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THE USE OF GEOPHYSICAL SURFACE METHODS FOR MILITARY GROUNDWATER DETECTION

May 1984

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Fort Belvoir, Virginia 22060

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This report summarizes information developed from 1980-1983 on the use of surface-deployed geophysical methods for military groundwater detection. The literature surveys and field testing investigations conducted during this period indicate the following: (1) Electrical resistivity and seismic refraction are the two geophysical techniques with the greatest near-term potential for success; (2) complementary seismic refraction and electrical resistivity surveys generally can be used successfully for groundwater detection when the water table occurs in unconsolidated sediments and generally can not be used successfully for detection of groundwater in confined rock

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aquifers; (3) the most significant factors affecting the probability of detecting groundwater are complexity/previous knowledge of existing geological conditions, skill of operator/interpretor, depth of aquifer, and thickness of aquifer; (4) rugged, reliable seismic refraction and electrical resistivity equipment is commercially available which would require very little adaptation for military groundwater detection application; (5) interpretation of the field data is often a complex process requiring an individual with significant background and training in the survey techniques; (6) rugged field microcomputer systems are commercially available which are suitable for processing and aiding in the interpretation of survey data; (7) computer software exists for both seismic refraction and electrical resistivity, but it is only quasi user-friendly and requires expertise to make competent interpretations.

PREFACE

The information contained in this report was developed under the guidance of the Petroleum and Environmental Technology Division; Logistics Support Laboratory; US Army Belvoir Research and Development Center; Fort Belvoir, Virginia, during the period 1980 to 1983.

The preparation of this report was accomplished under the supervision of Gerald R. Eskelund, Chief, Environmental Technology Branch; William F. McGovern, Chief, Petroleum and Environmental Technology Division; and John A. Christians, Chief, Logistics Support Laboratory.

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THE USE OF GEOPHYSICAL METHODS FOR MILITARY GROUNDWATER DETECTION

I. INTRODUCTION

1. Subject. This report summarizes information developed by the Petroleum and Environmental Technology Division, Logistics Support Laboratory, U.S. Army Belvoir Research and Development Center, from 1980 to 1983 on the use of surface-deployed geophysical methods for military groundwater detection.

2. Background. The need for groundwater becomes increasingly important in arid regions where surface water sources are non-existent, inadequate, or grossly contaminated (i.e., with NBC contaminants). Recent emphasis on desert operations has prompted the Army to initiate efforts to develop an integrated groundwater detection system consisting of: (a) groundwater statistical mapping overlays; (b) remote data collection techniques (i.e., satellite imaging devices); and (c) surface-deployed groundwater detection instrumentation. The mapping overlays and the remote data collection techniques will be used to identify areas which potentially contain groundwater. The surface-deployed groundwater detection instrumentation will identify the exact location within a potential area where the highest probability of drilling into an adequate water source exists. Thus, time and resources consumed drilling dry or low-volume water wells can be saved, and more adequate water sources can be developed quicker. The groundwater detection system will permit locating water resources closer to using units, thereby significantly reducing requirements for long-line bulk haul of water or large-scale water conduit systems.

During 1980-1982, an investigation was conducted by the Colorado School of Mines (CSM),[1] under the direction of the Belvoir R&D Center, for the purpose of summarizing the applicability of currently available geophysical methods for detecting groundwater and the relative success one might expect.

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[1] J. K. Applegate, R. D. Markiewicz, and B. D. Rodriguez, "Geophysical Detection of Groundwater," Colorado School of Mines; Golden, CO (1982).

In 1981, a Defense Science Board (DSB) Water Support Task Force[2] concluded that technology shortfalls exist in surface techniques for the detection of groundwater. These shortfalls in technology were also recognized in a Draft Letter of Agreement (DLOA) for a Subsurface Water Detector (SSWD), written by the U.S. Army Engineer School in 1981.[3] The consensus of those who reviewed the DLOA was that the concept was premature. In recognition of the groundwater detection technology shortfalls and in response to the questions raised by the DLOA, a Groundwater Detection Workshop was held at the U.S. Army Engineer Waterways Experiment Station (WES) in January 1982.[4] The workshop was co-sponsored by WES and the Belvoir R&D Center.

The conclusions of the Geophysics Working Group at the Groundwater Detection Workshop were: (a) There are two currently "fieldable" geophysical methods, electrical resistivity and seismic refraction, that are applicable to the groundwater detection problems and may offer a near-term solution to the identified detection technology shortfall; and (b) there are several state-of-the-art and emerging geophysical techniques that may have potential in the far term for application to the groundwater detection problem. Consequently, in 1982/83 a joint field testing investigation was conducted by CSM[5] and WES,[6] under the direction of Belvoir R&D Center, to assess the feasibility of using electrical resistivity and seismic refraction methods for military groundwater detection applications.

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2 Defense Science Board, "Report of the Defense Science Board Task Force of Water Support to U.S. Forces in an Arid Environment (U)," Office of the Deputy Secretary of Defense; Washington, DC (Secret) (1981).

3 U.S. Army Engineer School, "Draft Letter of Agreement (DLOA) for a Subsurface Water Detector (SSWD)," Department of the Army; Fort Belvoir, VA (1981).

