TECHNICAL REPORT M-74-4

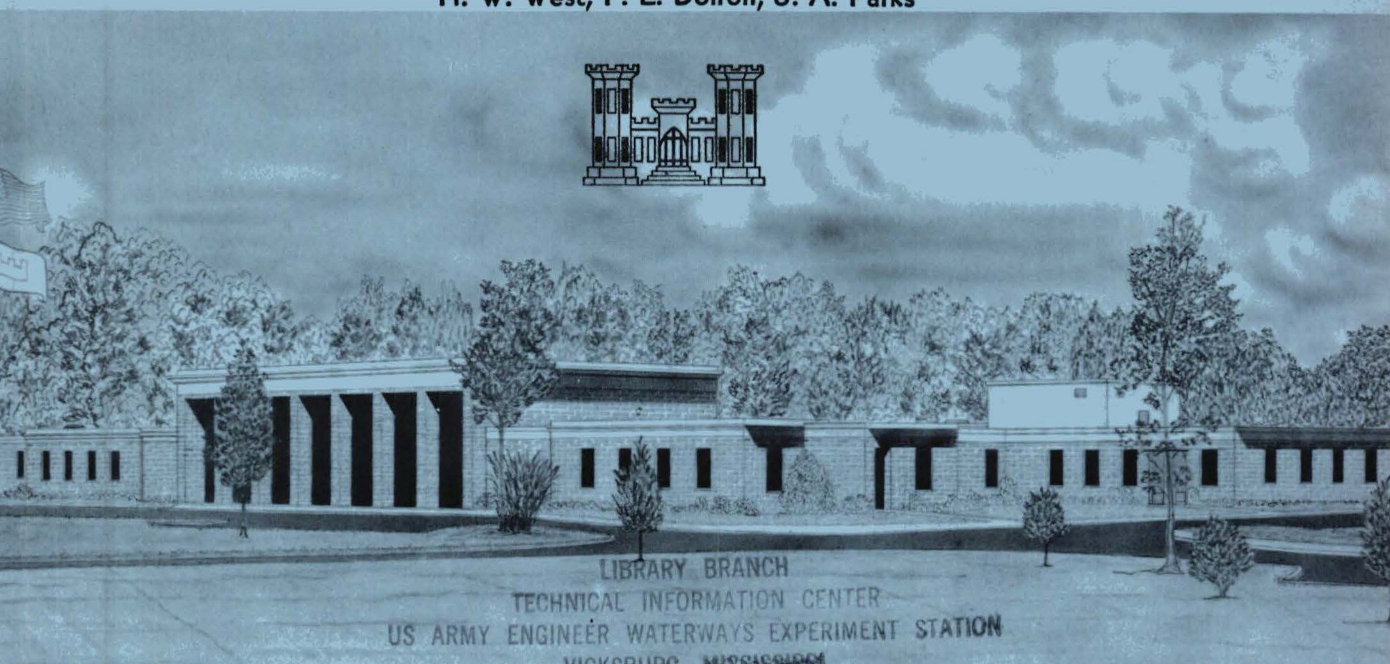
ANALYTICAL STUDY OF GROUND-SURFACE SHIELDING CHARACTERISTICS OF SELECTED ROAD TERRAINS

Volume I

DEVELOPMENT OF SHIELDING MODEL AND ANALYSES OF RESULTS

by

H. W. West, P. L. Doiron, J. A. Parks



June 1974

Sponsored by U. S. Army Materiel Systems Analysis Agency,
Aberdeen Proving Ground, Maryland

Conducted by U. S. Army Engineer Waterways Experiment Station
Mobility and Environmental Systems Laboratory
Vicksburg, Mississippi

TECHNICAL REPORT M-74-4

ANALYTICAL STUDY OF GROUND-SURFACE SHIELDING CHARACTERISTICS OF SELECTED ROAD TERRAINS

Volume I

DEVELOPMENT OF SHIELDING MODEL AND ANALYSES OF RESULTS

by

H. W. West, P. L. Doiron, J. A. Parks

June 1974

Sponsored by U. S. Army Materiel Systems Analysis Agency, Aberdeen Proving Ground, Maryland

Conducted by U. S. Army Engineer Waterways Experiment Station
Mobility and Environmental Systems Laboratory
Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS

FOREWORD

The study reported herein was authorized by the U. S. Army Materiel Systems Analysis Agency (AMSAA) and was conducted during June-December 1973 by personnel of the Environmental Simulation Branch (ESB), Environmental Systems Division (ESD), Mobility and Environmental Systems Laboratory (MESL), U. S. Army Engineer Waterways Experiment Station (WES).

The study was under the direct supervision of Mr. J. K. Stoll, Chief, ESB, and under the general supervision of Messrs. W. E. Grabau, Chief, ESD, and W. G. Shockley, Chief, MESL. It was planned and directed by Mr. H. W. West of the ESB and Messrs. J. Kramar, Chief, Special Activities Office, and M. Reches (Program Monitor) of AMSAA. Personnel of the MESL who contributed to the study were Ms. J. A. Parks, Messrs. P. L. Doiron, S. Winfrey, R. Erazo, and L. M. Rodriquez, and Dr. V. E. LaGarde of the ESB, and Messrs. C. E. Stevens and A. Vazquez of the Environmental Characterization Branch, ESD. The computer model used to calculate the shielding characteristics of the various road sites was developed by Ms. Parks, assisted by Dr. LaGarde. The supplementary computer programs used to portray the terrain characteristics of the various road sites were developed under other research programs by various staff members of the ESB. This report was prepared by Messrs. West and Doiron and Ms. Parks.

Acknowledgment is made to Mr. O. P. Bruno, Chief, Reliability, Availability and Maintainability Division of AMSAA, for his helpful suggestions and direction in the conduct of this study.

Director of WES during the study and preparation of the report was COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, METRIC TO BRITISH UNITS OF MEASUREMENT

Metric units of measurement used in this report may be converted to British units as follows:

Multiply	By	To Obtain
centimeters	0.3937	inches
meters	3.2808	feet
kilometers	0.6214	miles (statute)

SUMMARY

The mathematical model presented herein allows the user to determine the amount of shielding from munition bursts offered by the ground surface to targets (vehicles, personnel, etc.) on and moving along roads or in cross-country terrains. In the shielding model it is assumed that fragments and projectiles travel in straight-line trajectories; therefore, the amount of shielding offered by the ground surface to a target is calculated along the optical paths between the burst point and selected points on the target. The shielding values given by the model are maximum values.

Shielding characteristics in terms of probability of shielding for a point(s) on a target, or in terms of average shielding for a one-dimensional target of a specified height, can be obtained. The model variables include target height, number of target height intervals, locations of five target positions, elevations of six munition height-of-bursts (HOB), and eight horizontal target-to-HOB ranges.

Shielding results are provided for six road sites near Vicksburg, Miss., selected to be representative of a wide range of road configurations known to occur in various geographical regions. The ground-surface shielding results obtained for the six road sites show that shielding of a one-dimensional vertical target is significantly affected by both distance (or range) and burst height, and that shielding does not change appreciably for the different target positions that were evaluated along the center line of the road. However, since five target locations were in relatively uniform areas, it is believed that target location would have a significant effect on shielding on those roads that contain closely spaced cuts and fills. Of the six sites for which shielding calculations were made, site 6 contained the greatest amount of shielding; this amount increased with increasing range and decreased only slightly with increasing burst height. At sites 1 through 5, the shielding of the target varied between 0 and 25 percent for the different ranges and burst heights equal to and greater than 100 cm. For a burst height of 0 cm (i.e. ground burst), the shielding of the target varied between 10 and 55 percent for the different ranges.

