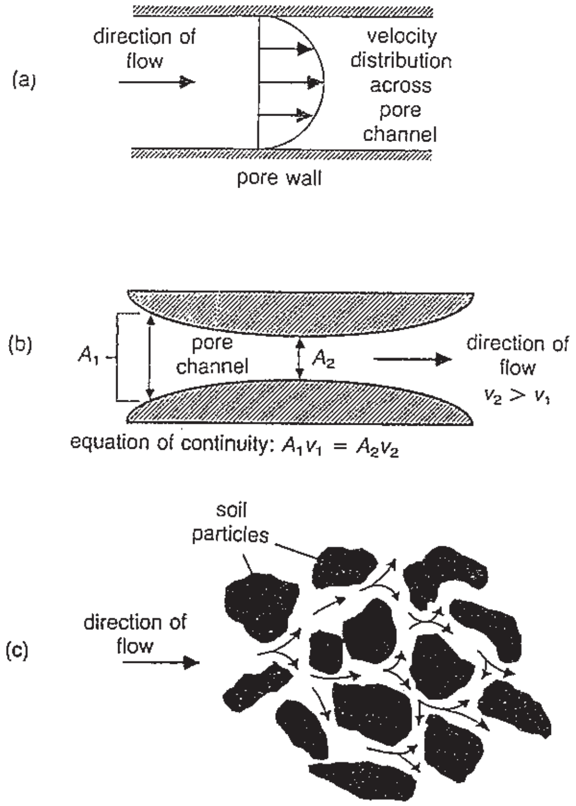

Fig. 3.1 Microscopic dispersion in soil: (a) effect of velocity distribution across single pore; (b) effect of variation in pore sizes: and (c) effect of tortuous nature of flow paths [after Freeze and Cherry (1979); and Fried (1975)].

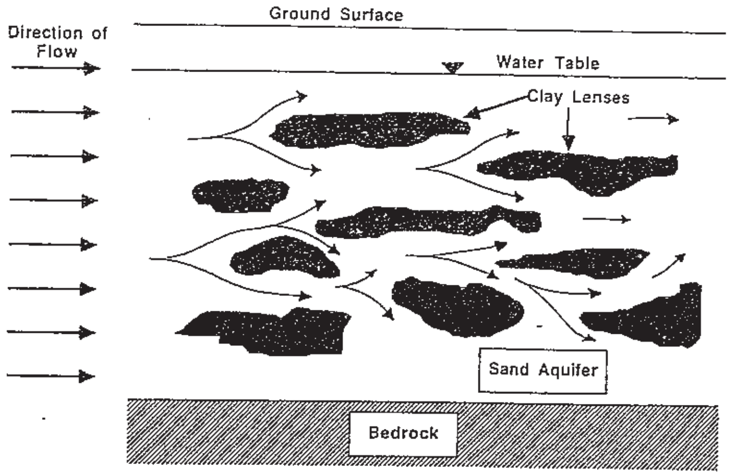

Fig. 3.2 Mechanical dispersion on large or regional scale.