4 Proceedings of "Groundwater Detection Workshop," 12 Jan 82 to 14 Jan 82, published by U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

5 P. R. Romig, B. D. Rodriguez, and M. H. Powers, "Geophysical Methodology Studies for Military Groundwater Exploration," Colorado School of Mines; Golden, CO (1983).

6 D. K. Butler and J. L. Llopis, "Assessment of Two Currently Fieldable Geophysical Methods for Military Groundwater Detection," U.S. Army Engineer Waterways Experiment Station; Vicksburg, MS (1983).

II. OVERVIEW OF GROUNDWATER AND METHODS OF DETECTION

3. Characterization of Groundwater. Groundwater is the water which fills pores or cracks in underground rock or sediment strata. It is recharged by nature according to the climate and geology of the area and is variable in both amount and quality. Not all rock or sediment strata are porous and permeable enough to contain a sufficient amount of water to be of practical use. Those rock or sediment strata that do have useable quantities of water are called "aquifers." Gravel, sand, sandstone, and limestone are among the best potential aquifers.

The porosity of the rock or sediment determines the storage capacity, and the permeability determines water movement through the strata. These two properties occur in varying degrees and are primarily dependent upon the following: (a) The number and configuration of interstitial openings; (b) the number and configuration of fractures, joints, and faults; and (c) the number and configuration of solution channels.

4. Water Dowsing. Water dowsing refers, in general, to the practice of using a forked stick, rod, pendulum, or similar device to locate groundwater and has been a subject of discussion and controversy for hundreds, if not thousands, of years. One of the first known divining rods was that mentioned in the Biblical passage in which Moses strikes a rock with his rod and water gushes forth (Numbers 20:9-11).

Although tools and methods vary widely, most dowsers (also called diviners or water witches) probably still use the traditional forked stick, which may come from a variety of trees, including willow, peach, and witch hazel. Other dowsers may use keys, wire coathangers, pliers, wire rods, pendulums, or various kinds of elaborate boxes and electrical instruments.

In the classic method using a forked stick, one fork is held in each hand with the palms upward. The bottom, or butt, end of the "Y" is pointed skyward at an angle of about 45°. The dowser then walks back and forth over the area to be tested. When he passes over a source of water, the butt end of the stick is supposed to rotate or be attracted downward. According to dowsers, the attraction of the water may be so great that the bark peels off as the rod twists in the hands. Some dowsers are said to have suffered blistered or bloody hands from the twisting.

Case histories and demonstrations of dowsers may seem convincing, but when dowsing is exposed to scientific examination, it presents a different picture. The U.S. Geological Survey, after reviewing numerous publications which report on scientifically controlled water dowsing experiments and investigations, have concluded that the expense of further tests on water dowsing is not justified.

5. Assessment of Conventional Geophysical Methods. Conceptually, the location of groundwater by geophysical methods should be straightforward. The presence of groundwater in rock significantly changes both its electrical and seismic properties. However, the change of physical properties when the rock is buried in the subsurface proves to be non-unique. Changes in rock properties other than percent saturation may trigger the same geophysical anomaly as going from a dry rock to a saturated rock. Hence, there is ambiguity in the interpretation of the existence of groundwater.

Gravity, magnetic, radiometric, and self-potential methods are of limited use for military groundwater detection application. The gravity and magnetic methods are potential field methods which respond to substantial changes in bulk density and magnetic susceptibility, respectively. Neither of these properties is related to small-scale aquifer characteristics. Radiometric methods are used principally in borehole surveys, not surface explorations. The self-potential method is sensitive to fresh groundwater only, is qualitative, not quantitative, and has a maximum groundwater depth detection of less than 300 feet.

The principal methods for groundwater detection are electrical and seismic methods. These are most applicable because water significantly alters the measured physical properties. The general characteristics of several electrical and seismic methods are summarized in Table 1. This table supports the conclusion that electrical resistivity and seismic refraction are the two geophysical techniques with the greatest immediate potential for success in military groundwater detection efforts. Tables 2 and 3 summarize the advantages and disadvantages of both methods. Neither method used alone is 100 percent successful. However, the methods compliment each other and when used in an integrated manner, the success rate improves substantially.

Other geophysical methods, such as electromagnetic and seismic reflection methods, may result in groundwater detection capabilities greater than those currently available with electrical resistivity and seismic refraction, but not before additional developmental advances are achieved.

