Apparent Resistivity

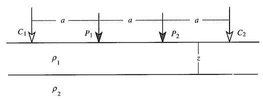
the potential difference is

$$\Delta V = V_{P_1} - V_{P_2} = \frac{\rho_1 i}{4\pi a}\left\{1 + 4\sum_{n=1}^{\infty}\frac{k_{1,2}^n}{\left[1+(2nz/a)^2\right]^{1/2}} - 2\sum_{n=1}^{\infty}\frac{k_{1,2}^n}{\left[1+(nz/a)^2\right]^{1/2}}\right\} \quad (5\text{-}33)$$

Remember that our ultimate goal is to develop an equation similar to Eq. 5-20 that provides values of apparent resistivity for various electrode spacings in the case of the horizontal interface. If we use the electrode spacings in Figure 5-11(a), we can rewrite Eq. 5-20 as

$$\rho_a = \frac{2\pi\Delta V}{i}\left(\frac{1}{\frac{1}{a} - \frac{1}{2a} - \frac{1}{2a} + \frac{1}{a}}\right) \quad (5\text{-}34)$$

(a)



Apparent Resistivity

$$\rho_a = \frac{2\pi a\Delta V}{i} \quad (5\text{-}35)$$

Equation 5-33 does not consider the contribution of the electrode at C_2, but this simply doubles the potential difference ΔV. We make this adjustment and then rewrite Eq. 5-35 using the expression for ΔV given in Eq. 5-33 to obtain

$$\rho_a = \left(\frac{2\pi a}{i}\right)\left\{\frac{\rho_1 i}{2\pi a}\left[1 + 4\sum_{n=1}^{\infty}\frac{k_{1,2}^n}{\left[1+(2nz/a)^2\right]^{1/2}} - 2\sum_{n=1}^{\infty}\frac{k_{1,2}^n}{\left[1+(nz/a)^2\right]^{1/2}}\right]\right\}$$

and

$$\rho_a = \rho_1\left\{1 + 4\sum_{n=1}^{\infty}\frac{k_{1,2}^n}{\left[1+(2nz/a)^2\right]^{1/2}} - 2\sum_{n=1}^{\infty}\frac{k_{1,2}^n}{\left[1+(nz/a)^2\right]^{1/2}}\right\} \quad (5\text{-}36)$$

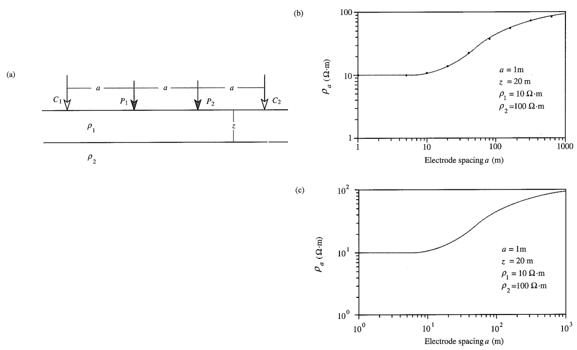
TABLE 5.4 Variation of Apparent Resistivity with Electrode Spacing for a Single Horizontal Interface

Electrode spacing a (m)	**1**
Depth of interface (m)	**20**
ρ_1	**10**
ρ_2	**100**
(Resistivities are in Ω · m)	

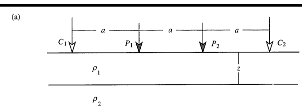
Apparent resistivity (Ω · m)	10

k	0.82				
n	k-factor	Divisor 1	Divisor 2	Sum 1	Sum 2
1.00	0.82	40.01	20.02	0.02	0.04
2.00	0.67	80.01	40.01	0.01	0.02
3.00	0.55	120.00	60.01	0.00	0.01
4.00	0.45	160.00	80.01	0.00	0.01
5.00	0.37	200.00	100.00	0.00	0.00
6.00	0.30	240.00	120.00	0.00	0.00
7.00	0.25	280.00	140.00	0.00	0.00
8.00	0.20	320.00	160.00	0.00	0.00
9.00	0.16	360.00	180.00	0.00	0.00
10.00	0.13	400.00	200.00	0.00	0.00
			Column totals	0.04	0.08

