MARINE GEOTECHNICS: PROBES AND MEASUREMENTS

RECOMMENDED MARINE GEOTECHNIC PROBES

PHYSICAL MEASUREMENTS

	PS Logger®	Full Waveform Triple Sonic	High Resolution Optical Televiewer (Hi-OPTV)®	High Resolution Acoustic Televiewer (HRAT)®	RGeo-eye® Camera	3-Arm Caliper	Verticality	Gyro	Nuclear Magnetic Resonance (NMR)	Natural Gamma	Formation Density	Dual Neutron	Small-Source Density
P Wave Velocity	Standard	Standard											
S Wave Velocity	Standard	Possible 2											
Poisson's Ratio	Standard	Possible 2											
Shear Modulus	Additional 1	Possible 1 2											
Young's Modulus	Additional 1	Possible 1 2											
Bulk Modulus	Additional 1	Possible 1 2											
Bulk Density									Additional 3		Standard		Standard
Natural Gamma		Standard	Optional	Optional		Optional	Standard	Standard		Standard	Standard	Standard	Standard
Porosity									Standard		Additional 3	Standard	Additional 3
Permeability									Standard				
Borehole Diameter				Standard		Standard					Standard		Standard
Borehole Deviation			Standard	Standard			Standard	Standard					
Borehole Inclination			Standard	Standard	Standard		Standard	Standard					
Borehole Wall Image			Standard	Standard	Standard								
Bed Boundaries Dip/Azimuth			Standard	Standard									
Fracture Identification			Standard	Standard	Standard								
Fracture Classification			Standard	Standard	Standard								
Fracture Dip/Azimuth			Standard	Standard									

Chart Key:

- Standard measurement
- Measurement Possible
- Additional Data Required
- Channel optional on probe

1 Requires bulk density data
2 Data possible in hard formations
3 Requires matrix density estimate

Robertson Geo provides downhole logging equipment and services for offshore geotechnical ground investigations.

From a comprehensive range of thirteen probes, up to eighteen subsurface parameters can be measured from the same surface setup.

Whether through our global logging services, rentals or equipment sales, all probes are supplied conformance tested under our ISO9001 quality system, with professional training always available.

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PS LOGGER®

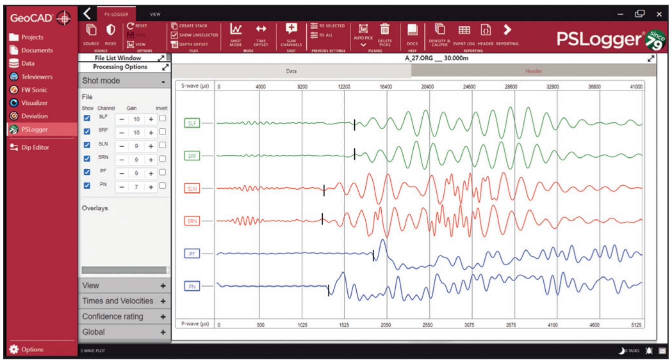
The PS Logger® is a unique sonic dipole probe that determines P and S wave velocities from a single borehole without the need for an external source.

Excellent data can be achieved across the spectrum of strata from unconsolidated sediments to the hardest of rocks.

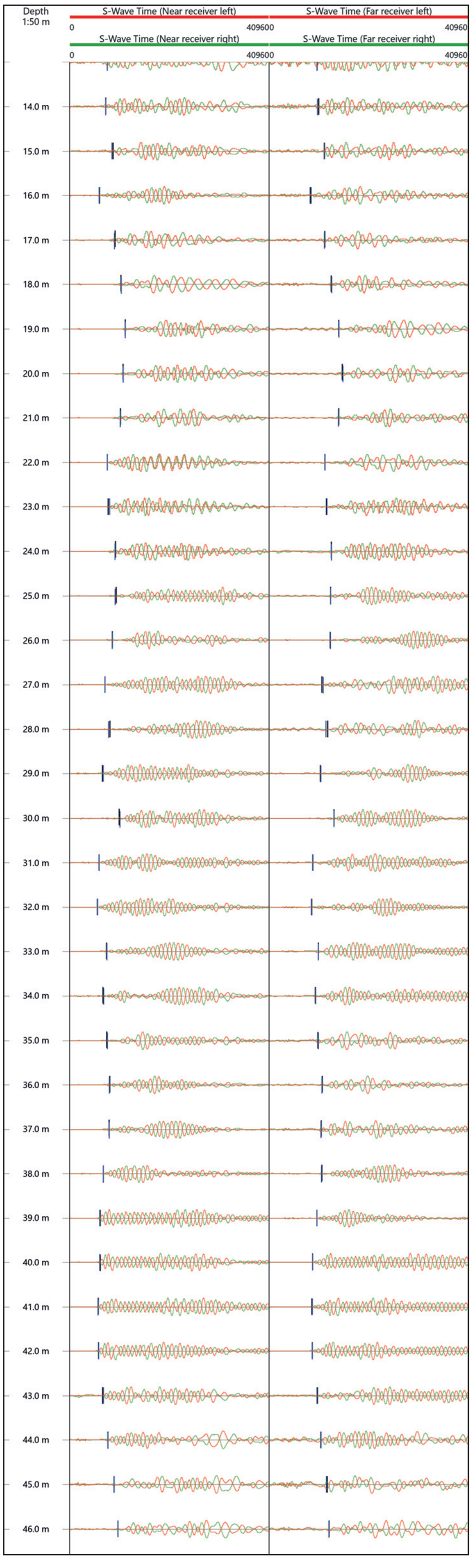
Derived Data	Application
Poisson's Ratio	Strength parameters for offshore ground characterisation, feeding into calculations and ground models for foundation design.
Bulk Modulus*	
Young's Modulus*	G_{max} is an important factor for OWF turbine design due to the complex nature of the forces acting on the structures.
Shear Modulus (G_{max})*	
P and S wave velocity	Earthquake zone characterisation
P wave velocity	Seismic reflection velocity control

