represents the median value of $\Delta h(d)$ for 36 paths in a specified direction. Figure 2.6 shows that paths in an east-west direction consistently show a larger interdecile range of terrain heights than those in a north-south direction. Data from the E-W paths suggest an asymptotic value $\Delta h = 80$ m, while those from the N-S paths suggest $\Delta h = 50$ m. The median value for paths in all six directions is $\Delta h = 62$ m. In the figure smooth curves calculated from (3) for $\Delta h = 50$, 62 and 80 m are compared with medians from profiles in each direction. The data for the mountain profiles do not show as consistent a directional trend, but in this case the east-west paths show the smallest values and the east-northeast paths tend to yield the largest values of $\Delta h(d)$ as shown on figure 2.7. The data for the most part fall between the limits $\Delta h = 800$ m and $\Delta h = 1000$ m, and the terrain is represented by the asymptotic value $\Delta h = 900$ m.

Figure 2.8 shows median values of $\Delta h(d)$ for the few Colorado mountain paths over which measurements were made, and a curve of $\Delta h(d)$ for $\Delta h = 650$ m. The value $\Delta h = 650$ m was assumed in calculating transmission loss to be expected over these paths. For the shorter paths this value is too large, as indicated in the figure. For the paths in Ohio and those in the Colorado plains, the value $\Delta h = 90$ m was assumed in calculating expected transmission losses. Figure 2.9 shows the corresponding smooth curve of $\Delta h(d)$ versus d compared with median values of $\Delta h(d)$ from path profiles. The symbol x, representing median values of $\Delta h(d)$ for Colorado plains paths, shows good agreement with the curve especially at the greater distances where most of the radio data were recorded. The square symbol represents median values of $\Delta h(d)$ for all Ohio paths at each distance, the circle represents values