Appendix A describes the general procedures used in the acquisition and recordings of on-site three-dimensional topographic data and presents the topographic data that were collected at the six road sites. Appendix B describes the interpolation procedure used in determining a

fine grid of equally spaced discrete elevations (i.e. 2-m grid points) from a set of randomly located (field measured) elevation points.

Appendix C presents examples of the tabular output of the shielding model. Volume II (published in limited quantity) contains the total tabular output of the shielding model.

ANALYTICAL STUDY OF GROUND-SURFACE SHIELDING CHARACTERISTICS OF SELECTED ROAD TERRAINS

VOLUME I: DEVELOPMENT OF SHIELDING MODEL AND ANALYSES OF RESULTS

PART I: INTRODUCTION

Objectives and Scope

1. The overall objective of this study was to determine the amount of shielding from munition bursts offered by the ground surface to targets (vehicles, personnel, etc.) on or moving along roads. The munition bursts were considered at various heights (on or above the ground) and various distances from the roads. The specific objectives of the study were to:

- a. Develop a mathematical computer program (i.e., a model) to calculate the shielding characteristics of various selected ground surface configurations, including those that might be encountered in both road terrains and cross-country terrains.
- b. Survey a limited number of road sites to obtain input data for the computer program in a above.
- c. Compute the shielding characteristics of the various selected road sites.
- d. Compare the shielding characteristics of the various selected road sites.

Approach

2. In this study consideration was given to the development of analytical procedures for determining answers to the following questions:

- a. How much ground-surface shielding is provided to targets, such as vehicles and personnel, from fragmenting munitions bursting at various distances from the road and at various heights on and above the ground?
- b. For those targets or portion of targets that are vulnerable

(or unshielded) to fragmenting munition, what are the target-fragment trajectory impact angles for different munition burst heights and ranges to target?

3. In pursuit of answers to these questions, analytical procedures for calculating the ground-surface shielding characteristics for various targets, ranges to targets, and munitions burst heights were developed. In addition to the shielding characteristics, the attitudes, or contact angles, of the unobstructed lines of sight, or optical path from the burst points to the unshielded portion of the target, were calculated.

4. In the shielding model in its present form it is assumed that fragments and projectiles travel in straight-line trajectories, which may or may not be a complete and/or accurate representation of the paths that certain fragments take. However, for fragments traveling at high velocities (greater than 500 m/sec*) and with relatively short (less than 100 m) travel paths, it is believed that the straight-line paths can be assumed to be characteristic of the trajectories. In any event, the shielding as calculated by the model provides the maximum ground-surface shielding that would be provided for targets traveling on or along the roads.

5. In the shielding model it is also assumed that the slant distances between the points on the target and the burst points for any given range circle of radius R have no effect on shielding.

6. The results of this study are intended to provide some insight into studies pertaining to the following:

a. Determination of the effects of ground-surface terrains on the vulnerability of different types of military targets on or moving along roads. The results of this study are restricted to determination of the ground-surface shielding effects (i.e. vegetation effects are not considered) of selected road terrains; however, the model is capable of determining the ground-surface shielding effects of any type of ground-surface terrain, including cross-country terrains.

---

* A table of factors for converting metric units of measurement to British units is presented on page vii.

b. Determination of the effects of ground-surface shielding on munition effectiveness and performance. Results should be useful in indicating the minimum burst height for maximum target exposure and, thereby, provide for maximum effectiveness of certain munitions.

c. Evaluation of body armor for military vehicles and personnel.

d. Fragment retardation and, possibly, fragment ricochet.

e. Determination of the cover offered by different road configurations to tactical vehicles on or moving along roads.

PART II: DEVELOPMENT OF THE GROUND-SURFACE SHIELDING MODEL

General Description

7. The ground surface shielding model is written in Fortran language to be used in the batch mode on a G-635 computer, and is designed to determine shielding characteristics for the following model variables:

- a. One-dimensional vertical target (or vertical line) of a specified height.
- b. Ten equally spaced target height intervals on the vertical target.
- c. Five different target positions along the center line of a road.
- d. Six munition heights of burst (HOB), on and aboveground. (It should be noted here that ten HOB's were enlisted by making two runs of the program.)
- e. Eight horizontal target-to-HOB ranges.

Terrain shielding, as calculated by the model, is defined as follows (see fig. 1): A point on a vertical target is said to be "shielded" if the optical path between a specified munition burst point and the point on the target is obstructed by the terrain surface. If a point on the target is shielded by the ground surface, the probability of shielding P_s equals 1; if the point is not shielded, the probability of shielding is zero. In addition to a determination of the shielding probability for each of 10 points (or height intervals) on the target, the average shielding for the vertical target is calculated. In the model if any one point on the target is shielded or visible, the height interval represented by that point is said to be also shielded or visible. The location of each point was at the top of the interval (see fig. 1). The "target shielding value" is calculated (see fig. 1) by projecting optical lines of sight from the burst point to each of 10 equally spaced points on the target and determining which, if any, of the lines of sight are obstructed by the terrain surface. Mathematically, this relation can be expressed as

$$S = \frac{T}{I}\,(T_h) \tag{1}$$

where

- S = average target shielding value, or fractional part of the target height that is shielded by the surface of the ground, for a specified burst point, percent
- T = first point or target height interval that is visible (or unshielded) from the burst point. In fig. 1, the first interval visible from the burst point is interval 4
- I = total number of target height intervals; for this study, 10 intervals were used
- T_h = total height of one-dimensional vertical target, centimeters. For this study a height of 300 cm was used.

8. To determine whether or not a specified line of sight is intercepted by the terrain, an elevation profile along a line between the target position and munition burst position is calculated using the topographic data that were generated in the study. (For a discussion of the procedures used in establishing the topographic (i.e. elevation) data arrays for the various road sites see Part III and Appendix B of this report.) The profile is determined by calculating the elevation of points at each 2-m distance along a line connecting the horizontal positions of the two points. The elevation of each point along the specified profile is then calculated using the following equation and the elevation data arrays that were generated for the various road sites.

$$z_{i,j} = \sum_{k=1}^{4} \frac{z_k}{R_k^2} \Bigg/ \sum_{k=1}^{4} \frac{1}{R_k^2} \tag{2}$$

where

- $z_{i,j}$ = the elevation at the $(i,j)^{th}$ grid position within the data array
- z_k = the elevations of the four nearest neighbors of grid points to the specified position (i,j). Each 200- by 200-m data array for this study consists of 10,201 grid points. The spacing of the grid points is 2 m.

R_k^2 = the square distances of each k^{th} data point from the $(i,j)^{th}$ grid point.

After the elevation of each respective 2-m point along the extracted profile is calculated, these elevations are compared with elevations along each projected line of sight at the same 2-m intervals. If the elevation of any one point along the ground profile is greater than the corresponding point along the specified line of sight, the line of sight is said to be intercepted by the ground surface, and the interval represented by that point of the target height is shielded.

Model Variables

One-dimensional vertical target and target position

9. Since tracked and wheeled vehicles and, to some degree, personnel must be considered three-dimensional targets in determining whether or not they might be vulnerable to fragmenting munitions, consideration was given to specifying the locations (i.e. x,y,z coordinates) of "points" on the outermost surface(s) of a target that might be subjected to fragment hits. To model a three-dimensional target, the target should be specified according to its three-dimensional outer surface or in terms of its sides, top, back, and frontal areas. For this study the height dimension of the target was represented by a vertical line of a specified height, and the length and depth dimensions of the target were represented by the xy position of the vertical line. These dimensions are illustrated in fig. 2. To define the vertical dimension more specifically, the vertical line (or target) is divided into ten intervals, and the shielding probability P_s is computed for each of these respective height intervals. For example, if the target is specified as being 300 cm tall and contains 10 height intervals, a shielding probability is computed for each 30-cm interval up to a height of 300 cm on the target. In addition to determining the shielding probability for each of the 10 height intervals on the target, the average shielding value (equation 1) for the target is calculated for each of five target positions (A through

E) along the center line of the road (see fig. 3). Since the five target positions were selected approximately along the road center line, only the length and height dimensions of a target were considered in determining shielding (i.e. the depth, or x-dimension, of the target was considered equal to zero).