** Requires bulk density value from formation density log or NMR log with laboratory core testing*

How the PS Logger® works
At each depth point three discreet shots are taken, one for P waves and two for S waves (left and right).
Firing causes a solenoid-operated hammer aligned across the borehole axis to strike the cylinder on opposite sides of the probe in turn, setting up pressure waves in the borehole fluid.
P waves are refracted at the borehole wall, travelling up the wall to be refracted back to the hydrophone.
S waves use indirect excitation of the borehole via a dipole pressure wave excited in the borehole fluid, producing a flexural wave that travels up the borehole wall at a velocity close to the S wave velocity of the formation at low PS Logger® source frequencies. The S waves are recorded on geophones aligned to the source.



PS Logger® Operating Characteristics	
Vessel Capability	Heave compensated drill ships, jack-up platforms, barges
Borehole Diameter	75mm to 300mm, Optimal – 100mm to 200mm
Maximum Depth	600m water depth or 6.5MPa
Drilling Mud	Excellent tolerance to muds, polymer-based muds optimal
Casing Pulls	Small probe diameter allows for easy transit through drill pipe
Measurements	3 shots statically at each predetermined depth interval (usually 0.5m or 1.0m)
Dimensions	Probe diameter 50mm, probe length 6.07m (1m filter tube), 7.07m (2m filter tube)
Source	Solenoid, hammer and strike cylinder arrangement (bi-directional)
Source Frequency	50Hz to 1kHz (peak dB at 300Hz)
Receivers	3D hydrophones (P traces), geophones (S traces) aligned to the source
Sampling	2.5µsec to 200µsec sample rates (Acquisition window – 5msec to 400ms)
Filters - Acquisition	Low pass - 1.2kHz to 20kHz
Filters - Processing	Band pass, Median, Gaussian
Software	PS Logger® (acquisition), GeoCAD® (processing)