Table 1. Groundwater Detection Matrix

Parameter	Electrical Resistivity	Electro-Magnetic	Self-Potential	Seismic Refraction	Seismic Reflection
1. Depth limitations—general application	More than adequate 10,000 ft	1,500 ft	200 ft	More than adequate 10,000 ft	10,000 ft
2. Depth limitation—optimum for groundwater detection	2,000 ft	500 ft	200 ft	1,000 ft	2,000 ft
3. Ability to discriminate groundwater—thickness of aquifer as percent of burial depth	15 percent	20 percent	10 percent	10 percent	5 percent
4. Types of groundwater	All except very fresh in clean sand	All except very fresh in clean sand	Fresh	All	All
5. Fresh water versus bound water	No	No	No	No	No
6. Skill/training required for interpretation*	2 mo class 2 mo field	2 mo class 4 mo field	1 mo class 4 mo field	2 mo class 4 mo field	6 mo class 4 mo field
7. Speed of data evaluation expressed as percent of field time					
a. Current	100 percent	100 percent	100 percent	100 percent	200 percent

Table 1. Groundwater Detection Matrix (continued)

Parameter	Electrical Resistivity	Electro-Magnetic	Self-Potential	Seismic Refraction	Seismic Reflection
b. Projected	50 percent	50 percent	50 percent	25 percent	75 percent
8. Tranportability of equipment	Very good	Very good	Excellent	Very good	Good
9. Ruggedness of equipment	Good	Good	Good	Good	Fair-good
10. Speed of coverage** (mi/d)	1	1.5	10	1	1
11. Equipment availability	Off-the-shelf	Off-the-shelf	Off-the-shelf	Off-the-shelf	Off-the shelf
12. Operational capability of current instrumentation	1,000 ft	1,000 ft	200 ft	500 ft	2,000 ft
13. Probability of detecting groundwater	60 percent	40 percent	50 percent	60 percent	40 percent

*Subject areas: Groundwater Geology; Electronics; Field Methodology; and Theory.
**Well-designed field equipment for this work could significantly improve speed of coverage.

Table 2. Advantages and Disadvantages of the Seismic Refraction Method

Advantages	Disadvantages
The equipment already exists to run seismic refraction lines and record the data produced.	The accurate interpretation of seismic refraction data depends upon having a certain amount of technical expertise and adequate experience.
Seismic refraction lines may be set up and run by three people with one 4-wheel drive vehicle.	By the nature of the method, exploration to a depth of 1,500 ft would require: running a seismic line 4,500 to 7,500 ft long; a rather sizable explosive source of seismic energy; burial of the charge perhaps 10 ft deep; and several shots to provide adequate coverage.
The refraction technique has been in use since the 1920's; therefore, a large body of literature exists concerning interpretation of refraction data.	Explosives must be available to the exploration party.
No excavations, other than a shallow hole for the explosive source, are necessary to run the surveys.	A saturated zone cannot be detected in every case because the acoustic properties of the saturated zone may not be unique or sufficiently different from the surrounding rocks.
About 3 to 10 seismic lines can be run in a 10-h field day, not including adverse travel conditions.	Running refraction lines over frozen ground often results in difficult interpretation problems.
The interpretation of the data requires a hand calculator but no other more sophisticated equipment.	

Table 3. Advantages and Disadvantages of the Electrical Resistivity Method

Advantages	Disadvantages
The equipment already exists to run electrical resistivity surveys.	The accurate interpretation of electrical resistivity data depends upon having a certain amount of technical expertise and adequate experience.
Electrical resistivity lines may be set up and run by three people with one 4-wheel vehicle.	By the nature of the method, exploration to a depth of 1,500 ft would require: end-to-end profiles of 3,000 to 4,000 ft; a large battery source and/or a portable generator source; and sensitive receiving gear.
The technique has been in use for many years; therefore, a large body of literature exists concerning interpretation.	Sounding to depths greater than approximately 750 ft creates logistical problems of handling long lengths of wire and more care for data acquisition, which significantly slows the survey.
No excavations are necessary to run the surveys.	A saturated zone cannot be detected in every case because the electrical properties of the saturated zone may not be unique or sufficiently different from the surrounding rocks or because the zone is of inadequate thickness.
About 3 to 10 electrical soundings to depths of 500 ft can be run in a 10-h field day not including adverse travel conditions.	Electrical resistivity is not useful for detecting conductive zones beneath highly conductive zones.
Simple interpretation of the data requires a hand calculator and matching curves but no other more sophisticated equipment.	Highly resistive, near-surface material requires extra effort to get current into the ground.