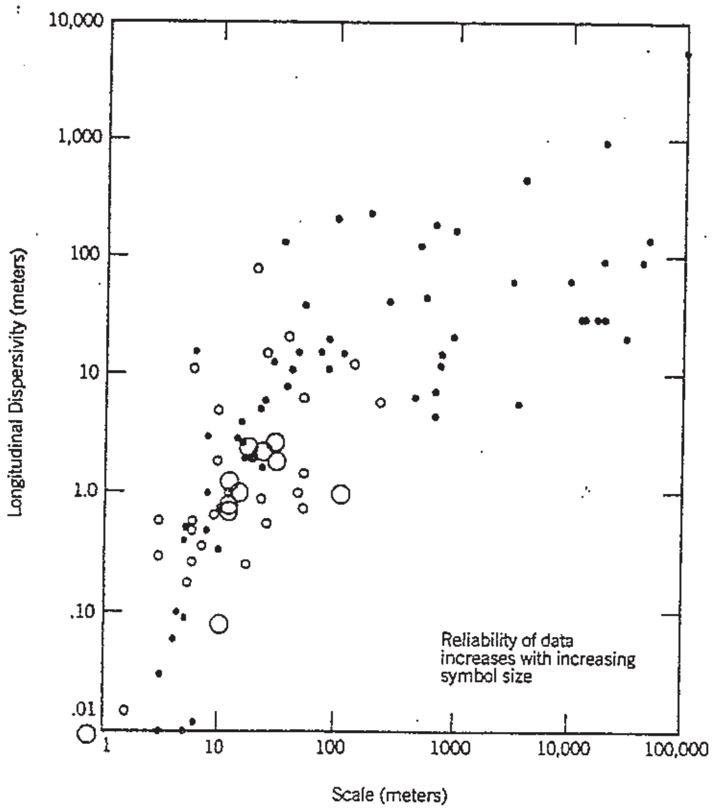

Figure 6.11 Scale of observation versus longitudinal dispersibility: reliability classification. Source: Gelhar et al., 1985.

Molecular Diffusion

TABLE 1. Self-Diffusion Coefficients for Representative Ions at Infinite Dilution in Water at 25° C

Anion (1)	$D_0 \times 10^{10}$ (m²/s) (2)	Cation (3)	$D_0 \times 10^{10}$ (m²/s) (4)
OH^-	52.8	H^+	93.1
F^-	14.7	Li^+	10.3
Cl^-	20.3	Na^+	13.3
Br^-	20.8	K^+	19.6
I^-	20.4	Rb^+	20.7
HCO_3^-	11.8	Cs^+	20.5
NO_3^- [a]	19.0	Be^{2+}	5.98
SO_4^{2-}	10.6	Mg^{2+}	7.05
CO_3^{2-}	9.22	Ca^{2+}	7.92
—	—	Sr^{2+}	7.90
—	—	Ba^{2+}	8.46
—	—	Pb^{2+}	9.25
—	—	Cu^{2+}	7.13
—	—	Fe^{2+} [a]	7.19
—	—	Cd^{2+} [a]	7.17
—	—	Zn^{2+}	7.02
—	—	Ni^{2+} [a]	6.79
—	—	Fe^{3+} [a]	6.07
—	—	Cr^{3+} [a]	5.94
—	—	Al^{3+} [a]	5.95

[a]Values from Li and Gregory (1974).

TABLE 2. Limiting Free-Solution Diffusion Coefficients for Representative Simple Electrolytes at 25° C [after Robinson and Stokes (1959)]

Electrolyte (1)	$D_0 \times 10^{10}$ (m²/s) (2)
HCl	33.36
HBr	34.00
LiCl	13.66
LiBr	13.77
NaCl	16.10
NaBr	16.25
NaI	16.14
KCl	19.93
KBr	20.16
KI	19.99
CsCl	20.44
$CaCl_2$	13.35
$BaCl_2$	13.85

TABLE 3. Representative Apparent Tortuosity Factors Taken from Literature

Soil(s) (1)	Saturated or unsaturated (2)	τ_a Values[a] (3)	Reference (4)
	(a) ^{36}Cl Tracer		
Bentonite: sand mixtures	Saturated	0.59–0.84	Gillham et al. (1984)
50% sand: bentonite mixture	Saturated	0.08–0.12	Gillham et al. (1985)
Bentonite: sand mixtures	Saturated	0.04–0.49	Johnston et al. (1984)
	(b) Cl^- Tracer		
Sandy loam	Unsaturated	0.21–0.35[a]	Barraclough and Nye (1979)
Sand	Unsaturated	0.025–0.29[a]	Porter et al. (1960)
Silty clay loam	Unsaturated	0.064–0.26[a]	Porter et al. (1960)
Clay	Unsaturated	0.091–0.28[a]	Porter et al. (1960)
Silt loam	Unsaturated	0.031–0.57[a]	Warncke and Barber (1972)
Silty clay loam; sandy loam	Saturated	0.08–0.22[a]	Barraclough and Tinker (1981)
Silty clay	Saturated	0.13–0.30[a]	Crooks and Quigley (1984)
Clay	Saturated	0.28–0.31[a]	Rowe et al. (1988)
	(c) Br^- Tracer		
Silty clay loam; sandy loam	Saturated	0.19–0.30[a]	Barraclough and Tinker (1981)
Sandy loam	Saturated	0.25–0.35[a]	Barraclough and Tinker (1982)
	(d) ^3H Tracer		
Bentonite: sand mixtures	Saturated	0.33–0.70	Gillham et al. (1984)
Bentonite: sand mixtures	Saturated	0.01–0.22	Johnston et al. (1984)

[a]Values were calculated using appropriate D_0 value from Table 1 with D^* value taken from reference.