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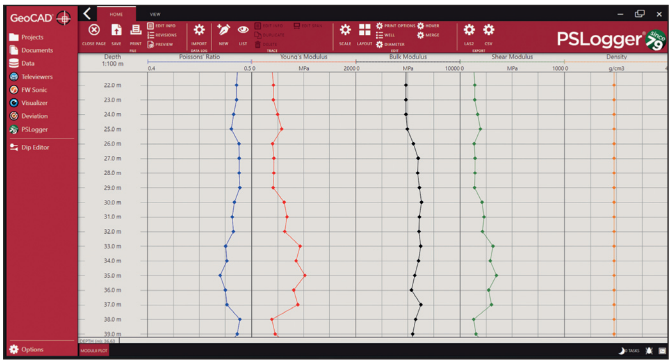
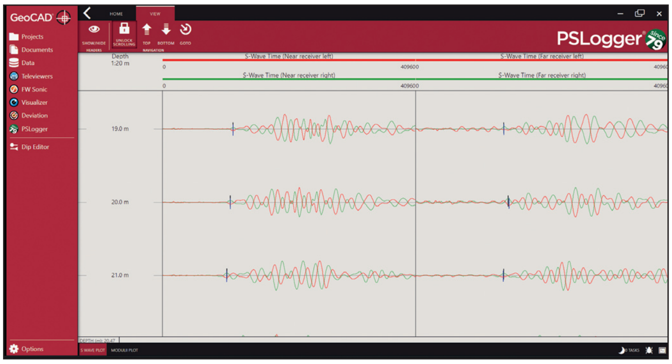
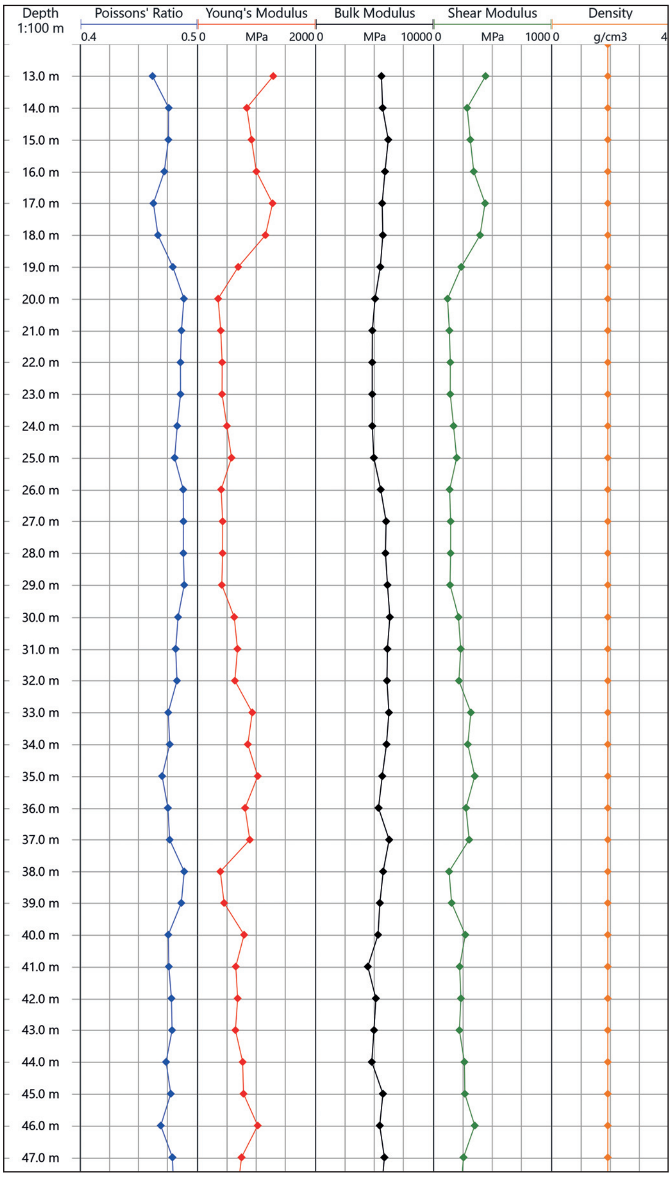
PS LOGGER®



PS Logger® Shear Wave Trace Quality Classification		
A	Excellent	Strongly defined arrivals, high coherence
B	Good	Arrivals defined, somewhat coherent
C	Poor	Arrivals are pickable, somewhat undefined, minimal coherence
D	Very Poor	Very poor, best estimate
E	Not Used	Indeterminate or no shear waves evident





Typical PS Logger® Shear Wave Responses in Commonly Found Strata

Strata Class	Strata	Trace Quality	Factors
Loose	Sand	A to E	Good data possible if borehole is not washed out
	Gravel	C to E	S wave definition possible
	Pebbles	C to E	S wave definition possible
Sedimentary	Clay	A to D	Best data from stiffer clays
	Siltstone	A to D	Good data usually achievable
	Mudstone	A to D	Good data usually achievable
	Chalk	A to C	Excellent data generally
	Sandstone	A to D	Excellent data in unweathered sandstone
	Limestone	A to C	Excellent data generally
Metamorphic	Any	A to B	Excellent data usually
Igneous	Any	A to B	Excellent data usually

Note: P wave arrivals are usually well defined in all formations

PS Logger® Data

Origin	Data	Detail
Recorded Traces	P channel Near	Full waveforms
	P Channel Far	
	S left channel Near	Full waveforms
	S left channel Far	Left polarised
	S right channel Near	Full waveforms
	S right channel Far	Right polarised
Derived	Vp	P wave or compressional velocity
	Vsl	S wave or shear velocity – left polarised
	Vsr	S wave or shear velocity – right polarised
	Vs	Average S wave or shear velocity
	v	Poisson's Ratio
Derived including Bulk Density	G	Shear modulus (G_{max})
	E	Young's Modulus
	K	Bulk Modulus