THE PARAMETER Δh(d) VERSUS DISTANCE

Colorado Mountains

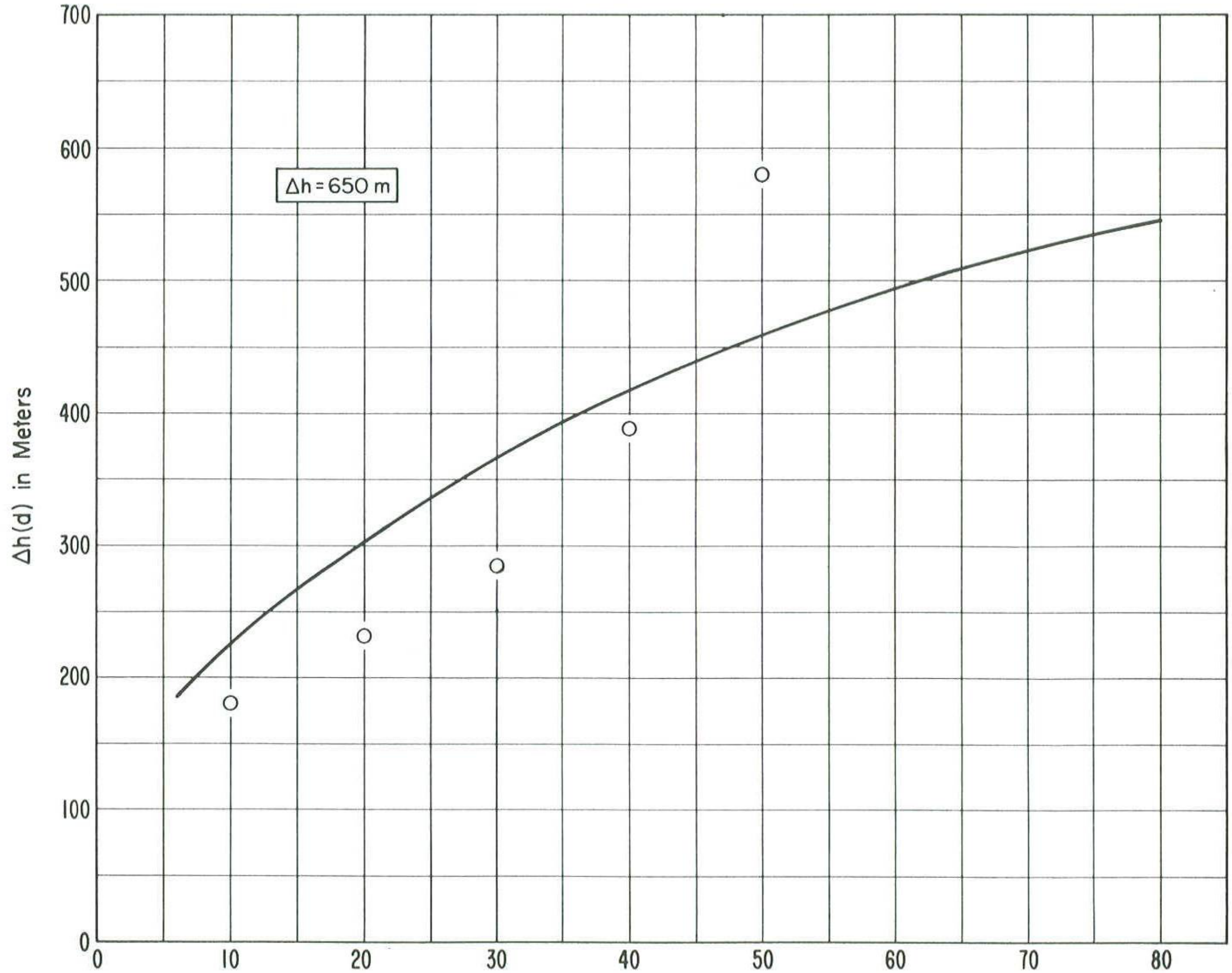

Figure 2.8

THE PARAMETER Δh(d) VERSUS DISTANCE

N. E. Ohio and Colorado Plains

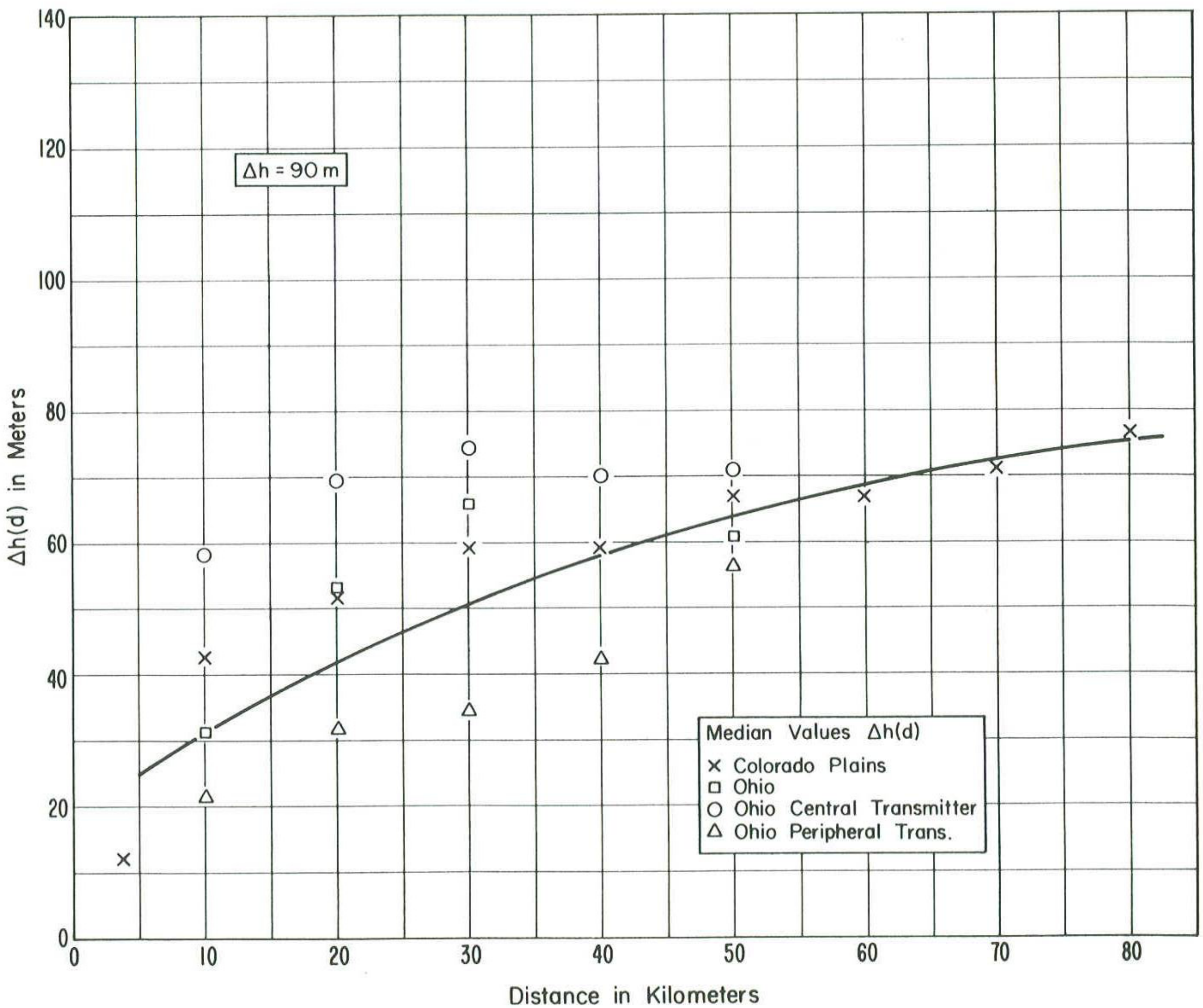

Figure 2.9

for the central transmitter, and the triangle those for the peripheral transmitters at each distance. Although the terrain in this Ohio area is obviously not homogeneous, the value $\Delta h = 90$ m was chosen as being representative of the terrain.

The following values of Δh were chosen as representative of the terrain in each of the areas for which terrain statistics were obtained:

Area	Δh in m
U.S. random	90
Plains grid	62
Mountain grid	900
Colorado plains (meas. paths)	90
Colorado mountains (meas. paths)	650
NE Ohio (meas. paths)	90

These figures provided most of the basis for the values of Δh listed in table 1 of the main body of the report.

2-3 The Horizon Distance, d_L

When a detailed terrain profile is available for a given path, the horizon distances d_{L1} and d_{L2} and their sum d_L may be obtained directly from the profile information and an estimate of the effective earth's radius. When individual path profiles are not available, median values of d_{L1} and d_{L2} are estimated as functions of the median effective antenna heights, the terrain irregularity factor Δh, and the corresponding distances to the horizon over a smooth earth.