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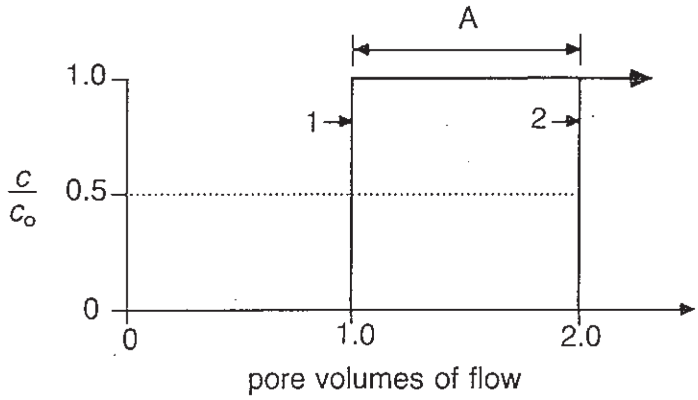
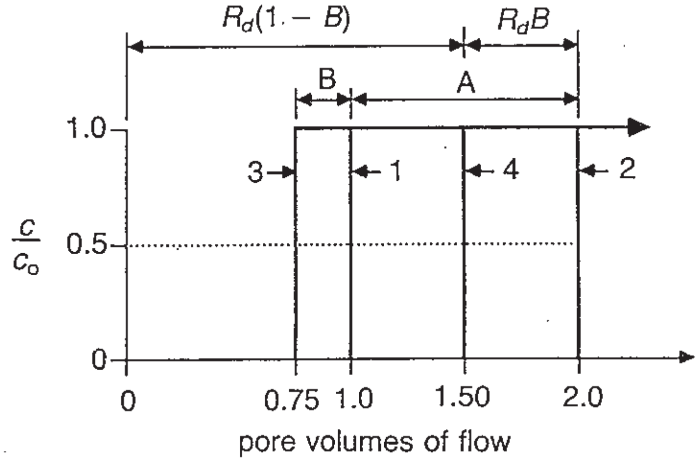
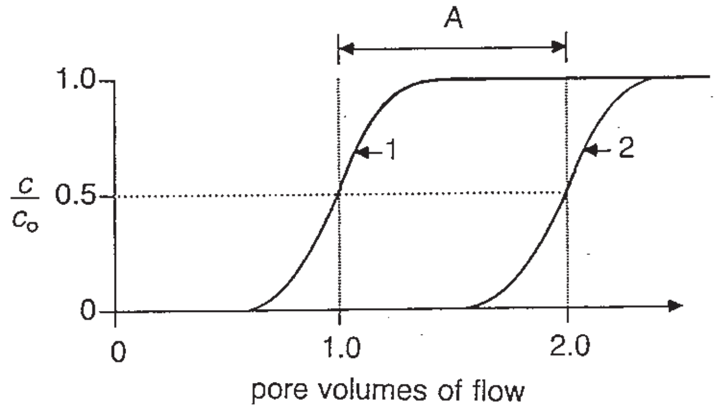

A
1.0
1
2
c/co
0.5
0
0
1.0
2.0
pore volumes of flow

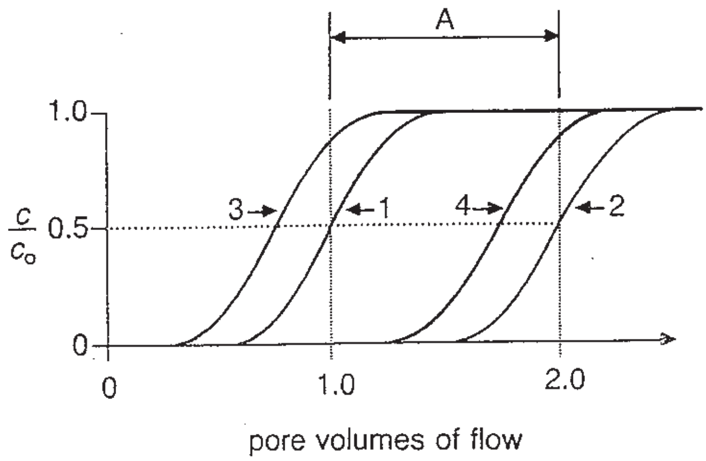
(a)