Munition HOB

10. Terrain shielding can be computed for any of six different HOB's in any one run of the program. In this study two runs of the program were made and 10 HOB's were considered: 0 (ground surface), 10, 25, 50, 75, and 100, 200, 300, 400, and 500 cm.

Target-to-HOB ranges

11. Terrain shielding can also be computed for eight horizontal target-to-HOB ranges in any one run of the program. The only limitation on the horizontal range value that can be considered is that the data array for the site must be large enough so that a circle with a radius equal to the range (radius R), centered at a specified target position(s), will lie inside the array. The ranges used herein were 10, 20, 30, 40, 50, 60, 70, and 80 m.

Number of burst points

12. The number of burst points considered for each HOB (i.e. on the surface and aboveground) and for each range is determined by specifying uniformly spaced points (at 3.1416-m intervals) along a circle of radius R (fig. 3). The total number of points for any one range is then calculated by the following equation:

$$N_t = \frac{2\pi R}{s} = 2R \qquad (3)$$

where

N_t = total number of burst points for each HOB and range

R = range

s = uniform spacing of burst points along the circumference of a circle of radius R and considered to be equal to π m, or 3.1416 m

Shielding calculations

13. Shielding is calculated (equation 1) for each specified burst point along the circumference of the circle of radius R . In addition to these shielding calculations, the average shielding of the target for the entire circle of radius R is calculated. Symbolically, the average shielding is represented by the following equation.

$$S_{jk} = \sum_{n=1}^{N_t} \frac{S_{jkn}}{N_t} \qquad (4)$$

where

S_{jk} = average shielding of target for all burst points along the circumference of the circle of radius R and specified HOB, percent. The subscript j represents the number of ranges (i.e., j = 1, 2, ... 8), and the subscript k represents the number of burst heights (i.e., k = 1, 2, ... 6).

$\sum_{n=1}^{N_t} S_{jkn}$ = sum of individual shielding values as calculated by equation 1 for each specified burst point along the circumference of the circle of radius R and specified burst point, percent.

N_t = total number of burst points along the circumference of the circle of radius R as calculated by equation 3.

Vertical target contact angle

14. To provide data for use in target vulnerability evaluations, the attitude (or contact angle) of the first line of sight (i.e. unobstructed optical path) between the specified burst point and the target is determined (see fig. 1). In addition to the vertical target contact angles for the individual burst positions along the circumference of the circle of radius (or range) R (see fig. 3), the average vertical contact angle for the entire circle of radius R is calculated.

PART III: GENERAL TERRAIN DESCRIPTIONS, TOPOGRAPHIC SURVEY PROCEDURES, AND GENERATION AND ANALYSIS OF ELEVATION DATA ARRAYS

15. This part of the report discusses the selection of road sites, their general ground-surface and vegetation characteristics, the topographic survey procedures used to determine the three-dimensional ground surfaces at each site, and the procedures used to establish the gridded elevation data arrays for use as input to the shielding model.

General Terrain Descriptions

Site selection

16. Six road sites were selected within an 80-km radius of Vicksburg, Miss. (see fig. 4). Each contained paved, two-lane, two-way roads, and was 200 m by 200 m in size (i.e. roadbed and surrounding terrain out to a distance of 100 m). These six sites were selected to cover a wide range of road configurations that are known to occur in various geographical regions, including Europe, Asia, the Middle East, and others.

Terrain descriptions

17. Road site 1. Road site 1 was on Mississippi Highway 27 near the town of Crystal Springs (see fig. 4). The site was situated in a road cut (fig. 5), and the center line had a downward slope of approximately 2 percent from southeast to the northwest. The heights of the shoulders (or banks) on both sides of the road varied from approximately 1 m on the southeast end to approximately 5 m on the northwest end. Computer-drawn perspectives looking southeast (fig. 6a) and northwest (fig. 6b) show how the three-dimensional ground surface varied at the site. (These perspectives are a series of vertical profiles equally spaced along the road center line and were generated using a computer program and the elevation data arrays described in paragraphs 29 and 30 below.) The vegetation occupying the site (fig. 7) consisted of small isolated trees and two wooded areas with trees in the 3- to 30-m height range.

18. Road site 2. Road site 2 was at mile 78.5 on the Natchez Trace Parkway just southwest of its intersection with Mississippi Highway 467. The road (fig. 5b) is slightly elevated above the surrounding terrain, which consisted of rolling pastureland on the southeast side and farmland on the northwest side. The center line of the road had a downward slope of approximately 2 percent from northeast to southwest. The surrounding terrain, in general, was very smooth but contained areas with gradual slopes (i.e. rolling topography). There was a small, well-pronounced drainage channel on the southwest side of the road, as depicted in the computer-drawn perspectives (see fig. 8). The vegetation on the site consisted of a few isolated trees and two areas of widely spaced trees and understory vegetation (fig. 9).

19. Road site 3. Road site 3 (see fig. 10a), located on Highway 2 approximately 6 km northwest of Lake Providence, La., was selected because of its dikes and irrigation canals, which are characteristics of the rice-growing regions of Louisiana and Mississippi. The center line of the road was almost flat (i.e. zero slope). In addition to the dikes and canals, there is also an unpaved access road that parallels the main highway. A ground-level panoramic view of the site is given in fig. 10a, and two computer-drawn perspectives are given in fig. 11. There was no woody vegetation material at the site.

20. Road site 4. Road site 4, on Highway 61 near the community of Onward, Miss., is in the Mississippi Delta farming region and the center line of the road contained zero slope. There is a rather large bayou (Deer Creek) on the west side of the road (fig. 10b). The road is elevated approximately 3-4 m, and the terrain on the east side is normally used for growing cotton or soybeans and is extremely smooth and flat. Fig. 12 provides two excellent perspectives of the bayou, the elevated road, and the flat farmland that make up the site. The only vegetation occupying the site was a line of rather large (height 20-35 m) isolated trees along a fence row (see fig. 13).

21. Road site 5. Road site 5 was also on the Natchez Trace Parkway at mile 81.5. The road (fig. 14a) is elevated above the adjacent terrain, except at the northeastern end of the site (i.e. the last 20 m

of road), which passes through a cut. The center line of the road had a small downward slope (less than 0.05 percent) from southwest to northeast. The terrain adjacent to the road on the southeastern side was primarily rolling grassland with a few widely spaced trees; whereas on the northwestern side, the terrain was flat to sloping and contained an extremely dense stand of vegetation. The perspectives (fig. 15) show how the three-dimensional ground surface varied at the site, and fig. 16 depicts the vegetation.

22. Road site 6. Road site 6 was on Highway 27 near the community of Hubbard, Miss. A ground panoramic view is given in fig. 14b, and computer-drawn perspectives are presented in fig. 17. The site had a road embankment and relatively flat topography on the southwest side of the road's center line and an extremely rough and undulating topography on the northeast side of the road. The center line of the road slopes downward approximately 4 percent from southeast to northwest. The vegetation on the site (fig. 18) consisted primarily of groups of widely spaced (3-10 m) trees of varying heights and stem diameters.