Apparent Resistivity vs. "a"

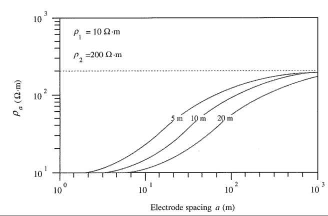


Same Resistivities
Different Depths

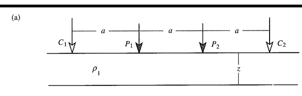


ρ_1 (Ω • m)	ρ_2 (Ω • m)	Depth to Interface
10	200	5
10	200	10
10	200	20

The important aspect of these curves is their similarities and differences, not the absolute values of the apparent resistivities and *a*-spacings.



Same Depth
Different Resistivity at Depth



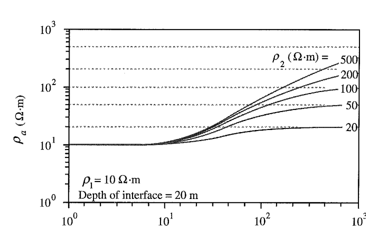
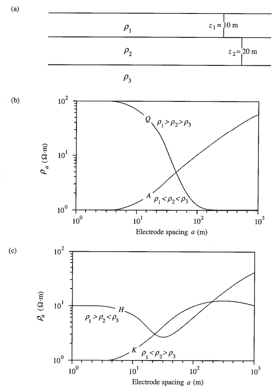


Figure 5-20 Apparent resistivity curves for constant depth to an interface. Resistivity of the layer above the interface also is constant. Dashed lines are drawn at resistivity values assigned to the layer beneath the interface. Pay special attention to the different curve forms for the various resistivities assigned to the deeper layer.

3 Layer Models



Suppression and Equivalence

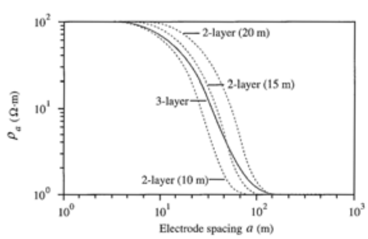
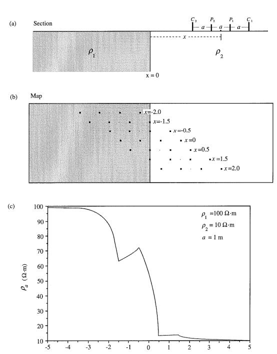


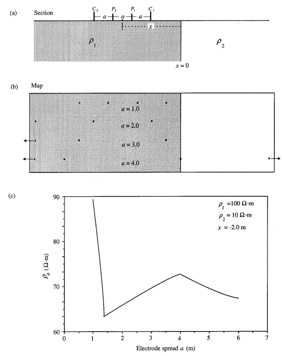
Figure 5-22 Comparison of two- and three-layer curves for similar depths and resistivities. The three-layer curve is a solid line (thickness of the first layer is 10 m; thickness of the second layer is 20 m; resistivities are 100, 10, and 1 Ω · m). Resistivities for the two-layer cases are 100 and 1 Ω · m. Depth of the interface is indicated for each curve.

Horizontal Survey across a Vertical Interface

Why is the change in apparent resistivity values much more pronounced between $x = -3$ to $x = -2$ than from $x = 3$ to $x = 2$? *Hint:* Note that the negative x-values are in the higher resistivity medium. Use the current density distribution model or a water-flow analogy to arrive at a qualitative explanation.



Vertical Survey across a Vertical Interface



Vertical Dike

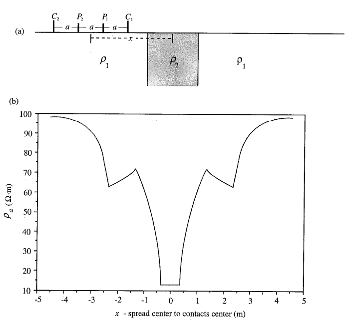


Figure 5-25 Constant-spread traverse across a vertical dike. (a) Diagram of relationships. (b) Qualitatively derived sketch of likely curve shape.