Rd(1 − B)
RdB
B
A
1.0
3
1
4
2
c/co
0.5
0
0
0.75
1.0
1.50
2.0
pore volumes of flow

(b)


A
1.0
1
2
c/co
0.5
0
0
1.0
2.0
pore volumes of flow

(c)


A
1.0
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2
c/co
0.5
0
0
1.0
2.0
pore volumes of flow

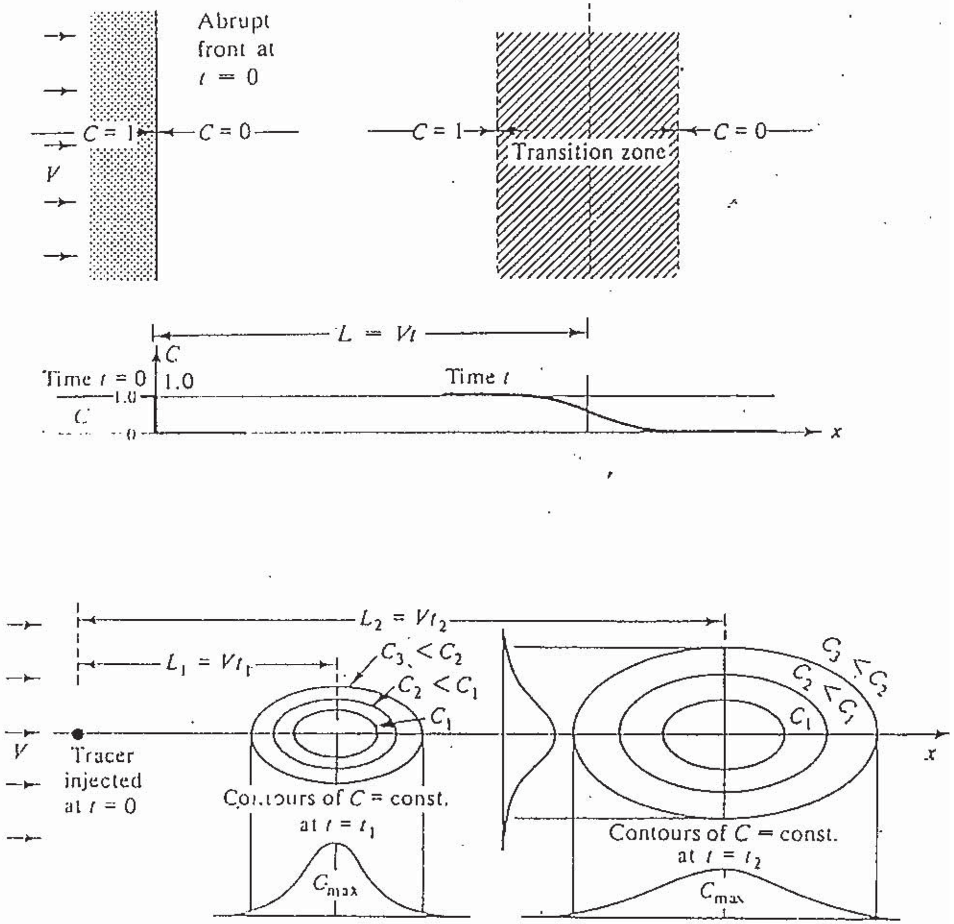

Fig.2.1.1(a)&(b) Spreading of Tracer
(a) :Longitudinal Spreading of Initially Sharp Front
(b) :Spreading of a Point Injection