Topographic Survey Procedures

23. To characterize the three-dimensional ground-surface configuration of each of the six road sites, 11 profiles spaced 20 m apart were established along the length of the 200-m roadway (fig. 19) in accordance with procedures outlined in Appendix A. A constant spacing of 20 m between profiles was selected primarily because of the uniformity of the road terrains at the six sites. However, in some cases variations did occur between profiles; in these cases survey points were taken at selected places between profiles, as needed, to delineate areas of changing slope. Of the six sites that were surveyed, all sites with the exception of site 2, contained straight alignments along the center line of the roadway. At site 2, the center line of the roadway was such that the southwest end of the center line was located approximately 4.7 m southwest of the base line and the northeast end was located 8.4 m southwest of the base line. The general survey

procedures for the various sites are discussed below.

General procedures

24. To survey the sites, a base line was set adjacent and approximately parallel to each road's center line. Along the base line, control points spaced 20 m apart were located using a theodolite, tape, rod, and standard survey procedures. The start of the base line (control point 1) was used as the origin of the three-dimensional survey, and all topography survey points were located with respect to this point. (The positive x-axis for the coordinate system was along the base line, and the positive y-axis was assumed to lie 270 deg clockwise to the positive x-axis.)

25. Once the 11 base-line control points were located, a theodolite was set up over each respective control point, and an elevation profile perpendicular to the base line was determined (fig. 19). The three-dimensional locations of selected points were taken along the profile as often as necessary to reproduce the geometry of the surface. The distance measurement to each point was determined either by taping or stadia. All changes in slope were included, and in those areas where the changes were indistinguishable, measurements were taken at no greater distance (or spacing) than 10 m along the profile.

26. The three-dimensional topography measurements (i.e. azimuth and distance data) obtained at each of the sites were recorded on a standard data form, as discussed in Appendix A, and then placed on cards for computer processing and analysis. The three-dimensional topography data were then used as input to a computer program to determine Cartesian (x,y,z) coordinates. The x,y,z coordinates for the sites are contained in tables A1-A6, Appendix A.

Survey of 250-m profiles

27. In addition to the survey of the 200- by 200-m road sites, two of the sites (sites 2 and 5) were selected for obtaining profile data on three lines (i.e. three different azimuths) approximately 250 m in length. These data were collected to determine the effects of target shielding over long distances.

28. The profile data were obtained on the three azimuths as

illustrated in fig. 20. These data were processed through the Cartesian coordinates program to determine the x,y,z coordinates of each survey point along the 250-m profiles (tables A7 and A8, Appendix A, for sites 2 and 5, respectively).

Generation and Analysis of Gridded Elevation Data Arrays

Generation of elevation data array

29. The three-dimensional coordinates of the survey points were used to establish an elevation network of grid points for use as input to the shielding model. The automated procedure used to determine the grid elevation array for each of the sites is discussed briefly below.

30. The Cartesian (x,y,z) coordinates of each surveyed point (tables A1-A6, Appendix A) were input on cards to the grid array program to determine the elevation of each 2-m grid point on the 200- by 200-m site. The total number of grid points in each array is 10,201. The computer storage of the grid elevation data is illustrated in fig. 21. A general interpolative algorithm that had been developed by the U. S. Army Engineer Waterways Experiment Station (WES) in support of another study* was used to calculate the elevations of each 2-m grid point within the array. This analytical procedure is described in detail in Appendix B of this report.

Analysis of gridded elevation arrays

31. The gridded elevation data that were generated from the basic field profile data represent a reasonable characterization of the three-dimensional ground surfaces at all six road sites. To illustrate how well the computed 2-m grid elevations compared with the field-surveyed elevation data, profiles were extracted (perpendicular to the road's center line) at three locations at each of the sites as shown in fig. 19. These data are discussed below.

---

* Study entitled "Methods for Assessing Effects of Military Construction Activities on Ecosystem" (Formerly: Catalog of Critical Environmental Elements, and Methodology for Establishing Baseline Profiles), sponsored by Office, Chief of Engineers, Washington, D. C.

32. Profile data. In figs. 22-27 the field-surveyed elevation data for the three selected profiles are compared with the computer 2-m grid elevation data that were obtained by interpolating between field-surveyed points. The field-surveyed and grid data for all sites, in general, show an excellent agreement along the measured profile, thereby reflecting that the elevation interpolation procedure (see Appendix B) provides a good representation of the geometry along the surveyed profiles. The only points along the three profiles that did not show a reasonable elevation comparison were those wherein the slope changes abruptly, such as at the top of the road embankment in profile A at site 1 (fig. 22) and at the bottom of the irrigation canals and the crest of the dikes in site 3 (see figs. 24 and 11). The poor agreement at these points can probably be attributed to the 2-m grid spacing used in the grid arrays. If these grid points had been specified at the same xy locations as the field-surveyed points, the agreement would probably have been much better.

33. Since very little field survey data were obtained between the measured 20-m profiles, no comparison could be made between the profiles represented by the grid data and the actual field elevations that occurred between the profiles. However, to illustrate the gradual changes that are inherent in the grid data between the surveyed profiles, grid data were extracted from 11 grid lines of site 1. This profile comparison is shown in fig. 28. As shown here, the grid data between the two surveyed profiles (i.e. profiles 20 and 40 m, respectively), show only gradual changes in the surface of the ground between the two measured profiles.

34. The elevation data presented in figs. 22-27 also show how the ground surface varies along a direction perpendicular to each road's center line. A review of these profiles indicates that the terrain adjacent to the road changes significantly over relatively short distances.

35. Slope data. The 2-m grid elevation data were also analyzed for changes in slope along profiles perpendicular to the base line and parallel to the base line. The results of these analyses are given in

fig. 29. Fig. 29 shows that the changes in slope are greater along grid lines perpendicular to the road than along those parallel to the road, which would be expected. Also, the sites show good agreement for slopes along both directions, except site 3, which contains dikes, irrigation canals, and a secondary access road (see perspectives in figs. 11a and 11b).

36. Contour data. To provide a quantitative areal description of the three-dimensional ground surface at each of the six road sites, computer-derived contour maps using an elevation interval of 60 cm were prepared. These maps (fig. 30) show that the local relief varies from approximately 250 cm at site 3 (fig. 30c) to approximately 1700 cm at site 6 (fig. 30f). The maps also reflect the uniform slopes that occur along the paved surfaces of each of the roads.

PART IV: GROUND-SURFACE SHIELDING CHARACTERISTICS

37. This part of the report discusses the ground-surface shielding characteristics of each of the six road sites. Calculations were made for 10 different height intervals on a one-dimensional vertical target 300 cm tall, positioned at 5 target locations along the center line of the road (see fig. 2), for 8 target-to-HOB ranges (10, 20, 30, 40, 50, 60, 70, and 80 m), and for 10 munition burst heights (0 or ground surface, 10, 25, 50, 75, 100, 200, 300, 400, and 500 cm). In addition, shielding calculations are also made for the six 250-m profiles surveyed at sites 2 and 5 (see fig. 20). The results for the six sites are discussed in detail in the following paragraphs.

Presentation of Ground-Surface Shielding Results

38. The detailed ground-surface shielding data for the one-dimensional vertical target that were obtained for each of the six road sites consisted of:

- a. Percent shielding of target by individual burst point (or azimuth) along the circumference of each circle or ranges 10, 20, 30, 40, 50, 60, 70, and 80 m, and burst heights of 0 or ground surface, 10, 25, 50, 75, 100, 200, 300, 400, and 500 cm (tables 1-60, Volume II).
- b. Average percent shielding of target for each of the 8 ranges and 10 burst heights (tables 1-60, Volume II).
- c. Target-LOS contact angle (θ) for each individual burst point, as indicated in a above (tables 1-60, Volume II).
- d. Average target-LOS contact angle for each of the 8 ranges and 10 burst heights (tables 1-60, Volume II).
- e. Probability of shielding of target for each 30-cm height interval, for each of the 8 ranges and 10 burst heights (tables 61-120, Volume II).