The estimates d_{L1} and d_{L2} computed using equation (5c) of the main body of the report,

$$d_{L1,2} = d_{Ls1,2} \exp(-0.07 \sqrt{\Delta h/he}) \text{ km}, \tag{5c}$$

approach the smooth-earth values d_{Ls1} and d_{Ls2} as the terrain factor Δh approaches zero or as the antenna heights become very large. To determine the constant in (5c), horizon distances were obtained for the sets of U. S. random, plains, and mountains profiles with pairs of antenna heights above ground, h_{g1} and h_{g2}, chosen as follows:

h_{g1}	h_{g2}	h_{g1}	h_{g2}	h_{g1}	h_{g2}
1	1	3	3	10	10
1	10	3	10	30	30
		3	30		

For paths of lengths 30, 40, 50, and 60 km, the horizon distances d_{L1}, d_{L2}, and the sum of the horizon distances d_L were obtained from each profile. Figures 2.10, 2.11, and 2.12 show cumulative distributions of d_{L1}, d_{L2} and d_L. As shown in table 2.1, these horizon distances are independent of path length, provided that the path length chosen is greater than d_L. Figure 2.10 shows cumulative distributions of d_{L1}, d_{L2}, and d_L for 101 random paths with $h_{g1} = h_{g2} = 1$ m. Figures 2.11 and 2.12 show similar distributions for 216 paths in the plains and in the rugged mountains with $h_{g1} = h_{g2} = 10$ m. Note that the median value of d_L is always greater than the sum of the medians of d_{L1} and d_{L2}.

