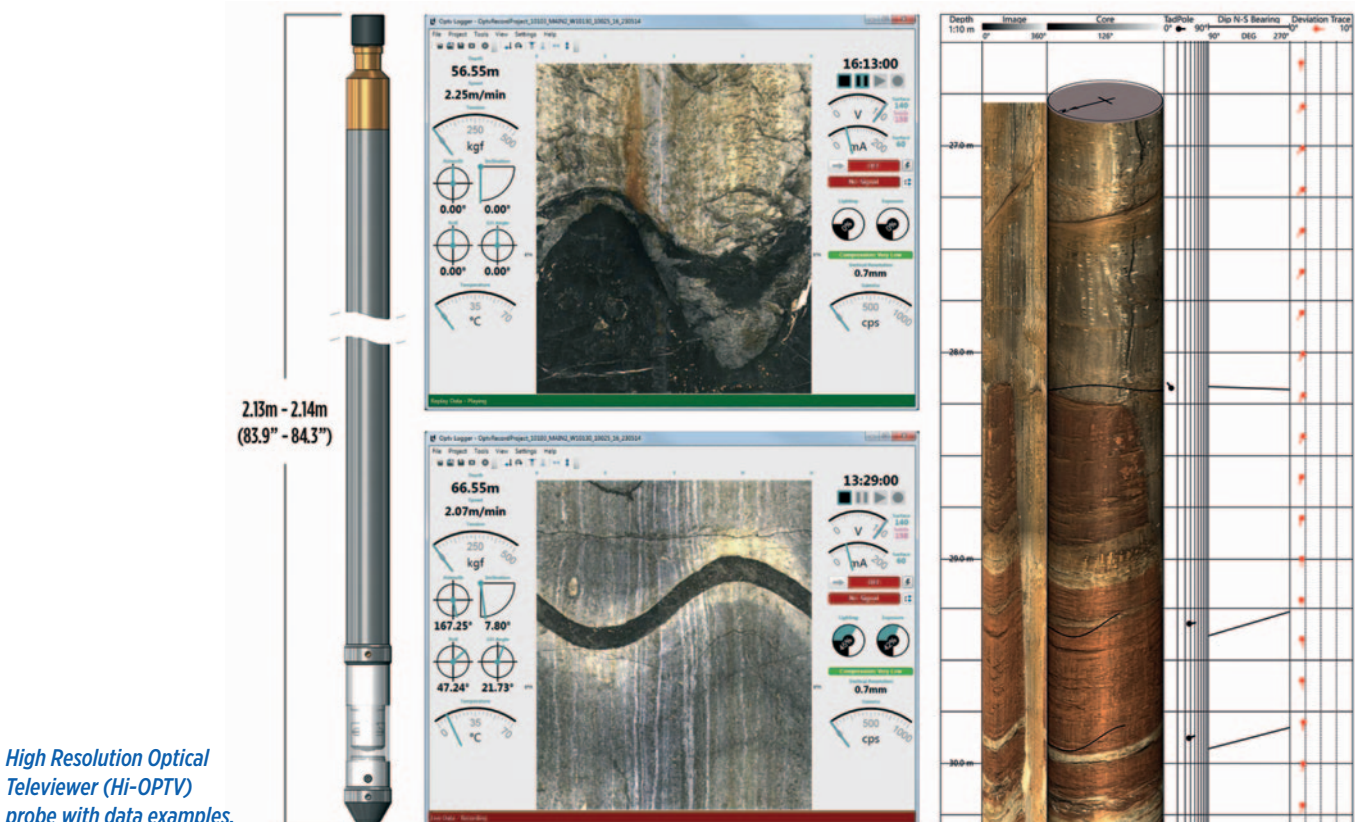
strata vertically where previously there was no connection there may be flows between layers. To quantify these flows, probes can be deployed to measure flow rates. For significant flows an Impeller Flowmeter such as the Robertson High Resolution Flowmeter can be used. For smaller flows a Heat Pulse Flowmeter, which collects data statically, can be used, targeted around areas identified by the Temperature/Conductivity logs. Where the water column is stratified, sealed samples for laboratory analysis can be extracted at specific depths using a Water Sampler probe.