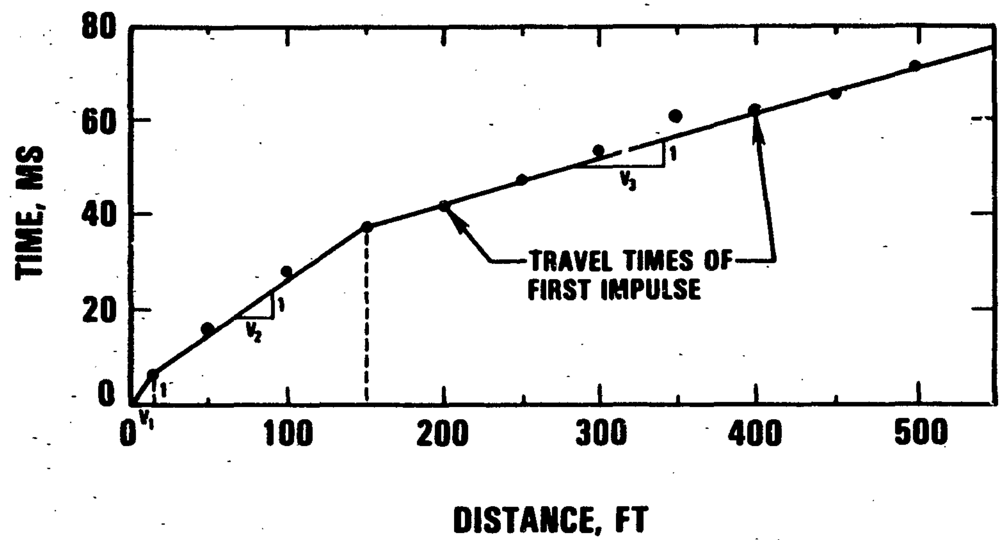
III. SEISMIC REFRACTION METHOD

6. Principle. The seismic refraction method consists of measuring the travel times of compressional and sometimes shear waves generated by an impulsive energy source to points at various distances along the surface of the ground. The energy is detected, amplified, and recorded so that its time of arrival at each point can be determined. The instant the impulsive energy source is released, the "zero time" is recorded along with the ground vibrations arriving at the detectors (geophones). The raw data consist of travel times and distances, the travel time being the interval between the zero time and the instant that the detector begins to respond to the disturbance. This time-distance information is then processed to obtain an interpretation in the form of velocities of wave propagation and structure of the subsurface strata. The process is illustrated schematically in Figure 1. All measurements are made at the surface of the ground, and the subsurface structure is inferred from interpretation methods based on the laws of wave propagation.

Generally, when depths to interfaces determined by the seismic refraction method are compared to "ground truth data" from nearby boreholes, the agreement is within ± 10 percent.

7. Equipment. The equipment required for seismic refraction surveys consists of the following: (a) multichannel seismograph for processing, recording, and storing data (Figure 2); (b) seismic sources; (c) geophones; and (d) seismic cable. The seismic source is usually a small explosive charge or a sledgehammer blow. Geophones are velocity transducers commonly used in straight-line arrays of 12 or 24. Seismic cables are multiconductors with geophone takeouts at constant-spacing intervals along its length. Commonly available seismic cable geophone takeout intervals for seismic refraction surveys are 10, 25, 50, and 100 feet. Total equipment weight required for seismic refraction surveying is about 350 lb, and the equipment is easily transportable in a "jeep-size" vehicle.

8. Personnel Requirements. Three field personnel are required for conducting seismic refraction surveys. Nonprofessional personnel can be trained to conduct the field surveys and also to process the data using existing, quasi user-friendly computer programs. However, interpretation of the field data is often a complex process requiring an individual with significant background and training in seismic refraction techniques.



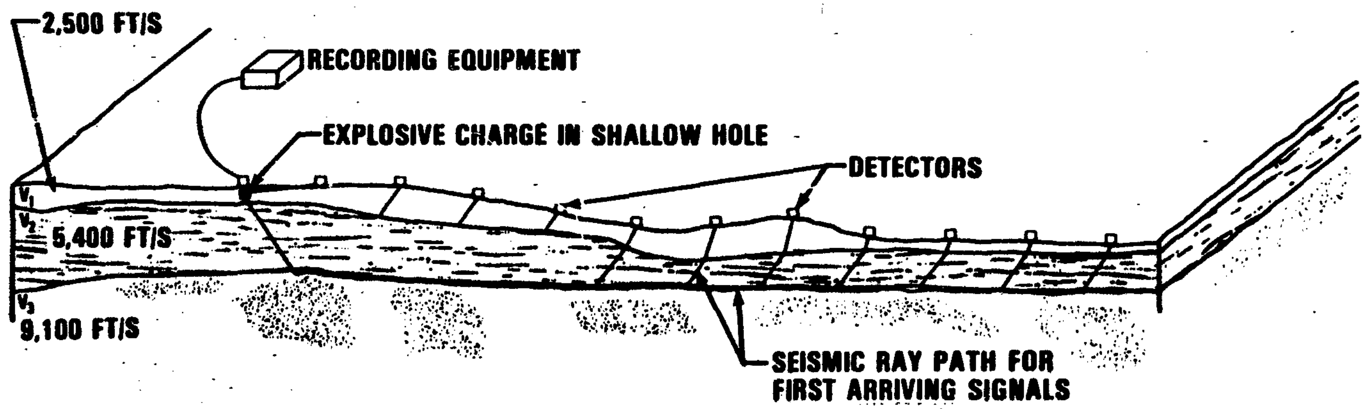


Figure 1. Schematic of seismic refraction survey.

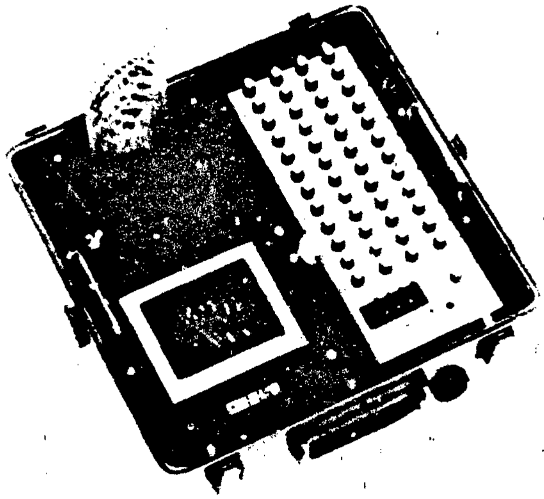


Figure 2. Digital multichannel seismograph.