Only a few copies of Volume II were published. However, copies are available for loan; persons interested may borrow copies by writing to U. S. Army Engineer Waterways Experiment Station, ATTN: WESFE, Vicksburg, Miss. 39180. Examples of the tabular output are given in Appendix C herein.

Analyses of Ground-Surface Shielding Results

Probability of shielding

39. The probability of shielding data for each 30-cm target height interval were averaged for the five target positions along the roadway (see fig. 3). The probability of shielding data for 6 of the 10 target height intervals (i.e. 30, 60, 120, 180, 240, and 300 cm) were then selected for comparison (figs. 31-36). These figures show considerable variation in shielding between the six sites and also variation among the six target heights for each of the sites. Most of the variation occurs at the lower munition burst heights (less than 300 cm); although site 6 (fig. 36) shows significant variations for burst heights of 200, 300, 400, and 500 cm, respectively.

Average shielding of 300-cm-tall target

40. The ground-surface shielding data for the 300-cm-tall target were averaged and plotted to illustrate the combined effects of different target positions, ranges, and burst heights (figs. 37-42 for sites 1-6, respectively). These figures show that the average shielding of the 300-cm-tall target is significantly affected by both distance (or range) from the target and burst height at all six sites. However, the shielding does not change appreciably for the different target positions (i.e. positions A-E) along the center line(s) of the road(s), probably because they cover a relatively short distance(s) (40 m) in areas that tended to be uniform parallel to the road center line. The effects of the target location would probably be quite significant for roads that contain several cuts and fills within a short longitudinal distance.

41. In addition to the comparison of the average shielding for the various target positions along the center line of each of the roads, the average shielding characteristics of the six sites were compared (fig. 43). Fig. 43 shows that for a burst height of 0 cm (or ground surface burst), the average shielding of the 300-cm-tall target varied between 10-85 percent for the six sites; but for burst heights equal to and greater than 100 cm, target shielding at sites 1-5 varies only

between 0 and approximately 25 percent. Site 6 has the greatest amount of shielding. Not only does site 6 portray the greatest amount of shielding, but also the shielding increases with increasing range and decreases, only slightly, with increasing burst height (up to 500 cm aboveground).

42. The primary reason for the increase in target shielding with increasing range, as indicated by site 6 and to a certain extent by site 1 (see fig. 43), is the decrease in the elevation of the ground surface with increase in range from the target (see figs. 27 and 22).

Shielding along 250-m profiles

43. The average shielding characteristics for the 300-cm-tall target along the six 250-m profiles, three each at sites 2 and 5, are shown in figs. 44 and 45, respectively. These figures show varying amounts of shielding along the three profiles. The primary difference between the profiles of the two sites is the shielding portrayed by ranges from 10 to 60 m to approximately 120 to 150 m; although profile C (azimuth 108°) at site 5 (see fig. 20) shows shielding decreasing for burst heights equal to and greater than 100 cm for ranges greater than 180 m.

Average vertical target contact angle

44. Figs. 46-51 show the average vertical contact angles (or attitudes of the first unobstructed optical paths as shown in fig. 1) between the burst points and the target for each of the eight ranges, six burst heights, and five target positions along the center line of the roads. These data indicate that the vertical contact angle of a fragment with a target is significantly affected by range and burst height, and that the degree of the effect is directly dependent upon the local relief portrayed by the site (see contour maps, fig. 30). Fig. 52 is a comparison of the average vertical contact angles along the six sites.

Supplemental Considerations

Site intervisibility

45. To show the ground surface areas of the six road sites that

are open (i.e. visible) and those that are in defilade from a target 90 cm tall located at the center of the site, intervisibility plots* were prepared and are included in fig. 53. These plots show the portions of the sites that would have the most target exposure and vulnerability from ground bursting munitions. Although only one target height (90 cm) was assessed by the intervisibility algorithm, fig. 53 shows that the open regions and those in defilade on each of the different sites tend to occur as linear strips along and parallel to the length of the roads.

Determining the shielding effects of vegetation

46. As presently structured, the shielding model does not contain considerations for determining the shielding effects offered by vegetation on the landscape. To provide some insight into whether or not vegetation should be given proper consideration, fig. 54, which was abstracted from another study,** is included. The graphs in this figure show two-dimensional computer-drawn views of a tropical forest that was surveyed by WES in three dimensions, in support of a munition evaluation study.† Fig. 54c shows the degradation effects of the vegetation stand on a bundle of horizontal, parallel beams of an infinitesimal size as they are projected horizontally through a selected portion of the forest (or vegetation). From the graph, which relates the number of beams and distance penetrated, it is noteworthy that of the total number (900) of beams that entered the vegetation all but approximately 125 had encountered a branch or stem of a tree before reaching a distance of 24 m. This particular figure (fig. 54) indicates that vegetation provides considerable visual shielding; however, the degree of shielding against munitions depends upon the density (i.e. number and size of stems and branches in three-dimensional space) of the vegetation stand.

---

* The target intervisibility program was developed by WES in support of Tactical Effectiveness Testing of Antitank Missiles (TETAM) for the U. S. Army Combat Developments Experimental Command, Fort Ord, Calif.

** Terrain Reconnaissance Airborne System (TERRAS) Study.

† Degradation Effects Study sponsored by U. S. Army Picatinny Arsenal, Dover, N. J.

47. It is believed that the shielding effects of the vegetation would be very significant along a large number of road types that would have to be considered in materiel evaluations, and, therefore, the shielding effects of vegetation should be incorporated into the shielding model.

Inputs to Materiel Programs

48. The detailed ground-surface shielding data generated in this study should provide the necessary framework for performing detailed analyses of selected materiel systems (or hardware), such as those identified in Part I. If such analyses are to be performed, the shielding data could be placed by machine onto magnetic tapes or discs for use with computer programs that perform various materiel systems evaluations.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

49. It is concluded that the primary objective of this study, i.e. to develop a mathematical model for predicting the amount of shielding from munition bursts offered by the ground surface to targets (vehicles, personnel, etc.) on or moving along roads, was achieved. The shielding model in its present form assumes that fragments and projectiles travel in straight-line trajectories, which may or may not be a complete and/or accurate representation of the paths that certain fragments take. However, for fragments traveling at high velocities (greater than 500 m/sec) and with relatively short (less than 100 m) travel paths, it is believed that the straight-line paths can be assumed to be characteristic of the trajectories. In any event, the shielding as calculated by the model provides the maximum ground surface shielding that would be provided for targets traveling on or along the roads.

50. The ground-surface shielding results obtained for the six road sites that were selected to be representative of a wide range of road configurations known to occur in various geographical regions show that shielding of a one-dimensional vertical target is significantly affected by both distance (or range) and burst height, and that shielding does not change appreciably for the different target positions that were evaluated along the center line of the road. However, since the five target locations were in relatively uniform areas, it is believed that location would be significant on those roads that contain closely spaced cuts and fills. Of the six sites for which shielding calculations were made, site 6 contained the greatest amount of shielding; this amount increased with increasing range and decreased only slightly with increasing burst height. At sites 1-5, the shielding of the target varied between 0 and 25 percent for the different ranges and burst heights equal to and greater than 100 cm.

51. Although the shielding model in its present form calculates only the shielding effects of the ground surface (i.e. vegetation

effects are not considered), it is capable of determining the ground-surface shielding effects of any type of ground-surface terrain, including both road terrains and cross-country terrains.

