Memorandum Report No. 1

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ELECTRIC WELL LOGGING PARAMETERS AND EQUIPMENT

by

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November 22, 1965

Appendix I

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ELECTRIC WELL LOGGING PARAMETERS AND EQUIPMENT

In spite of its almost universal application in oil exploration and growing application on the mainland in ground-water exploration (Pirson, 1963; Guyod, 1957), electric well logging has not to date been used in Hawaii. Because of the peculiarities of Hawaiian geology and hydrology (Stearns,1946; Cox, 1954), it may be expected that the parameters and methods of application found useful here will differ somewhat from those in continental areas, and only experience will indicate what will be of value.

These notes have been compiled in the review of equipment for possible acquisition by the WRRC for a research program on electric well-logging applications, with the particular immediate goal of logging parameters in wells of the Mokuleia area, Oahu, in conjunction with studies of apparent resistivity by surface methods. Leonard Palmer of the WRRC, Daniel Lum of the Hawaii Division of Water and Land Development, and Tom Moses of the U. S. Geological Survey in Menlo Park have contributed to this development. The notes are duplicated to facilitate review and criticism by the several interested members of the staff of the WRRC, HIG, USGS, and DWALD.

In the proposed WRRC research program, three criteria of importance in judging equipment are versatility, portability, and simplicity. Speed of operation is of small importance and capacity for great depth ($>$1500 feet) is of no value. Compromises will be necessary, because versatility is, to some extent, incompatible with portability and simplicity.

Following some notes on stock loggers available, a variety of electric well logging parameters and compatible functions are discussed below indivisually, with regard first to their general application to ground-water work, second to their possible applicability in Hawaii, and third to stock equipment availability. Information on availability of equipment is based largely on standard catalogs from the WIDCO, Neltronic and Industrial Instrument companies, but additional data is being sought from these companies and others.

Loggers

Loggers differ from each other in the functions they perform (and hence the instrumentation in the surface equipment), the cable they use and methods for handling it, and their portability.

Of stock loggers available, two types appear to be of interest to the WRRC project, very small loggers because of their great portability, and moderate sized loggers (still considered portable) because of their greater versatility. Serious attention should be given to the possibility of adding to the versatility of the very small loggers by independent modules, because of the much lower portability of the moderate sized loggers, although the inconvenience and expense of attaining versatility in the very small loggers may be considerable.

Significant information on the two types of loggers considered is tabulated below:

Model	Depth Capacity, Ft.	Winch Drive	Basic functions	Typical Basic Price $	Typical Weights lbs.	Typical Secondary Control* Price, $	Typical Supplementary Functions
Very small	750 to 1000	hand	SP, R	4,195	30 to 70	-----	----
Moderate size	1000 to 2000	elect-hydr.	SP, R	7,500	430	1,080	NR,DR,G, T,S,F,M, C,CL,IS, PC.

*Required for performance of most supplementary functions.

The very small loggers are available in two packages, the electronics and recorder in a suitcase, and the reel on a back-pack, or in one piece, easily carried. The moderate sized loggers are considerably heavier and need 110 vac 60 c power. If one of them is to be used it would best be mounted in a vehicle which, for access to wells remote from roads, should be 4-wheel dr. Probably the best solution would be to mount one of them in a covered Jeep or equivalent, and drive an alternator from a power takeoff.

Spontaneous - potential (SP).

Natural potential resulting from electro-chemical reactions between well fluid and formations at formation boundaries (Guyod, 1957; Doll, 1949). Potentials in clay or shale usually used as reference. Semi-quantitative indicator of formation resistivity if used with drilling mud of known resistivity.

Of clear interest in Hawaiian wells and test holes only in mud-filled wells where these penetrate sedimentary sections or weathered ash beds. There is no information on the spontaneous potentials that might be generated in basalt lavas.

Usually provided as part of the basic logging equipment. Best results are obtained by using well insulated but not armored cable.

Single-electrode resistivity (Ṙ)

Essentially equivalent to normal resistivity as measured across a very short base. Has better resolution than NR, and shows resistivity contrasts consistently and at correct level. However, resistivities shown are only qualitative and response is decreased in large wells especially if well fluid has a low resistivity. (Guyod 1957, 1965).

Useful for locating base of casing. May be of interest in some Hawaiian well exploration where the sections consist of sediments as well as lavas. In basalt lava sections, possibly of interest as a supplement to NR logs providing greater resolution, greater accuracy in resistivity boundary levels, and checking the sense of resistivity changes.

Usually provided as part of the basic logging equipment. Does not require armored cable.

Normal resistivity (NR)

Apparent resistivity of formation. Quantitative determinations are possible for thick, essentially homogeneous formations, although resolution is limited and indicated resistivity changes may be inconsistent. Formation penetration is usually considered to be about 2X base spacing and the resolution about 1-1/2 X base spacing, hence 32 to 128 in., and 24 to 96 in. respectively with usual electrode spacing. Extra long spreads, sometimes used, are known as long normal (LNR) (Pirson, 1963:81-95).

If sufficient consistent results can be obtained in basalt sections of Hawaiian wells, method would provide resistivity values useful in interpreting apparent resistivities indicated in surface surveys. Under static conditions, where resistivity of the water in a well is the same as that of the water in the formation opposite, the ratio of formation and water resistivities may be useful in estimating porosity. It seems probable that resistivities will show very great variability with high resolution, and that greater electrode spacings will produce more meaningful results.

Applicable to most logger systems by adding sonde and logger module. Requires armored cable. Typical costs are about $3,000.