Although not strictly maintenance, information for casing design and pump deployment can be obtained

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by measuring the hydrogeological characteristics of the surrounding strata. Electric and Focussed Electric logs measure formation resistivity and conductivity while the Dual Neutron probe measures porosity. Most recently Robertson Geo have partnered with Vista Clara to deploy the Javelin Nuclear Magnetic Resonance probe which provides detailed information on porosity, water content distribution and permeability, using multiple depths of investigation.

The industry sector that most commonly requires regular monitoring is the water industry. Water service companies that abstract potable water for public consumption are responsible for the water quality and the continuance of supply. In addition to the extensive continuous monitoring of water quality, when the well is offline it presents a good opportunity to conduct a detailed investigation. This invariably means that a visual image is taken and casing integrity checked and can also include water level checks, characterisation of the static water column for pump placement, measurement of static flow rates, collection of samples from specific depths and identification of any biological build up. Apart from routine maintenance these investigations



High Resolution Optical Televiewer (Hi-OPTV) probe with data examples.

Table showing probes commonly used for borehole monitoring with outputs and typical data benefits:

Probe	Outputs	Benefit
CCTV Camera	Down and side facing video	Video image record
RGeo-Eye® camera	Fish eye view video	Small diameter
High Resolution Optical Televiwer	Unwrapped borehole image	Highest resolution
High Resolution Acoustic Televiwer	Unwrapped borehole image	Works in cloudy water
3-Arm Caliper	Diameter	Highlights anomalies
Borehole Geometry	X and Y diameters	Shows ovalisation
Temperature/Conductivity	Temperature/Conductivity	Shows ingress/egress
Hi-Res Impeller Flowmeter	Flowrate	For large flowrates
Heat Pulse Flowmeter	Flowrate	For small flowrates
Water Sampler	Samples	For laboratory analysis
Cement Bond Log	Amplitude	Grouting integrity
Electric Log	Formation resistivity	Resistivity profile
Focussed Electric Log	Formation conductivity	Conductivity profile
Dual Neutron	Porosity	Formation porosity profile
Nuclear Magnetic Resonance	Water content distribution	Permeability profile

may also be triggered by diminished abstraction rates or the need to upgrade pumps and filters to meet increased demand.

For water bottling companies, soft drinks manufacturers and breweries a continual supply of high quality water is also required. Water is extracted from specific aquifers which have a desirable level of trace elements within them and casing integrity is vital to ensure that only water from the chosen aquifer is abstracted.

Other industries which by necessity consume large volume of water can potentially benefit from having in-house water supply boreholes with appropriate inspection and maintenance programmes.

Underground mine workings once abandoned are often left to flood with groundwater and contaminants from the disused mine can leach into groundwater supplies if not managed. This is of obvious concern when the ores removed included heavy/dangerous metals. Pumping stations may be set up to abstract water from boreholes drilled into the mine workings to avoid contamination and these require regular borehole monitoring inspection.

The last remaining deep coal mine in the UK was closed in 2015 leaving a legacy of deep mine workings which were allowed to flood. These remaining shafts still require routine inspection both for structural integrity and to monitor the water column. Camera surveys, water sample collection and temperature conductivity logs are regularly undertaken by the custodians.

The old deep coal mines, although abandoned for mineral extraction, have enjoyed a new lease of life by companies extracting methane for small scale power

generation purposes. Boreholes leading down to the interconnected mine networks need routine inspection usually involving a camera survey to ensure a regular methane supply. An exciting further development of these structures could involve the extraction of geothermal energy from the deepest mines.

With all probes capable of being deployed from a single vehicle set up, down to depths in excess of 1,000m, Robertson Geo provides calibrated data sets which inform the borehole owners of the historical condition of their boreholes. Whatever the legal requirements are the benefits of having such documented records over time cannot be overstated.

More info can be found at www.rgeo-services.com