Channel is Similar to Vertical Dike Model

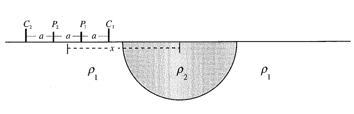
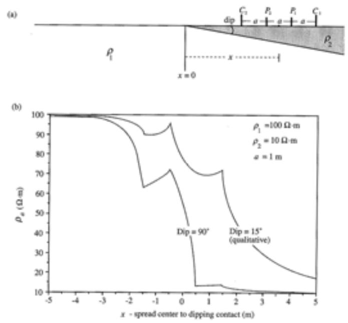


Figure 5-26 Hemispherical sink with diameter substantially greater than electrode spacing a.

Sloping Interface



Field Methods

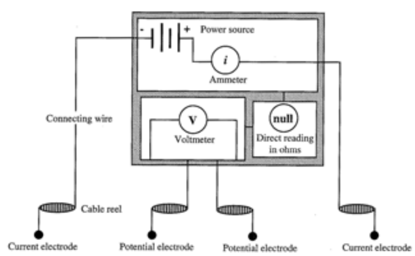
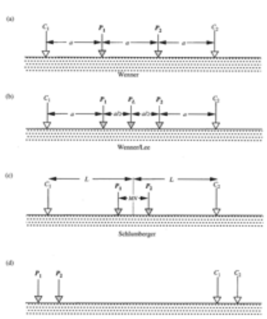


Figure 5-28 Schematic of main elements of electrical-resistivity surveying system including electrodes, power source, ammeter, voltmeter, and direct-reading device.

Field Methods



Schlumberger Method

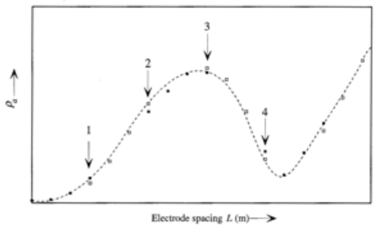


Figure 5-31 Apparent resistivity values illustrating effect of changing *MN* spacing during Schlumberger expanding-spread traverse. *MN* spacing changed when *L* values equivalent to positions 1, 2, 3, and 4.

Wenner/Wenner+Lee

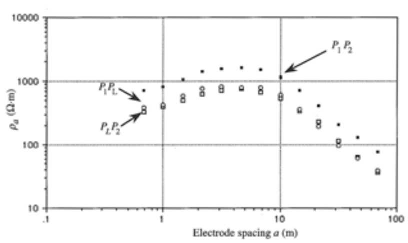


Figure 5-32 Apparent resistivity values obtained with a Wenner array near Hatfield, Massachusetts. Note that the Lee modification values are very similar and mimic the Wenner values closely.

Resistivity of Earth Materials

Material	Resistivity (Ω·m)
Wet to moist clayey soil and wet clay	1s to 10s
Wet to moist silty soil and silty clay	Low 10s
Wet to moist silty and sandy soils	10s to 100s
Sand and gravel with layers of silt	Low 1000s
Coarse dry sand and gravel deposits	High 1000s
Well-fractured to slightly fractured rock with moist-soil-filled cracks	100s
Slightly fractured rock with dry, soil-filled cracks	Low 1000s
Massively bedded rock	High 1000s

Curve Matching

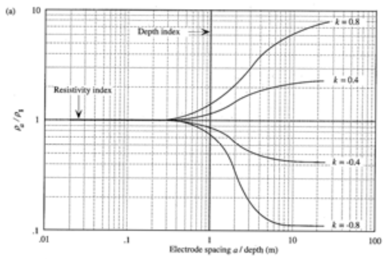
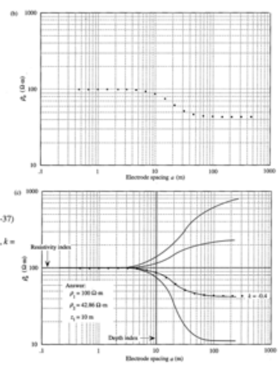


Figure 5-33 Basic procedures for curve matching. (a) Master curves for several possible *k*-values. (b) Field data plotted on the same scale as (a). (c) Answer obtained by superimposing field-data curve on master curves.