Small Strain Moduli Calculations

Given: P wave velocity Vp, Shear wave velocity Vs and bulk density ρ

Poisson's Ratio	v = ((Vp/Vs)^2 – 2) / (2*(Vp/Vs)^2 – 2)
Shear Modulus	G = ρ*Vs^2
Young's Modulus	E = 2*G*(1 + v)
Bulk Modulus	K = E / ((3*(1 - 2*v))

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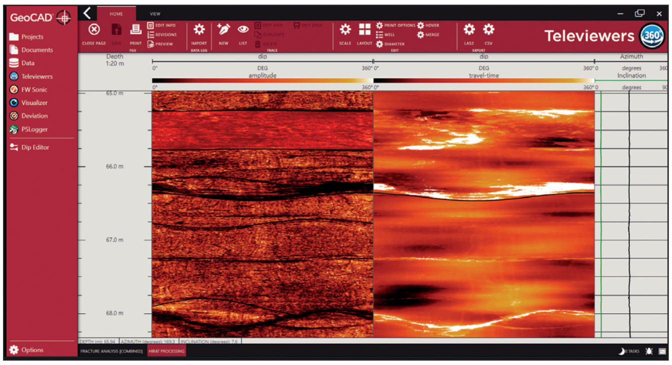
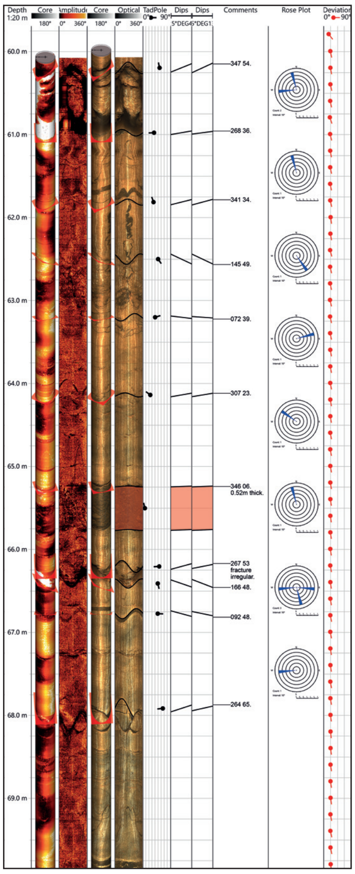
HIGH RESOLUTION ACOUSTIC TELEVIEWER (HRAT)®

The High Resolution Acoustic Televiewer (HRAT)® provides a continuous high-resolution oriented ultrasound image of the borehole wall. Once processed, this data is used to identify and accurately delineate in-situ geological features, invaluable when core sampling is incomplete or not undertaken.

How the High Resolution Acoustic Televiewer (HRAT)® works
The probe uses a fixed acoustic transducer and a rotating acoustic mirror to scan the borehole walls with a focussed ultrasound beam.
The amplitude and travel time of the reflected acoustic signal are recorded as separate image logs.
Features such as fractures reduce the reflected amplitude and appear as dark sinusoidal traces on the log.
The travel-time log is equivalent to a 360° caliper and shows diameter changes within open fractures and breakouts.
Directional information is also recorded and used to orient the images.





HRAT® TELEVIEWER

High Resolution Acoustic Televiewer (HRAT)® Data		
Origin	**Data**	**Detail**
Recorded	Amplitude image	Detailed image differentiating hard and soft strata
	Travel-time image	Detail for open fractures and breakouts
	Orientation data	Gx, Gy, Gz, Hx, Hy, Hz, magnetic toolface
Derived	Picked features	Bedding and fractures
	Feature dips and azimuth	Classified and tabulated
	Tadpole plots	Dip and azimuth
	Stereographic projections	Grouped and averaged features display
	Rose diagrams	Statistical analysis of features
	Borehole deviation	Tilt and azimuth, bullseye and 3D plots
	True vertical depth	Tabulated

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3-ARM CALIPER

The 3-Arm Caliper probe provides a single continuous log of borehole diameter, recorded by three spring-loaded mechanically coupled arms in contact with the borehole wall. An optional natural gamma log can also be recorded.

3-Arm Caliper Operation
The 3-Arm Caliper runs into the borehole with the arms retracted. Upon surface command the arms are opened, allowing the spring-loaded arms respond to borehole diameter variations as the probe is raised up the borehole.

3-Arm Caliper Data	Application
Diameter	QC for other logs possibly affected by washouts and diameter changes
	Detection of obstructions and open fractures
	Borehole integrity check before committing more expensive probes
	Discrimination between hard and soft lithology
Natural Gamma	Delineation of strata boundaries
	Correlation between boreholes