Recommendations

52. Since the shielding results exhibited by the six road sites indicate, in general, that selected targets on or moving along roads are shielded to some degree by the ground surface, it is recommended that the effects of vegetation be accounted for, so as to determine the total shielding afforded by the terrain. The shielding effects of the vegetation would be very significant along numerous road types that would have to be considered in materiel evaluations and, therefore, it is recommended that vegetation effects be incorporated into the shielding model. It would also be worthwhile to consider shielding effects of man-made factors such as buildings and other objects.

53. If the shielding data generated by this study are to be used in materiel studies, as discussed in Part I, it is recommended that these data be placed on magnetic tapes or discs for use as input to computer programs that would be used (or developed) in these studies.

54. Since this study was limited to the examination of the shielding characteristics of only six road sites, it is recommended that a few additional road sites, including ones that contain a number of cuts and fills and other characteristic configurations, be sampled to determine the shielding characteristics in these road terrains. It is also recommended that a limited number of cross-country sites be selected and sampled to determine the ground-surface shielding characteristics of cross-country terrains.

55. Since the analytical procedures used to calculate shielding characteristics in this report may not be as adequate as one might hope for in determining shielding of targets for use in target vulnerability studies, it is recommended that work be continued on the further development of the shielding model to allow for the following considerations:

a. Equations that more adequately describe the true three-dimensional paths or trajectories of fragments and projectiles.

b. Methods for modeling the outermost surface of a three-dimensional target.

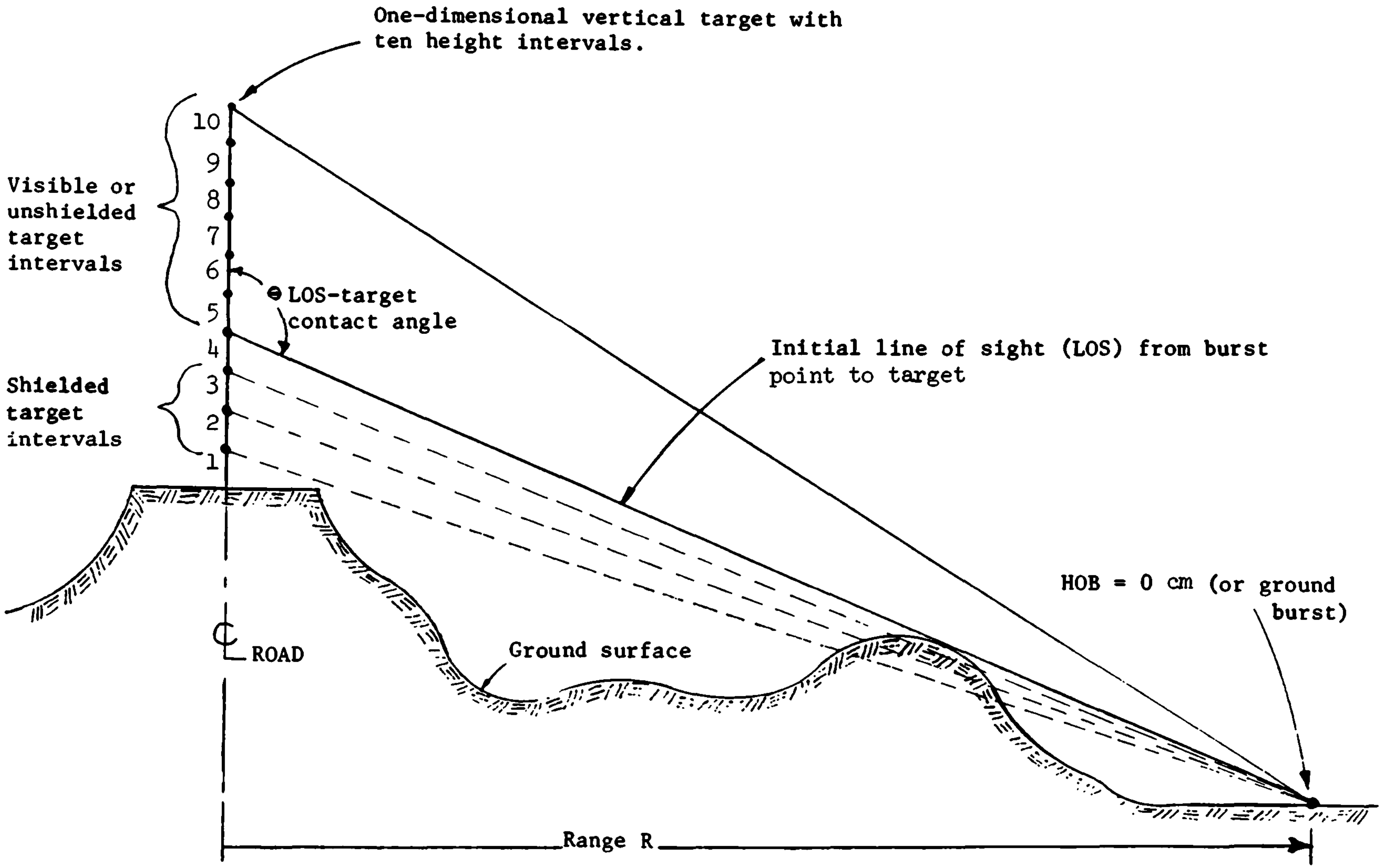


Fig. 1. Shielded and unshielded height intervals on one-dimensional vertical target, range R and HOB = 0 (or ground burst)