9. Interpretation. The seismic refraction method is a survey technique in which the source locations and geophones are along a common line. The length of the line should be from three to four times the desired depth of investigation. Figure 1 illustrates the concept of the seismic refraction method, where the time-distance plot represents the arrival times of the first event at each geophone location. The first event at a given geophone will be due to a wave which propagates directly from the source or to a wave which is refracted along an interface with a higher velocity material, and the arrival time-distance data will generally define a straight-line segment for each subsurface layer. The first-arrival time-distance plot can be interpreted to give the velocities of subsurface soil/rock layers and depths to interfaces. The availability of digital seismographs (Figure 2) and powerful microcomputers now makes it possible to automate much of the seismic data processing interpretation procedure and to accomplish it expeditiously in the field.

The physical principle involved in detection of the water table by seismic methods is that the compression-wave velocity of saturated sediments is considerably greater than the same sediments in dry or only partially saturated conditions. For shallow depths of less than 100 ft, the characteristic compression-wave velocity for saturated sediments is 5000 ft/s, although some weathered rocks and massive clay deposits can have this velocity also. For depths greater than 100 ft, the compression-wave velocity of the saturated sediments can be as high as 7500 ft/s. The smallest velocity contract at the water table will occur in very fine grained sediments, where the velocity contrast can be as small as 500 ft/s. When the water table occurs as an unconfined surface in rock, there will always be a velocity increase at the water table, but it may be small. Where the groundwater occurs in a confined rock aquifer, there will be little in the seismic data to suggest the presence of groundwater without independent or complementary information.

10. Limitations. Limitations of the seismic refraction method include the following:

a. Insufficient Velocity Contrast. If there is no seismic velocity contrast between two adjacent layers, or if the contrast is very slight, the underlying bed will not be detected.

b. Blind Zone. With a certain combination of bed thicknesses and velocities, the first arrival at the surface from a given layer will be masked by arrival from other layers both deeper and shallower.

c. Velocity Inversion. This condition exists when an underlying bed below some overburden layer has a lower velocity instead of a greater velocity than the beds near the surface. The resulting refraction of the wave is deeper into the earth instead of shallower, thus no waves reach the surface from this low velocity layer.

IV. ELECTRICAL RESISTIVITY METHOD

11. Principle. Surface electrical resistivity surveying is based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivities and distribution of the surrounding soils and rocks. The resistivity of a material is numerically equal to the resistance of a specimen of the material with unit dimensions and is a fundamental or characteristic parameter of the material. Most soils and rocks conduct current primarily electrolytically; i.e., through interstitial pore fluid. Thus, porosity, water content, and dissolved electrolytes in the water are the controlling factors in determining resistivity rather than the soil or rock type. A major exception to this generalization is clay, which can conduct current both electrolytically and electronically. The usual practice in the field is to apply an electrical current between two electrodes implanted in the ground and to measure the difference of potential between two additional electrodes that do not carry current. Expanding the electrode spacing allows one to investigate deeper within the earth. The potential measuring electrodes are usually held at a fixed spacing, while the outer electrodes (current electrodes) are expanded. Two of the most common electrode arrays are illustrated in Figure 3.

