5. WELL LOGGING

- Applicable to materials in vicinity of wellbore
- Variety of logging signals available
- Recorded continuously with depth.

Methods

Gamma Ray
- Measures natural gamma radiation
- Pick up clay layers to .3m resolution

Density Log
- Artificial source ^{137}Cs @ probe base and gamma detector @ top
- Adsorption of gamma radiation by rock is proportional to density (Compton effect)

Neutron Log
- Artificial Neutron source
- Measure backscattering to determine moisture content (presence of Hydrogen) → porosity log.

Electric Log
- Apparent resistivity in sidewall rock (Multiple pt. arrays)
- May simultaneously measure self potential
- Records mixed resistivity ∴ correct for mud/water effects

Salinometer
- Resistivity of borehole fluid.

Temperature

Sonic velocity

Caliper

Flowmeter

Deviation

Table 2.4. Logging methods, measured parameters and objects of investigation

Symbol	Parameter	Result	Object
GR	count of natural gamma radiation	natural radioactivity of rocks	petrography clay content
D	counts of compton scattered rays	density of rocks	fracturing, porosity
N	counts of secondary neutron-neutron rays	lithology	stratigraphy porosity
EL, ES	apparent resisitivity	true resistivity	hydraulics, lithology
ML, MLL	apparent resistivity at borehole wall	true resistivity small scale	lithology, hydraulics
IEL	app. conductivity, focused induction	true conductivity	lithology
FEL, LL	focused electric log	true resistivity of rock	lithology
SP	self-potential (probe-to-surface)	sources of electric potentials	oxidizing bodies
SAL	resistivity of borehole fluid	salinity	total salt content of fluid
TEMP	temperature of borehole fluid	geothermal field	thermal gradient
SONIC SV	travel time of seismic waves	seismic velocity	seismic velocity
CAL	borehole diameter	shape of borehole walls	correction of other logs
FLOW	revolutions of a spinner	velocity of fluid flow	zones of in- and outflow of water
DV	compass and dipmeter	inclination + azimuth of borehole	spatial drill path
OPT	video signals, photography	state of borehole walls	direct view of lithology