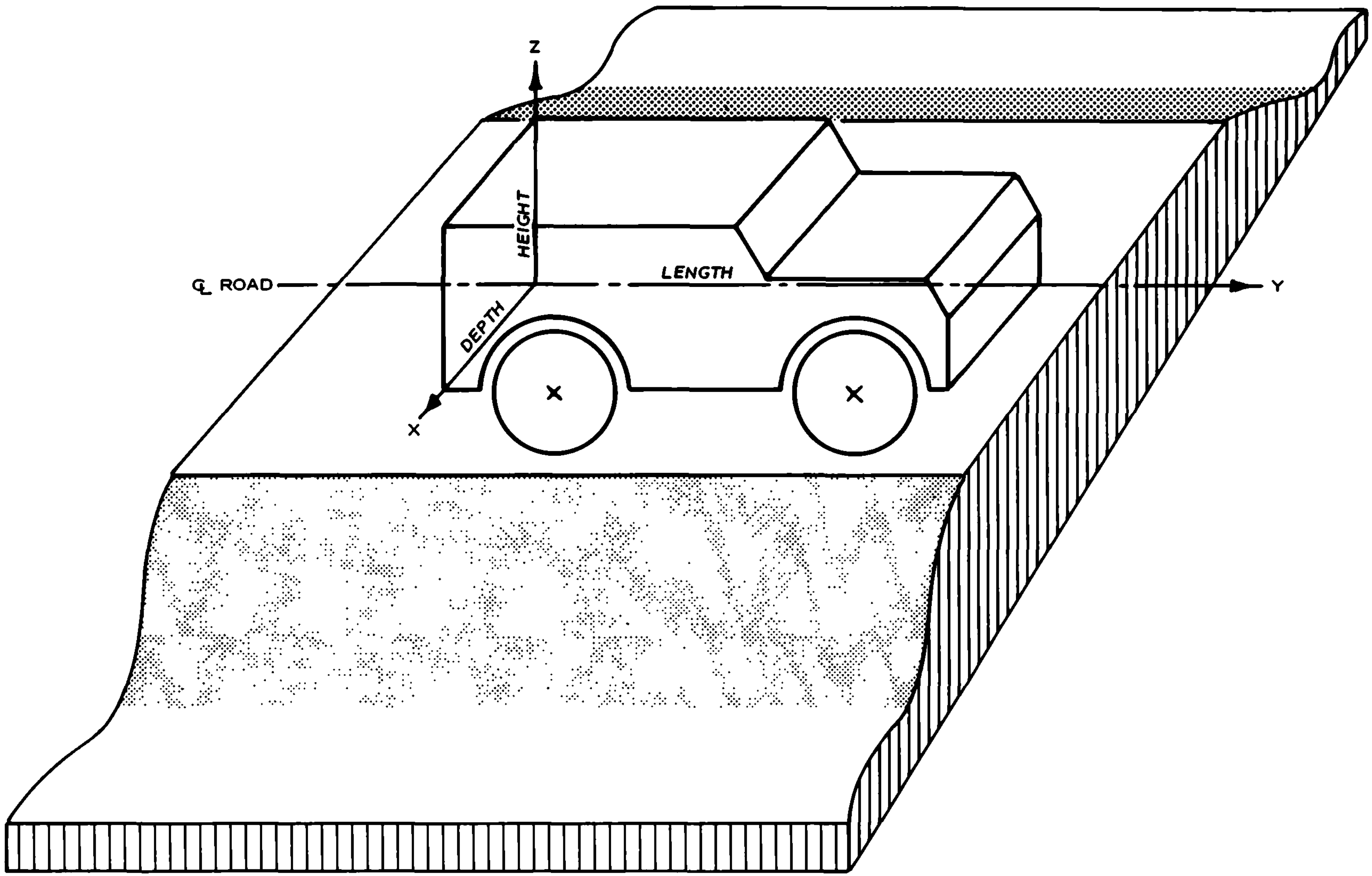


Fig. 2. Considerations in modeling a three-dimensional target

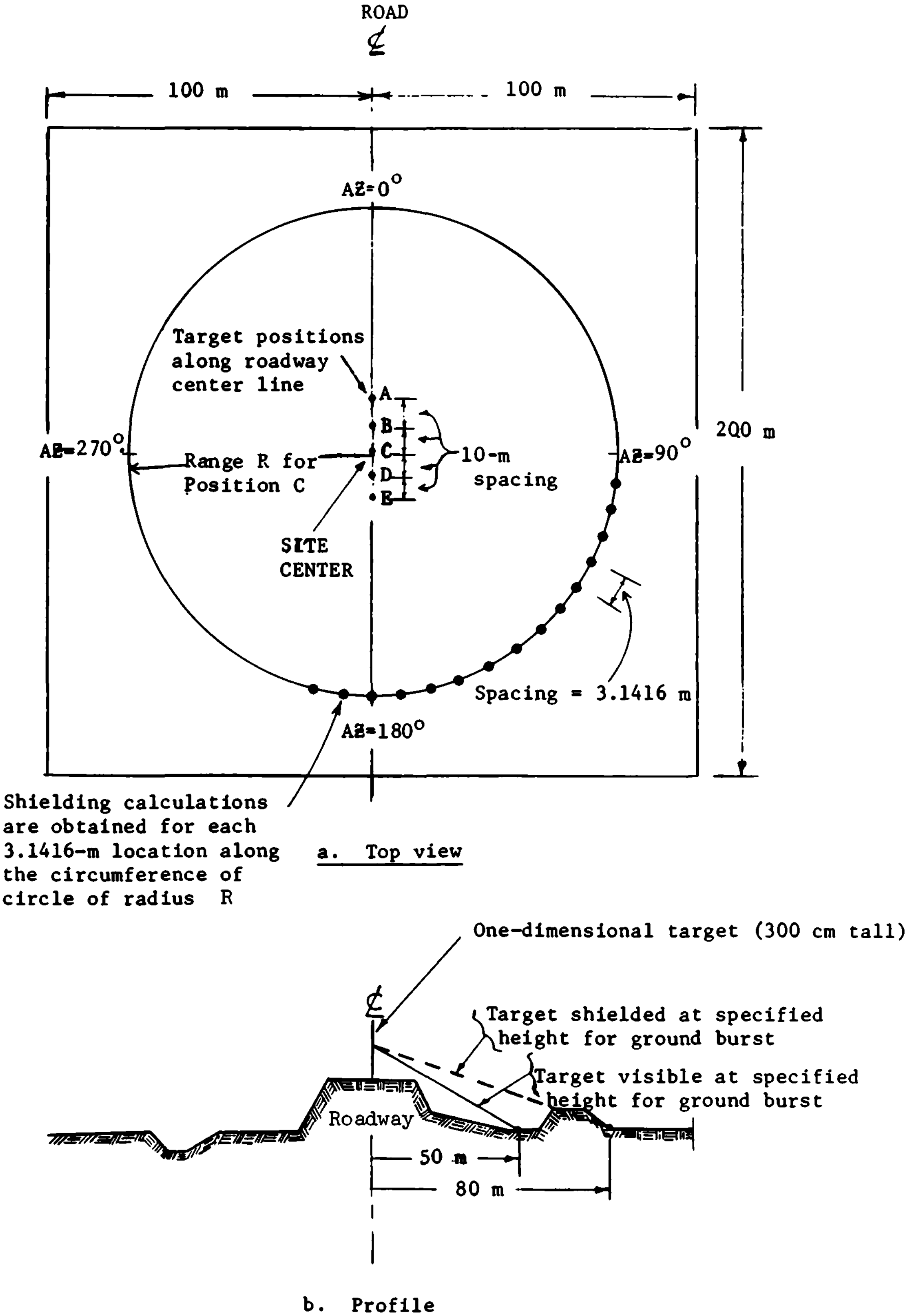


Fig. 3. Considerations in obtaining terrain shielding characteristics

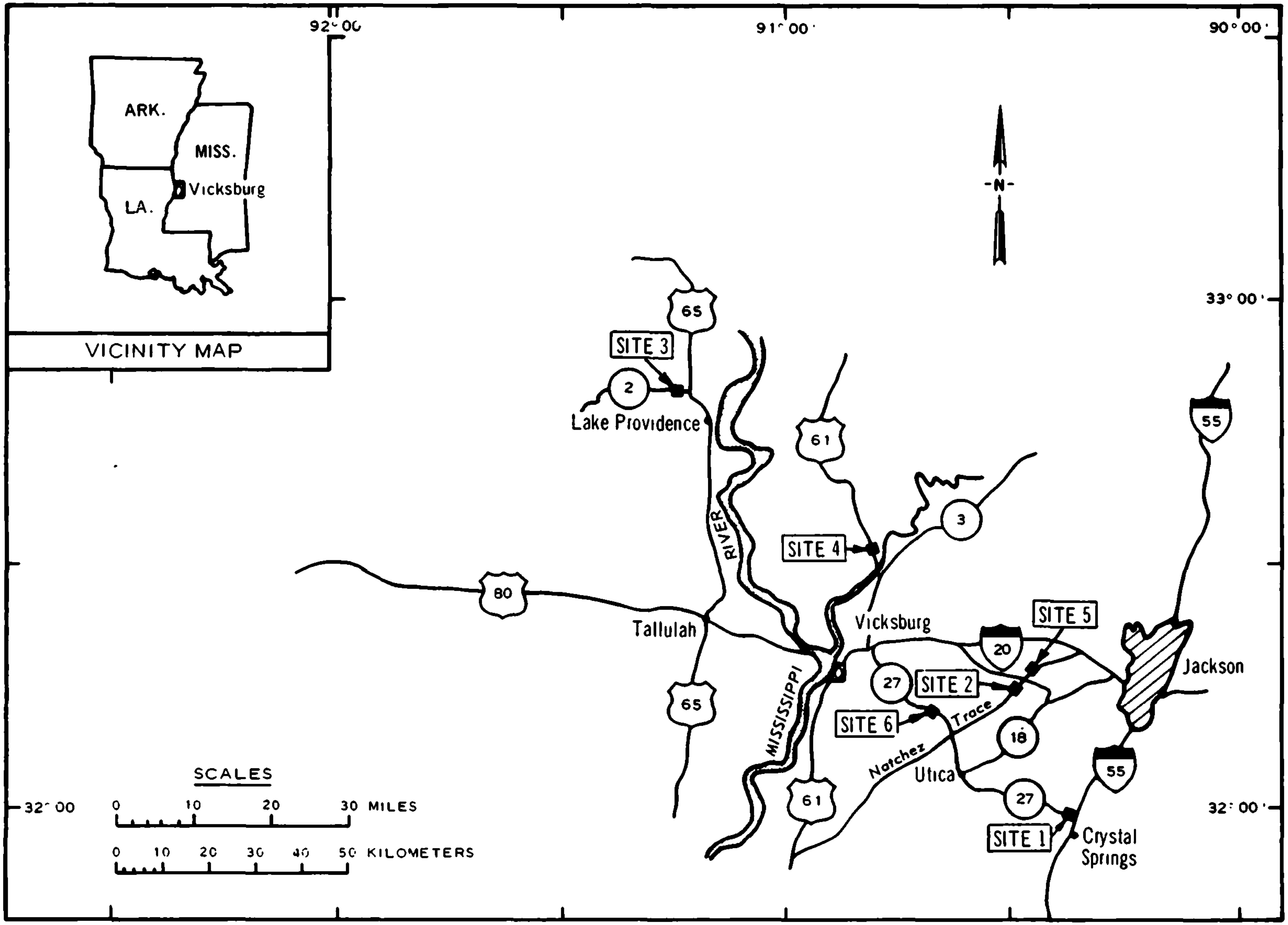
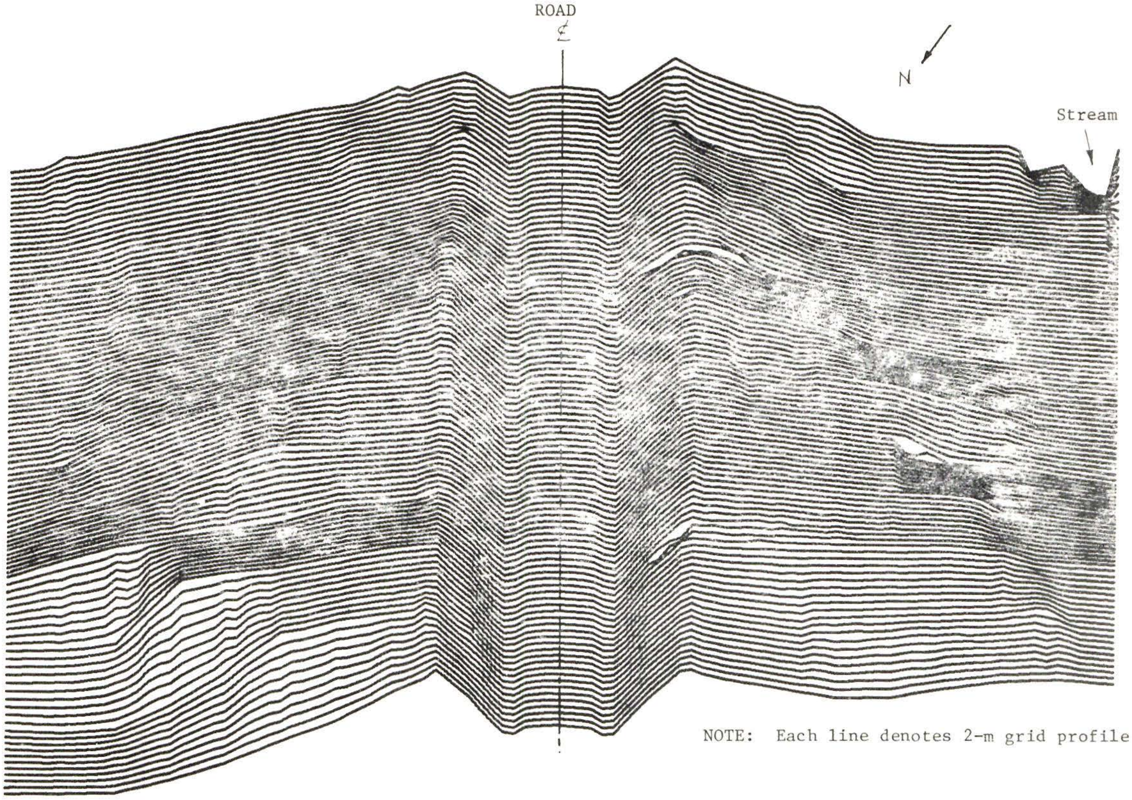