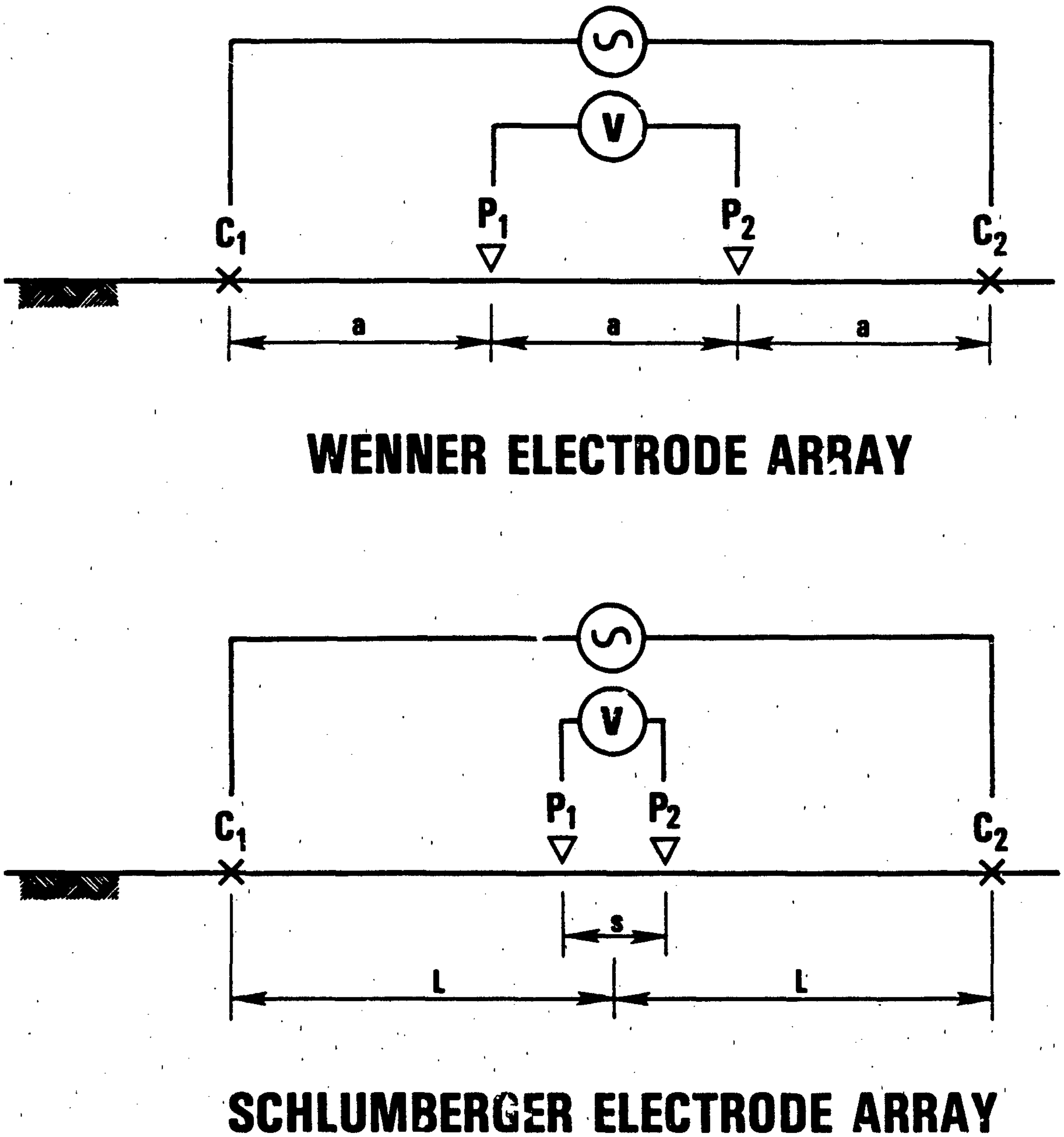


Figure 3. Two common electrode arrays.

Generally when depths to interfaces determined by the electrical resistivity method are compared to "ground truth data" from nearby boreholes, the agreement is within ± 20 percent.

12. Equipment. The equipment for electrical resistivity surveys consists of the following: (a) power upply (12-volt batteries); (b) instrument for measuring current and potential difference (Figure 4); (c) four stainless steel electrodes; (d) cable; and (e) nonconducting tape for measuring distances. Total equipment weight for the electrical resistivity system is about 110 lb, and the equipment is easily transportable in a single "jeep-size" vehicle.

13. Personnel Requirements. A minimum of three field personnel are required for conducting on electrical resistivity sounding. Nonprofessional personnel can be trained to conduct the field soundings and also to process the data using existing, quasi user-friendly computer programs. However, interpretation of the field data is often a complex process requiring an individual with significant background and training in electrical resistivity techniques.

14. Interpretation. The measured apparent voltage at the potential electrodes is used in conjunction with the input current to compute an apparent resistivity based on the geometric factor for the electrode spacing. Standard interpretation schemes require one to compute the resistivity of various spacings. These apparent resistivity values are plotted as a function of the electrode spacing which is assumed to relate to the depth of investigation. The sounding should be carried out to an outer electrode spacing of at least twice the desired depth of investigation. Measurements are commonly plotted on a log-log plot of apparent resistivity versus one-half of the current electrode spacing (Figure 5).

Electrical resistivity data can be interpreted using either a curve-matching procedure or a computerized inversion method. In the curve-matching technique, the apparent resistivity curves are compared to characteristic curves based on relative resistivities to assess the resistivity and the thicknesses of discrete layers. The computerized inversion method uses the apparent resistivity data to compute in an iterative fashion, the "best fit" resistivities and thicknesses for discrete layers. While the inversion method is desirable in terms of consistency and ease of operation, it also can make many of the standard errors that are inherent in computer interpretation, such as honoring all points of data. Therefore, even if inversion methods are used, one should still plot the data by hand, look at the general shape of the curve, and evaluate the results as a check.