CUMULATIVE DISTRIBUTIONS OF HORIZON DISTANCES

U.S. Random Paths

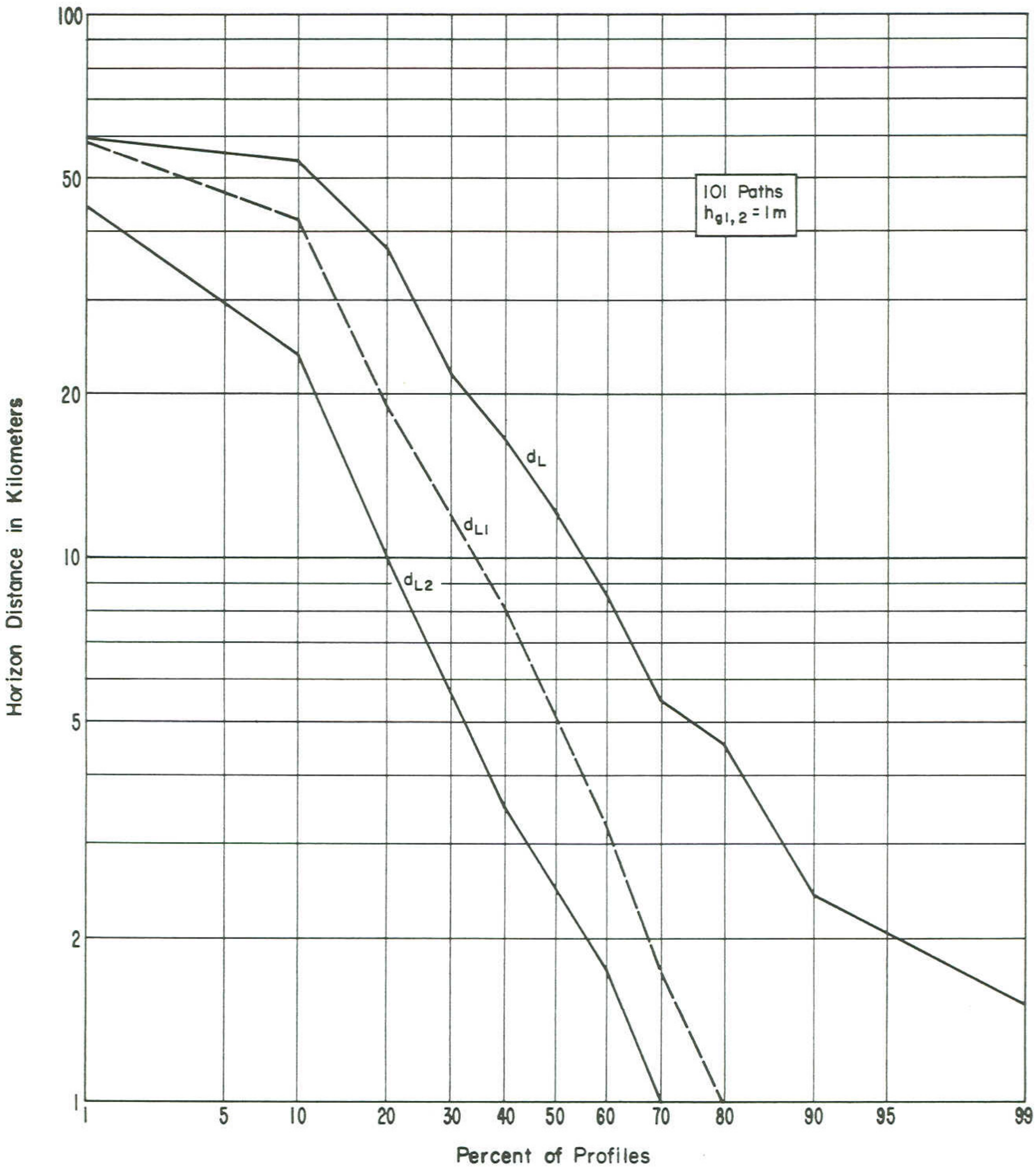

Figure 2.10

CUMULATIVE DISTRIBUTIONS OF HORIZON DISTANCES