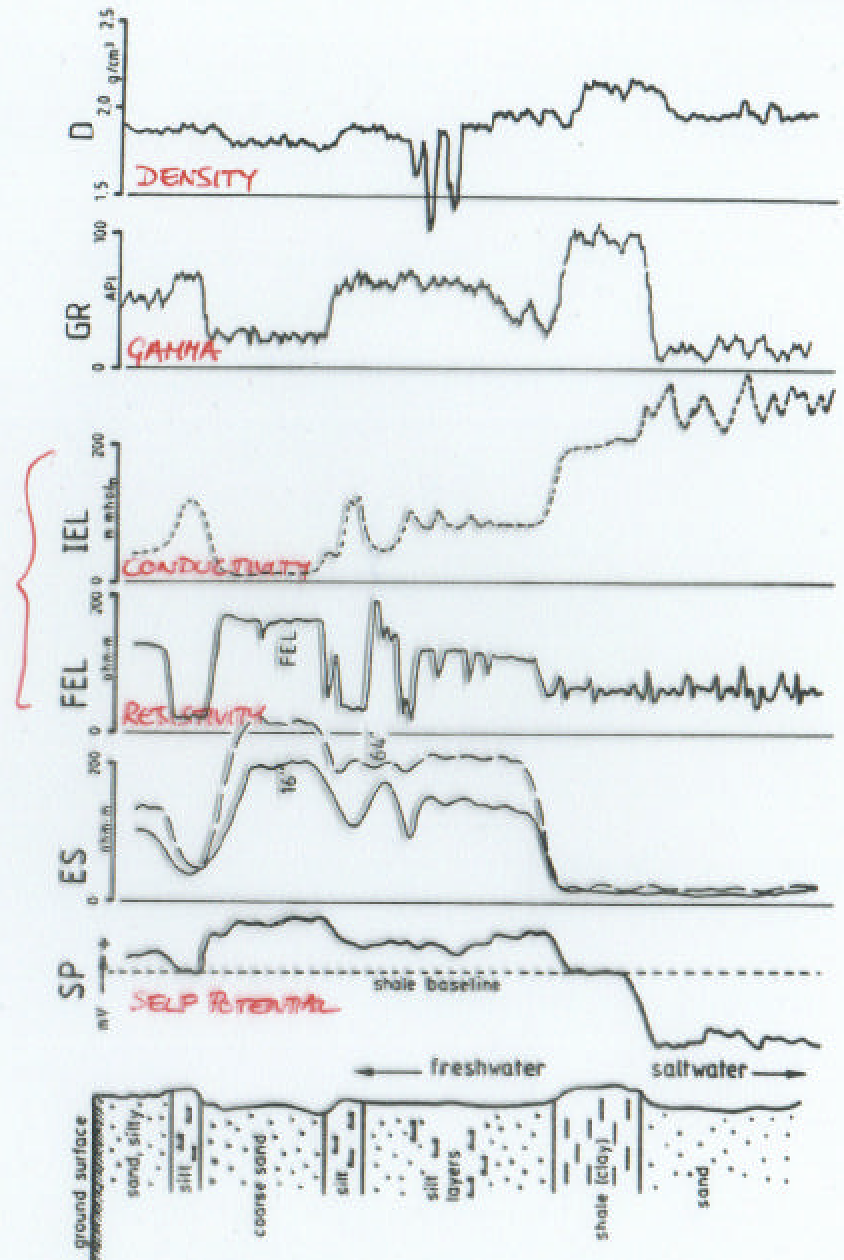

Fig. 2.24. Comparison of different logs with the lithology of cores.
SP = self-potential survey; ES = electrical survey measures resistivity in 16" and 64" point array; FEL = focused electrical log for thin layers; IEL = induction electric log measures electric conductivity; GR = gamma ray measures natural radiation; D = density log by artificial gamma source and detector

Table 2.4. Logging methods, measured parameters and objects of investigation

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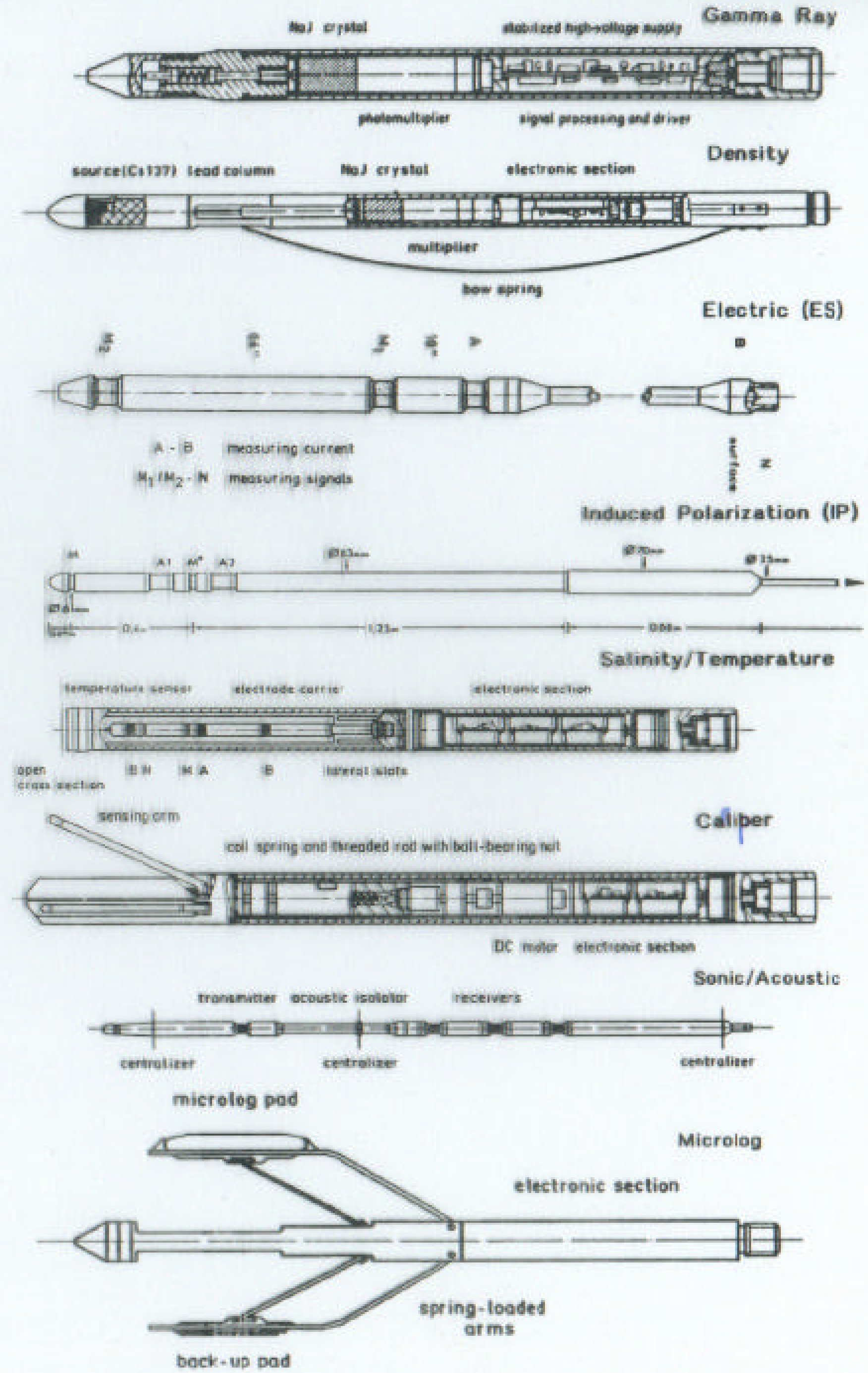

Fig. 2.25. Probes for geophysical well logging

This table is intended as a general guide. The application ratings given are based upon actual experience at a large number of sites. The rating system is based upon the ability of each method to produce results under general field conditions when compared to other methods applied to the same task. One must consider site-specific conditions before recommending an optimum approach.