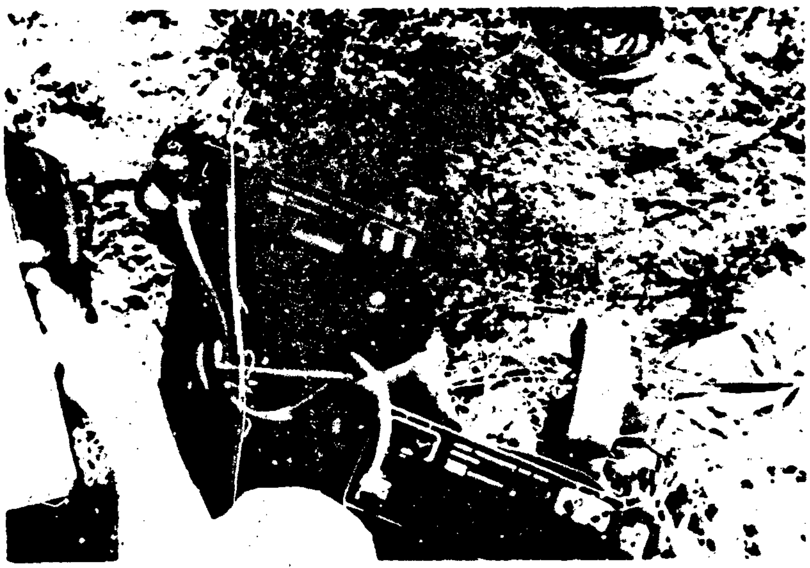


Figure 4. Resistivity instrument for measuring current and potential difference.

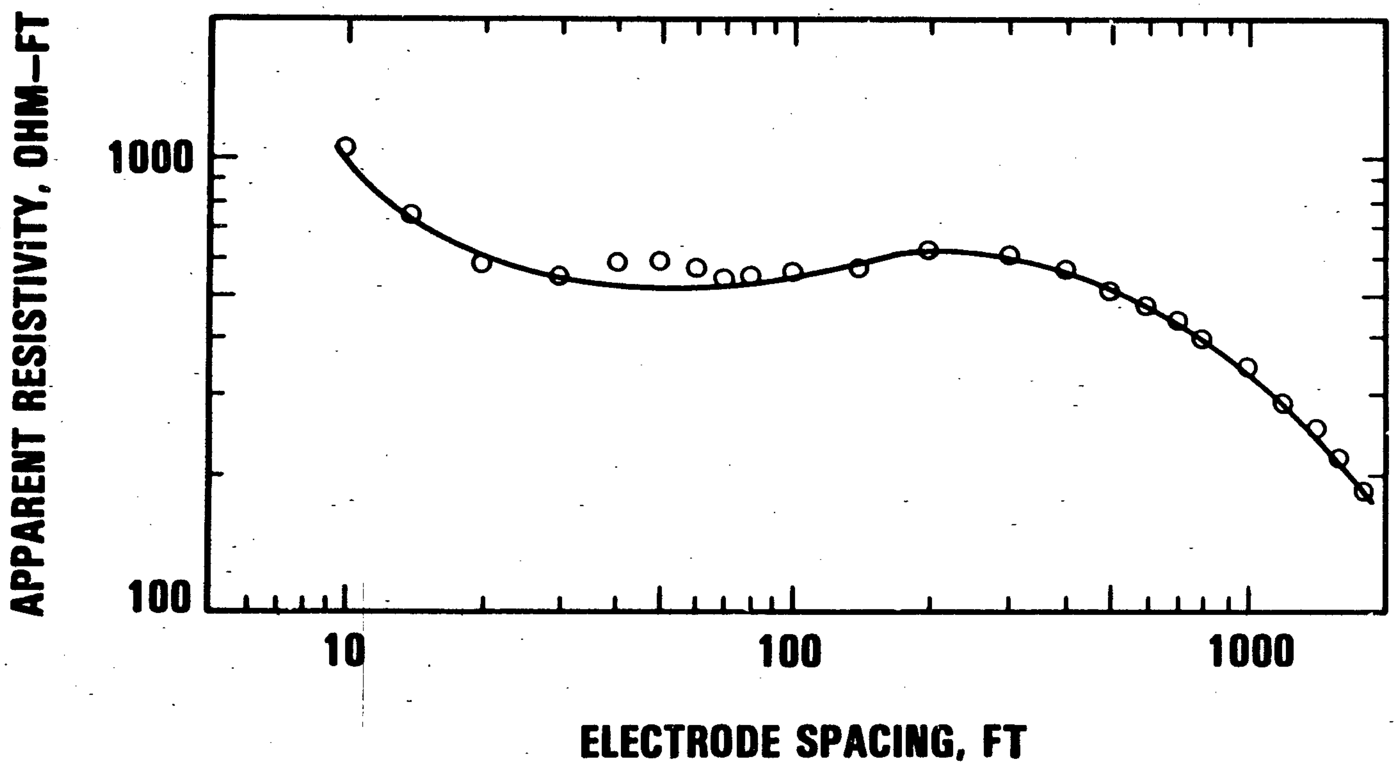


Figure 5. Sample log-log plot of electrical resistivity data.

The most common and successful use of resistivity sounding is for detecting the fresh water-saltwater interface, which will always be detected by the occurrence of a prominent resistivity decrease. Detection of the water itself is a more difficult problem. Under a favorable conditions, the water table will be detected as the top of a conductive or less resistive layer; since, except for unusual conditions, even fresh potable groundwater is much lower in resistivity than the dry aquifer material. The most favorable conditions will be when the water table occurs in unconsolidated sediments with little clay content. Dry silts, sand, and gravel will have resistivities of 1000 ohm-ft and greater; for fresh water, the resistivity at the water table will decrease to range of 50 to 200 ohm-ft. In sediments with considerable clay content, the resistivity contast will be much smaller and may be undetectable. At the fresh water-salt water interface, the resistivity of the aquifer will decrease considerably, perhaps to less than 1 ohm-ft.