U.S. Plains Paths

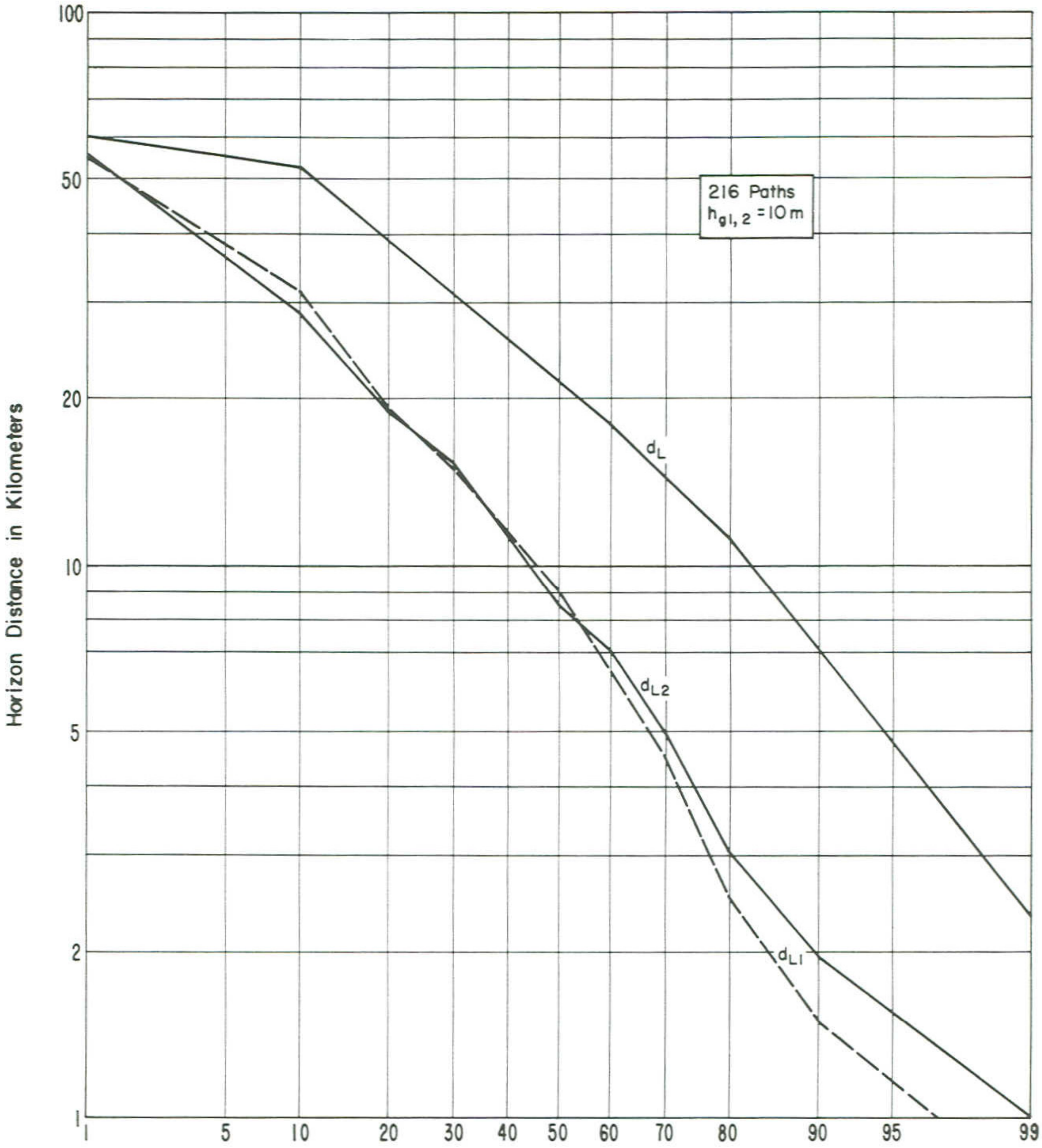

Figure 2.11

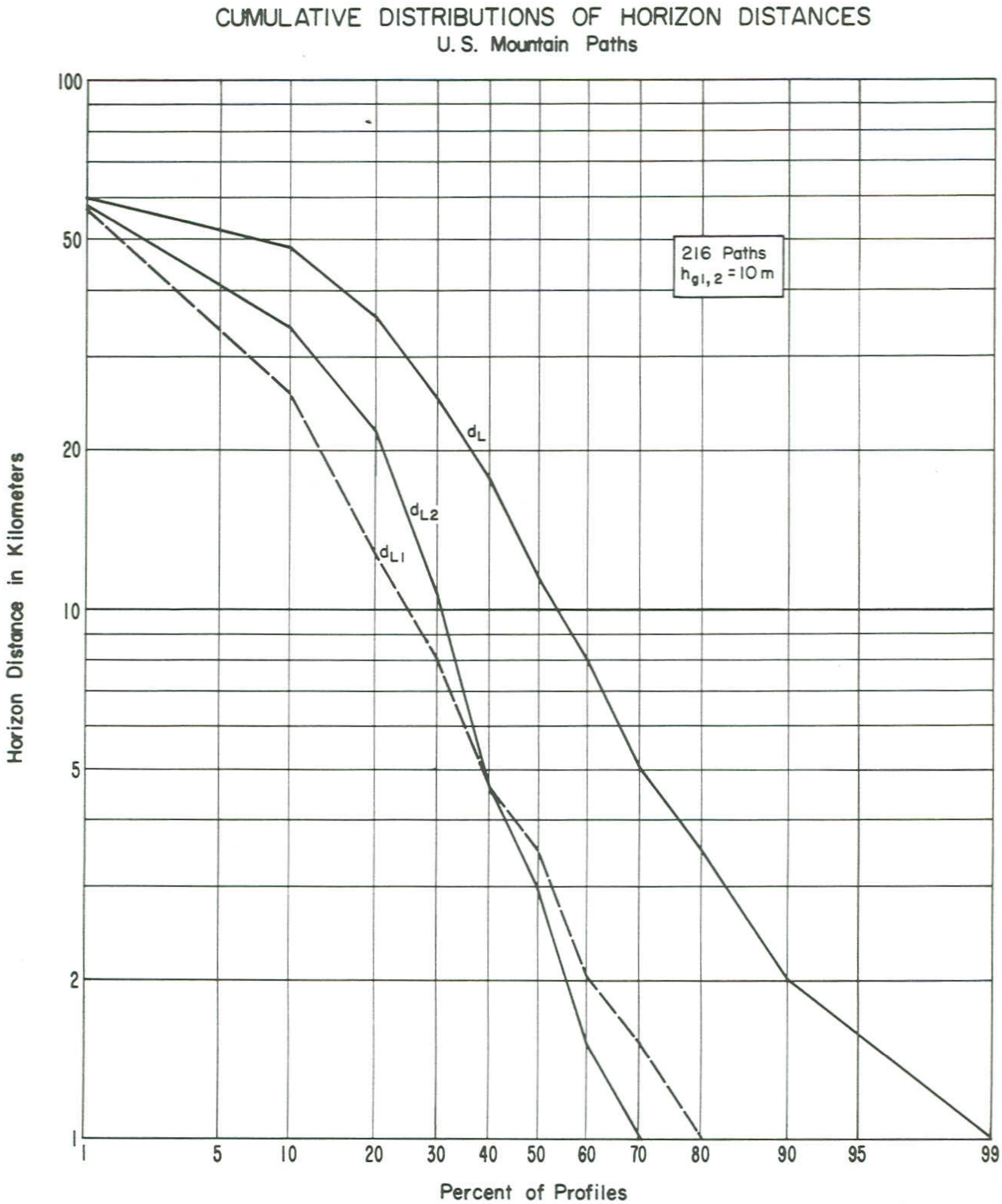
CUMULATIVE DISTRIBUTIONS OF HORIZON DISTANCES
U. S. Mountain Paths
216 Paths
$h_{g1,2}$ = 10 m
d_L
d_{L2}
d_{L1}
Horizon Distance in Kilometers
100
50
20
10
5
2
1
1
5
10
20
30
40
50
60
70
80
90
95
99
Percent of Profiles