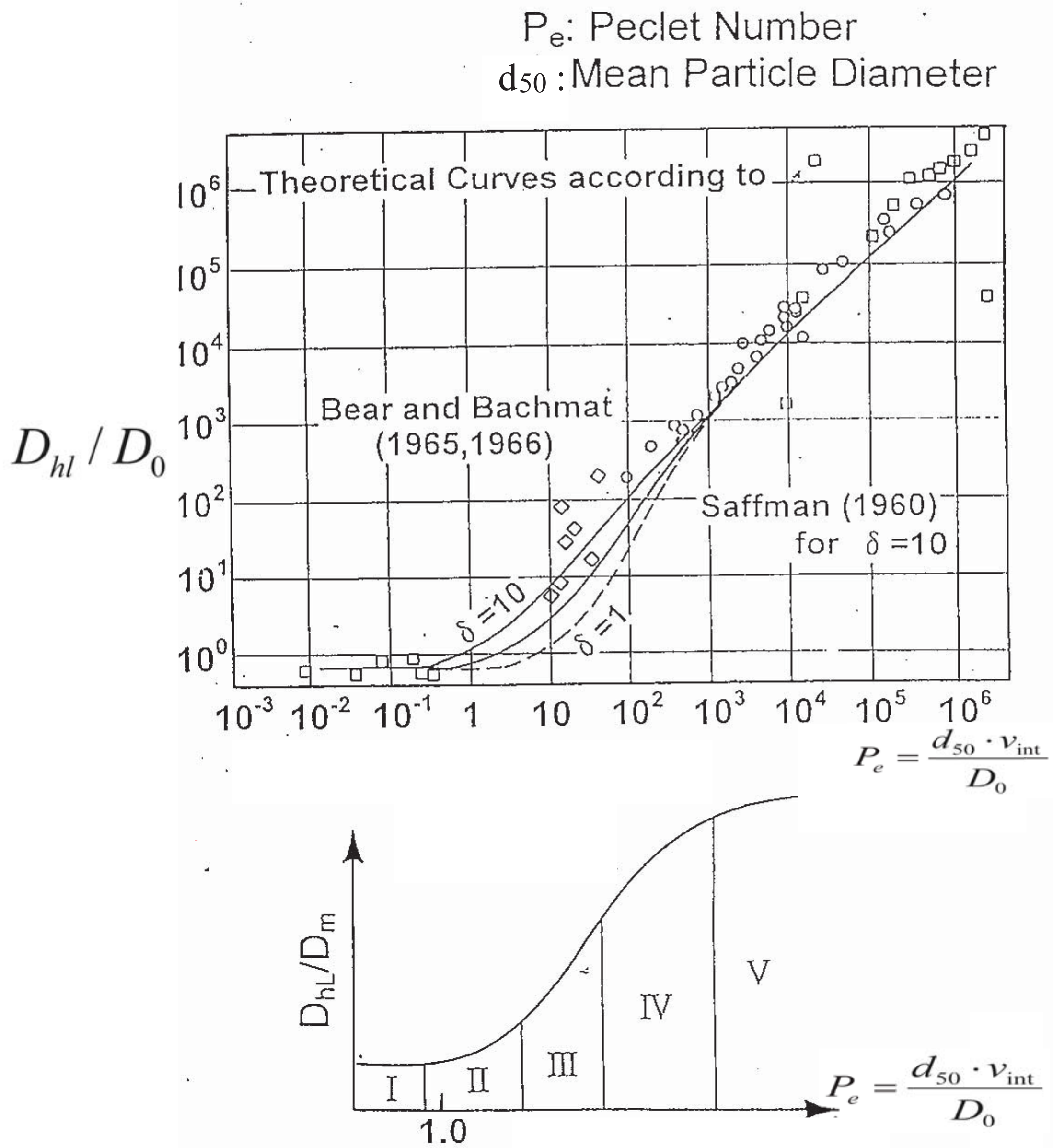

Fig.1.2.2 Relationship between Molecular Diffusion and Longitudinal Hydrodynamic Dispersion (Bear, 1987)

2.9 Effects of Transverse Dispersion

The ratio of longitudinal to transverse dispersivity (α_L/α_T) in an aquifer is an important control over the shape of a contaminant plume in two-dimensional mass transport. The lower the ratio, the broader the shape of the resulting plume will be. Figure 2.14 shows various two-dimensional shapes of a contaminant plume, where the only factor varied was the ratio of longitudinal to transverse dispersivity. This illustrates the fact that it is important to have some knowledge of the transverse dispersivity in addition to the longitudinal dispersivity. There is a paucity of data in the literature on the relationships of longitudinal to transverse dispersivities. From the few field studies available, α_L/α_T is in the range of 6 to 20 (Anderson 1979, Klotz et al. 1980). In addition, dispersivity ratios based on field studies are based on fitting the diffusional model of dispersion to cases where it might not be applicable.