15. Limitations. Limitations of the electrical resistivity method include the following:

a. Geometric Problems. The effect of lateral changes in resistivity, either through dip or through changes in rock type, significantly alters the results since the method does not indicate these lateral changes, but rather averages large volumes of earth.

b. Resistivity Contrast. The physical properties or extent of individual layers cannot be defined when there is a lack of discrete resistivity changes between layers.

c. Conductive Zones. A shallow conductive zone allows most of the current to flow through this zone and very little current to penetrate below it, thereby discouraging efforts to resolve the zones below the conductor.

V. INTEGRATED USE OF SEISMIC REFRACTION AND ELECTRICAL RESISTIVITY METHODS

16. Complementary Methods. Electrical resistivity and seismic refraction methods are complementary in the sense that they respond to or detect different physical properties of geologic materials. In cases where both methods detect the water table, one method serves to confirm the results of the other method or to resolve ambiguities. Also, certain conditions, such as the presence of a fresh water-saltwater interface, can be detected by one method but not the other.

17. **Results of Field Testing.** During 1982 to 1983, a joint field testing investigation was conducted by CSM and WES, under the direction of the Belvoir R&D Center, to assess the feasibility of using electrical resistivity and seismic refraction for military groundwater detection application. Two field sites were selected, each representing a common groundwater occurrence. White Sands Missile Range (WSMR), New Mexico, was the site for an alluvial aquifer with an unconfined water table. Fort Carson, Colorado, was the site for a confined (artesian) rock aquifer. Five locations were selected at WSMR with water table depths ranging from approximately 60 to 450 ft and water quality varying from fresh to brackish. For the location selected at Fort Carson, the depth to the top of the aquifer was approximately 270 ft and the thickness was approximately 100 ft.

An assessment of the integrated methodologies used for the field testing revealed the following:

a. Geophysicists possessing no prior knowledge of the in-situ geology were able to predict the presence and depth of groundwater at a fair-to-good confidence level.

b. Geophysicists possessing some knowledge of the in-situ geology were able to predict the presence and depth of groundwater at a fair-to-excellent confidence level.

c. Geophysicists possessing a complete knowledge of the available in-situ geologic information were able to predict the presence and depth of groundwater at a good-to-excellent confidence level.

d. Used in concert, seismic refraction and electrical resistivity can be used successfully to detect groundwater in alluvial materials. The groundwater assessment is more straightforward for those cases where the groundwater occurs in coarse-grained sediments (sands and gravels) as opposed to fine-grained sediments (silts, clays).

e. Seismic refraction and electrical resistivity techniques are not very useful in rock aquifers.

f. Both methods are relatively slow and require significant lengths of electrical cable for field data acquisition (Table 4).

Table 4. Speed of Performing Seismic Refraction/Electrical Resistivity Surveys

Maximum Depth of Investigation (ft)	Estimated Number of Complete Geophysical Assesements per Day for a 3-Man Crew*
30	5-6
100	3-4
600	1-2
>600	1

*An assessment relates to measurements at one point.

18. Computer Requirements. The complexity of gathering, processing, and interpreting geophysical survey data can be greatly reduced via the use of computers. Figure 6 depicts a microcomputer suitable for field use for processing electrical resistivity and seismic refraction data. Generally, a microcomputer with 32 K bytes RAM or greater is required. Computer software exists for both seismic refraction and electrical resistivity, but it is only quasi user-friendly and requires expertise to make competent interpretations. Much of the software will run only on large mainframe computers. Very little user-friendly software exists for small mobile microcomputers. A user-friendly seismic refraction processing and interpreting software prackage was developed by CSM as an integral part of their geophysical methodology study. Throughout the program, helpful advice was written in plain English in such a way that the user would not have to read a lengthy manual in order to run the programs.

Figure 6. Completely self-contained field microcomputer for geophysical surveys.

VI. CONCLUSIONS

19. Conclusions. Based upon studies conducted under the direction of the Belvoir R&D Center from 1980 to 1983 on the use of surface-deployed geophysical methods for military groundwater detection, the following conclusions are drawn:

a. Electrical resistivity and seismic refraction are the two geophysical techniques with the greatest near-term potential for success.

b. Complementary seismic refraction and electrical resistivity surveys generally can be used successfully for groundwater detection when the water table occurs in unconsolidated sediments and generally can not be used successfully for detection of groundwater in confined rock aquifers.

c. The most significant factors affecting the probability of detecting groundwater are complexity/previous knowledge of existing geological conditions, skill of operator/interpretor, depth of aquifer, and thickness of aquifer.

d. Rugged, reliable seismic refraction and electrical resistivity equipment is commercially available which would require very little adaptation for military groundwater detection application.

e. Interpretation of the field data is often a complex process requiring an individual with significant background and training in the survey techniques.

f. Rugged field microcomputer systems are commercially available which are suitable for processing and aiding in the interpretation of survey data.

g. Computer software exists for both seismic refraction and electrical resistivity, but it is only quasi user-friendly and requires expertise to make competent interpretations.

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