Lateral resistivity (LR)

Apparent resistivity of formation obtained with a different electrode configuration from that used in NR logging. The electrode base is generally considerably greater than in NR logging, but formation penetration and resolution are considered to be only about 1X base length. Extra long spacings are known as long lateral (LLR). (Pirson 1963:97-110).

If lateral and long lateral configurations can be built or obtained at reasonable cost, it seems that they should be tried in Hawaiian sections.

Availability of lateral configurations not yet determined.

Dry Wall Resistivity (DR)

Provides single electrode resistivity in dry wells if wall is not mud caked.

Applicable to some logging systems by adding sonde and firing circuit in logger at a cost of about $900. Requires armored cable.

Resistivity, measured by induction

Resistivity may be measured by induction methods. Such methods, if applied in well logging should permit estimation of resistivity in wells with plastic casing. (Duesterhoift, 1961).

Availability of induction-measured resistivity equipment has not yet been determined.

Gamma radiation (G)

Gamma radiation originating from potassium or other radioactive elements. Conventionally used to indicate clay concentration, as distinct from limestone and sandstone which are deficient in sources of gamma radiation. Sometimes used to distinguish K-rich ash. (Kokesh, 1951).

Basalts are potassium bearing, whether in the form of ash or flows. Andesites have a potassium content approximately twice that of basalt. In Hawaii, it is conceivable that andesite ash beds might be detected in a series of basalt flows, but probably not basalt ash beds. In wetter climates potash may be concentrated in the upper horizon of the soil, hence weather zones may be detectable whether on ash or flows. Gamma radiation may be of interest in sedimentary sections.

Applicable to most logging systems by adding sonde and logger module at costs from $2,000 to $2,625. Can be operated in dry holes if armored cable is used.

Gamma - Gamma (GG)

Back-scattered gamma radiation from source suspended above or below detector. Used in determining bulk density of formation. (Pickell and Heacock 1960).

Of potential use in Hawaii in determining porosity of lava flows above or below water level. May be very difficult or impossible to use successfully in wells with irregular walls.

Equipment availability not yet determined. Can be operated in dry but not in metal-cased holes.

Neutron (N)

Slow neutrons back-scattered from a fast neutron source suspended above or below detector. Used in determining hydrogen-atom or -ion concentration. (Fearon, 1949).

Of potential interest in Hawaii in determining porosity of lava flows below the water table. May be very difficult or impossible to use in wells with irregular walls.

Equipment availability not yet certain. Can be operated in dry and cased holes.

Conductivity (C)

Conductivity (reciprocal of resistivity) of fluid in hole.

Of great interest in Hawaii as an indicator of salinity. Some conductivity logs have been run by the Experiment Station HSPA using simple equipment. For quantitative work requires simultaneous temperature logging. Also of potential use, together with normal resistivity, in deriving formation porosity.

Very suitable equipment, compatible with loggers, involving a sonde and control module which indicates temperature also, available at a cost of $3,400.

Part	Sonde diam.	Sensitivities ohm-m	Sensitivities °F	Applicable in holes Dry	Applicable in holes Cased	Price
DWSM	3.25	3 selectable ranges	0.5 or better	No	Yes	$3,400

Temperature (T)

Temperature of the fluid in the hole. (Guyod, 1946).

Of interest in Hawaii in study of ground-water temperatures. Also needed to convert hole-fluid resistivities to salinities.

Available by adding sonde and logger module, but note that temperature is also provided by the II DWSM discussed under conductivity.

Flow (F)

Velocity of fluid in hole.

Of interest in Hawaii in detecting flow between aquifers and aquifer horizons, and, if operated during draft or recharge, the distribution of flow through the depth of the well. The U. S. Geological Survey and the

Experiment Station, HSPA have run flow profiles in Hawaiian wells using simple equipment.

Equipment, involving sonde and logger module, available at prices ranging from $1,750 to $4,500 depending on sensitivity.

Magnetism (M)

Vertical component of the magnetic field. Little interest for ground-water exploration in Hawaii at the price.

Applicable to logging systems by adding sonde and logger module at a cost of $6,500.

Acoustic velocity

Velocity of sound through the formation, from which porosity may be determined if velocities in solid and saturating fluid fractions are known.

Of potential interest in Hawaii as an indicator of porosity, also to calibrate surface seismic surveys. Might be very difficult or impossible to use successfully if wells have considerable wall irregularity.

Equipment is available but price has not been determined.

Acoustic amplitude

Has been suggested as a means for estimating degree of fracturing in otherwise massive formations. (Walker, 1962).

Of possible interest in Hawaii similarly.

Would presumably use same down hole equipment as acoustic velocity but surface electronics would measure attenuation. Equipment is available but price has not been determined.

Caliper (S)

Diameter of well.

Of possible interest in Hawaii in conversion of flow velocities to discharges, perhaps in interpretation of resistivity and other electric logger and for planning cementing and other remedial measures in wells. May be essential to success of gamma, gamma-gamma, neutron, and acoustic surveys.

Applicable to logging systems by addition of sonde and logger module, at a cost of about $2,250.

Collar locator (CL)

Detects casing collars by magnetism.

Little use in Hawaii at the price.

Applicable to logging systems by addition of sonde and logger module at a cost of about $600.

Injector - Sampler (IS)

Injects trace fluids or collects samples of well fluid.

Little interest in Hawaii at the price.

Applicable to logging systems by addition of sonde and logger module at a cost of $2,300.

Perforating control (PC)

Fires casing perforator.

No use in Hawaii now known.

Applicable to logging systems by addition of module at a cost of $1,450.

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