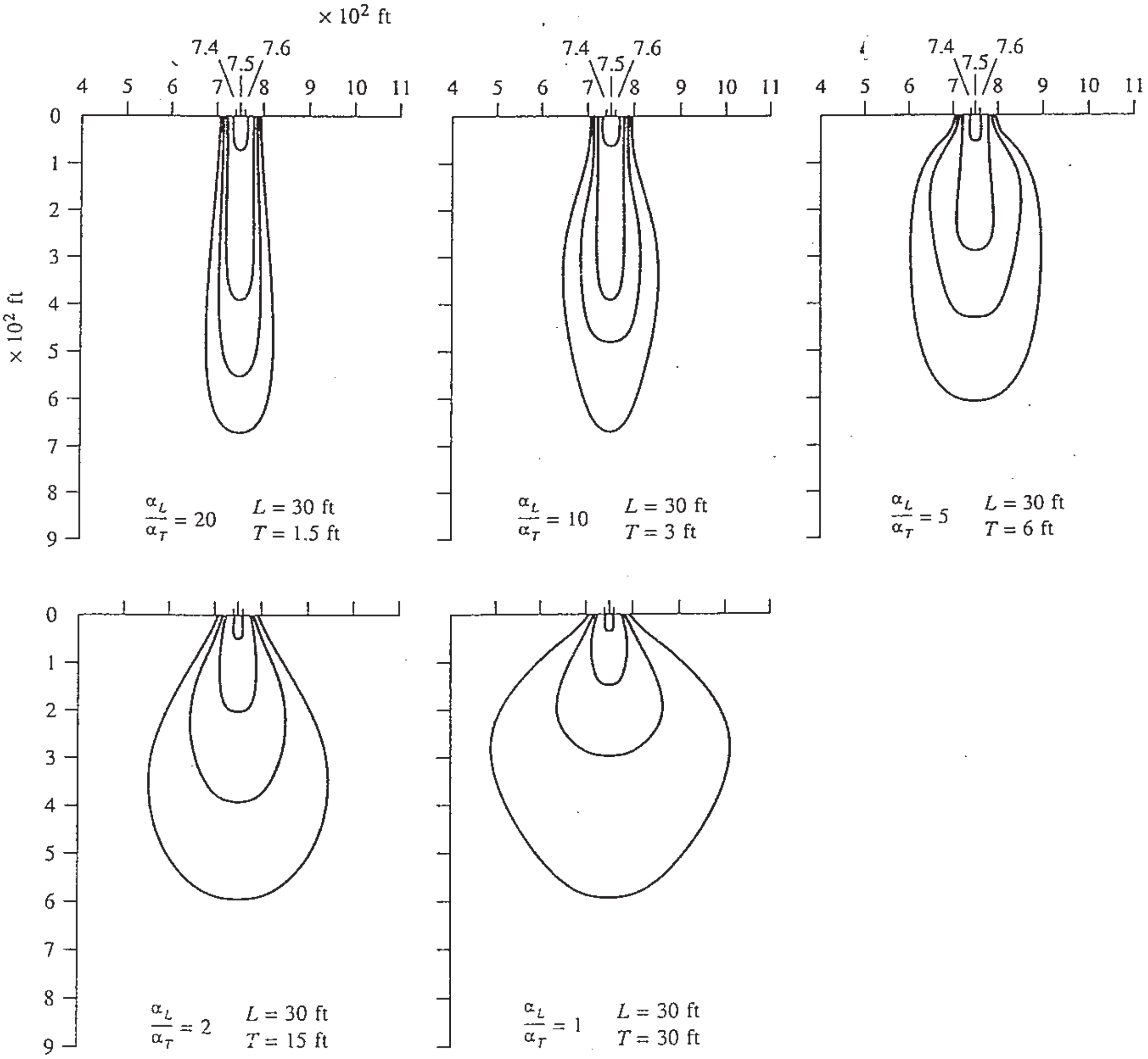

FIGURE 2.14 The effect of changing dispersivity ratio on the spread of a contaminant plume from a continuous source. *Source:* Robert L. Stollar.