Figure 2.12

Table 2.1

Median Values of Horizon Distances

$h_{g1,2}$	1, 1			3, 3			3, 10			10, 10 m		
d_{km}	d_{L1}	d_{L2}	d_L	d_{L1}	d_{L2}	d_L	d_{L1}	d_{L2}	d_L	d_{L1}	d_{L2}	d_L
Random												
30	4.0	2.5	10.5	6.0	3.5	13.5	5.8	8.0	15.5	9.0	8.0	18.5
40	4.5	2.0	12.0	6.5	3.0	13.5	6.2	6.5	18.0	9.5	6.5	20.0
50	4.5	3.0	10.5	6.5	4.0	13.5	6.5	6.0	18.0	10.5	6.0	21.0
60	5.0	1.8	12.2	6.5	3.5	15.0	6.5	5.5	17.0	10.5	5.5	19.5
Plains												
30	3.5	4.0	11.0	5.0	5.0	14.5	4.8	9.0	18.5	8.0	9.0	21.5
40	3.5	4.2	12.5	5.5	5.0	14.5	5.5	9.5	18.0	8.5	9.5	21.0
50	3.5	4.0	12.5	6.0	5.5	16.0	6.0	9.0	19.0	9.0	9.0	22.0
60	3.5	4.5	12.5	6.0	6.5	16.8	6.0	8.5	19.0	9.0	8.5	21.2
Mountains												
30	3.0	1.5	6.5	3.0	1.5	6.5	3.0	2.0	6.8	3.5	2.0	7.0
40	3.0	2.5	10.5	3.0	2.5	10.5	3.0	3.0	11.0	3.5	3.0	11.0
50	3.0	2.5	9.0	3.0	2.5	9.0	3.0	3.0	10.0	3.5	3.0	10.5
60	3.0	2.0	9.5	3.0	2.0	9.5	3.0	3.0	10.5	3.5	3.0	11.5

The constant in (5c) was estimated by computing the smooth earth distances d_{Ls1} and d_{Ls2} that correspond to these median values of d_{L1} and d_{L2} and rewriting (5c) as

$$d_{L1,2} = d_{Ls1,2} \exp(-k_{1,2}\sqrt{\Delta h/he}) \qquad (2.1a)$$

$$k_{1,2} = \log_e (d_{Ls1,2}/d_{L1,2})(\Delta h/he)^{-1/2} . \qquad (2.1b)$$

The median of all computed values was $k = 0.07$.

Table 2.2 shows calculated values of d_{Ls1} and d_{L1} for four antenna heights for the random, plains, and mountains paths. Table 2.3 shows a) median values of d_L from profiles and b) corresponding calculated values for seven antenna height combinations.

The values show rather good agreement in all areas for low to medium antenna heights, with a decided tendency to overestimate d_L when both antennas are as much as 30 m above ground, especially in the mountains. These comparisons are all made assuming effective antenna heights equal to structural heights.

2-4. The Elevation Angle θ_e

For each of the large number of terrain profiles available, the elevation angles θ_{e1} and θ_{e2} were computed using (3.1) of annex 3, and for each profile the sum of these angles θ_e was also computed. Figures 2.13, 2.14, and 2.15 show cumulative distributions of θ_{e1}, θ_{e2}, and θ_e given in milliradians. These are plotted on logarithmic probability paper, but it should be kept in mind that a small percentage of these angles are negative, especially in the group of plains paths. As previously observed for the horizon distances d_{L1}, d_{L2}, and d_L, these

Table 2.2

Calculated values of d_{Ls1} and d_{L1}*

h_{e1}	1	3	10	30 m.
Random Paths, $\Delta h = 90$ m, $N_s = 310$, $a = 8640$ km.				
d_{Ls1}	4.16	7.20	13.15	22.77
d_{L1}	3.1	5.6	10.7	20.2
Plains Paths, $\Delta h = 62$ m, $N_s = 290$, $a = 8330$ km.				
d_{Ls1}	4.08	7.07	12.91	22.36
d_{L1}	3.2	5.5	10.8	20.2
Mountain Paths, $\Delta h = 900$ m, $N_s = 250$, $a = 7850$ km.				
d_{Ls1}	3.96	6.86	12.53	21.70
d_{L1}	1.6	2.7	6.4	14.8

*$d_{L1} = d_{Ls1} \exp(-0.07\sqrt{\Delta h/he})$

Table 2.3

The Sum of the Horizon Distances d_L

$h_{e1,2}$	1, 1	3, 3	1, 10	3, 10	10, 10	3, 30	30, 30 m
Random Paths							
a)	11.2	13.5	15.2	17.5	19.7	24.2	35.2
b)	6.2	11.2	13.8	16.3	21.4	25.8	40.4
Plains Paths							
a)	12.5	15.2	17.2	18.7	21.4	25.5	35.4
b)	6.4	11.0	14.0	16.3	21.6	25.7	40.4
Mountain Paths							
a)	9.2	9.2	10.2	10.2	10.7	11.2	13.5
b)	3.2	5.4	8.0	9.1	12.8	17.5	29.6

a) Median value from profiles

b) Calculated using (5e)