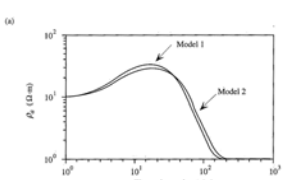
Curve Matching

$$\rho_2 = \left(\frac{1+k}{1-k}\right)\rho_1 \qquad (5\text{-}37)$$

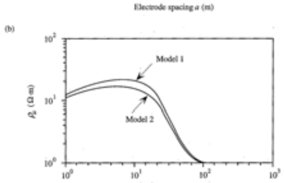
it is straightforward to determine ρ_2. Figure 5-33(c) provides values of $\rho_1 = 100\ \Omega \cdot m$, $k = -0.4$, and $z_1 = 10$ m. Equation (5-37) then provides a value of 42.86 $\Omega \cdot m$ for ρ_2.



Equivalence and Suppression

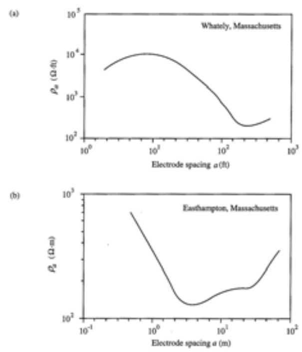


Model 1 – 3 m, 10 Ohm-m
10 m, 100 Ohm-m
inf., 1 Ohm-m
Model 2 - 3 m, 10 Ohm-m
20 m, 50 Ohm-m
inf., 1 Ohm-m

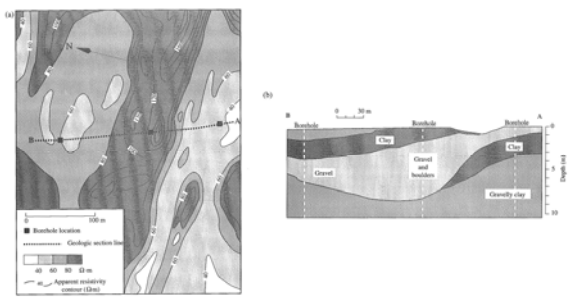


Model 1 – 1 m, 10 Ohm-m
1 m, 40 Ohm-m
1 m, 10 Ohm-m
7 m, 40 Ohm-m
inf., 1 Ohm-m
Model 2 - 1 m, 10 Ohm-m
13 m, 20 Ohm-m
inf., 1 Ohm-m

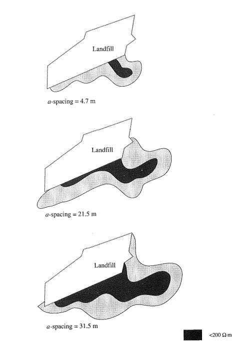
Expanding Spread Surveys



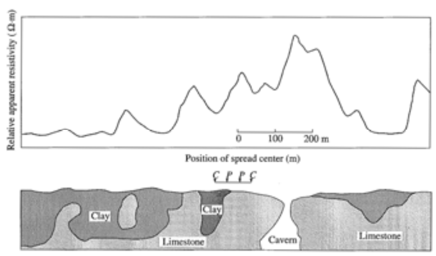
3D survey of Stream Channel (6.1 m spacing)



Leachate Plumes



Air Filled Cavern/Limestone
(a = 30.48 m)



Horizontal Survey of Faults
(a = 30.48 m)

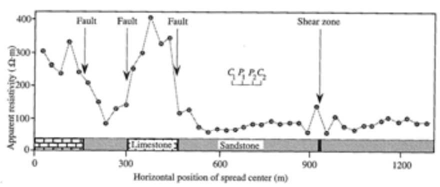


Figure 5-39 Apparent resistivity curve for a constant-spread traverse over faults in Illinois. Wenner array, *a*-spacing = 30.48 m, spread-center spacing = 30.48 m. Curve form is similar to that predicted over vertical contacts. (Based on data in Hubbert, M. K., 1932, Results of earth-resistivity survey on various geologic structures in Illinois: American Institute of Mining and Metallurgical Engineers Technical Publication 463, p. 16.)