In some cases a method rated 3 or NA may in fact solve the problem due to unique circumstances. For example, seismic refraction is rated NA for evaluating organic contaminants. However, in some cases where the contaminant flow is controlled by bedrock, the seismic method may provide an effective evaluation by mapping bedrock depth.

Organic Vapor Analysis

Application	GPR	EM	Res.	Seis.	MD	Mag.	OVA
Evaluation of natural geologic and hydrologic conditions							
Depth and thickness of soil and rock layers and vertical variations	1[a]	2	1	1	NA	NA	NA
Mapping lateral variations in soil and rock (fractures, karst features, etc.)	1[a]	1	2	2 (Refr.) 1 (Refl.)	NA	NA	NA
Depth of water table	3	2	1		NA	NA	NA
Evaluation of subsurface contamination and post-closure monitoring							
Inorganics (high TDS and electrically conducive)							
Early warning contaminant detection	3	1	2	NA	NA	NA	NA
Detailed lateral mapping	3	1	2	NA	NA	NA	NA
Vertical extent	3	2	1	NA	NA	NA	NA
Changes of plume with time (flow direction and rate)	3	1	2	NA	NA	NA	NA
Post cleanup/closure monitoring	3	1	2	NA	NA	NA	NA
Organics (typically nonconducive)							
Early warning contaminant detection	3	3	3	NA	NA	NA	1
Detailed lateral mapping	2[a]	2	3	NA	NA	NA	1
Vertical extent	2[a]	3	2	NA	NA	NA	2
Changes of plume with time (flow direction and rate)	3	3	3	NA	NA	NA	1
Post cleanup/closure monitoring	3	3	3	NA	NA	NA	1
Location of buried wastes and delineation of trench boundaries							
Bulk waste trenches—without metal	1	1	2	3	NA	NA	NA[d]
Bulk waste trenches—with metal	1	1	2	3	1[a]	1[b]	NA[d]
Depth of trenches and landfills	2	3	2	2	NA	NA	NA[d]
Detection of 55-gal steel drums	2[a]	2	NA	NA	1[a]	1	NA[d]
Estimates of depth and quanity of 55-gal steel drums	2[a]	3	3	NA	2	1	NA[d]
Location of utilities							
Buried pipes and tanks	1	1[c]	NA	NA	1[c]	1[b]	NA[c]
Potential pathways of contaminant migration via conduits and permeable trench backfill	1	2	NA	NA	2	2	NA[d]
Abandoned wells with metal casing	3	NA	NA	NA	2	1[b]	NA[d]

1 = Primary choice under most field conditions.
2 = Secondary choice under most field conditions.
3 = Limited field application under most field conditions.
NA = Not applicable.
[a] Shallow.
[b] Assumes ferrous metals to be present.
[c] Assumes metals to be present.
[d] Assumes no vapors present.

Note: Many site-specific conditions may dictate the choice of a method rated 2 or 3 in preference to a 1.

Magnetic detector

Source: Benson, 1988

Table 3-3 Applications of Selected Field Investigation Techniques for Waste Disposal Sites

APPLICATIONS	SEISMIC	SEISMIC MONITORING	SONAR	GRAVITY	MAGNETIC	RESISTIVITY	ELECTROMAGNETIC	RADAR	TIME-DOMAIN REFLECTOMETRY	RADIOMETRICS	BOREHOLE LOGGING
	METHODS										
DEPTH TO BEDROCK	●					○	○	●			
FAULT DETECTION	●				●		●				●
FRACTURES IN ROCK		○						○		○	●
BURIED CHANNELS	●			○		●	●	●			
GROUND WATER SURFACE	○					○	○	●	○		●
SOIL WATER CONTENT	○					○	○	●	●	●	●
WATER DEPTH			●					●			
SUB-BOTTOM STRATIGRAPHY	●		●					●			
SEA BED SCOUR			●								
ICE THICKNESS							○	●			
PERMAFROST MAPPING	●					●	●	●	○		
PEAT THICKNESS	○					●	●	●			
SOIL STRATIGRAPHY	●					○	○	●		○	●
SAND & GRAVEL MAPPING	○					●	●	●			
LEACHATE PLUMES						●	●	○		●	●
SALT WATER INTRUSION						●	●	○	○		○
BURIED DRUMS					●	○	●	○			
BURIED PIPES & CABLES					○		●	○			
BURIED CAVITIES & TUNNELS	●			○	○		●	●			
VOIDS AROUND PIPES		○						○			
SUBSIDENCE (SLOPES & TUNNELS)	●	●		○			○	●	○		
PHYSICAL PROPERTIES	●	○		○	○	○	○	○	●	●	●
ELECTRICAL GROUNDING						●	●				
RIPPABILITY	●										
RADIOACTIVE HAZARDS											

SOURCE: Modified From MultiVIEW Geoservices Inc.

● OFTEN APPLICABLE
○ SOMETIMES APPLICABLE

Figure 3-12 Summary geophysical techniques