Fig. 4. Location of road sites near Vicksburg, Miss.

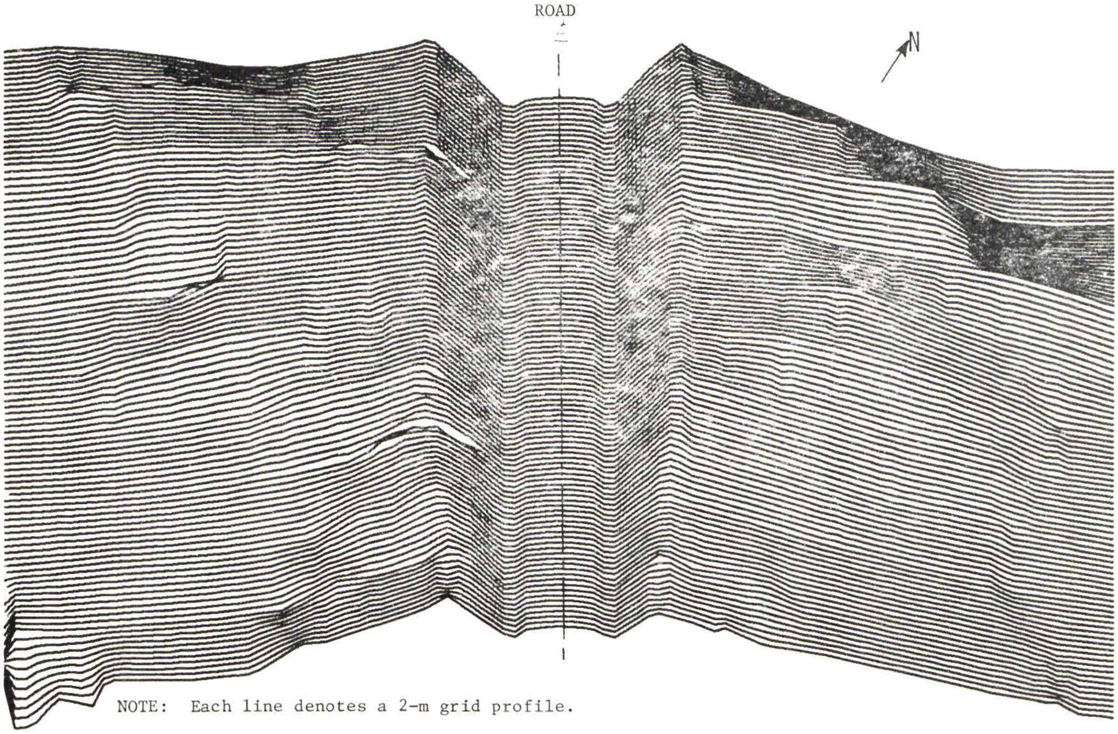
a. View northwest, road site 1

b. View southwest, road site 2

Fig. 5. Ground panoramic views of road sites 1 and 2



a. Looking southeast



b. Looking northwest

Fig. 6. Perspectives, road site 1

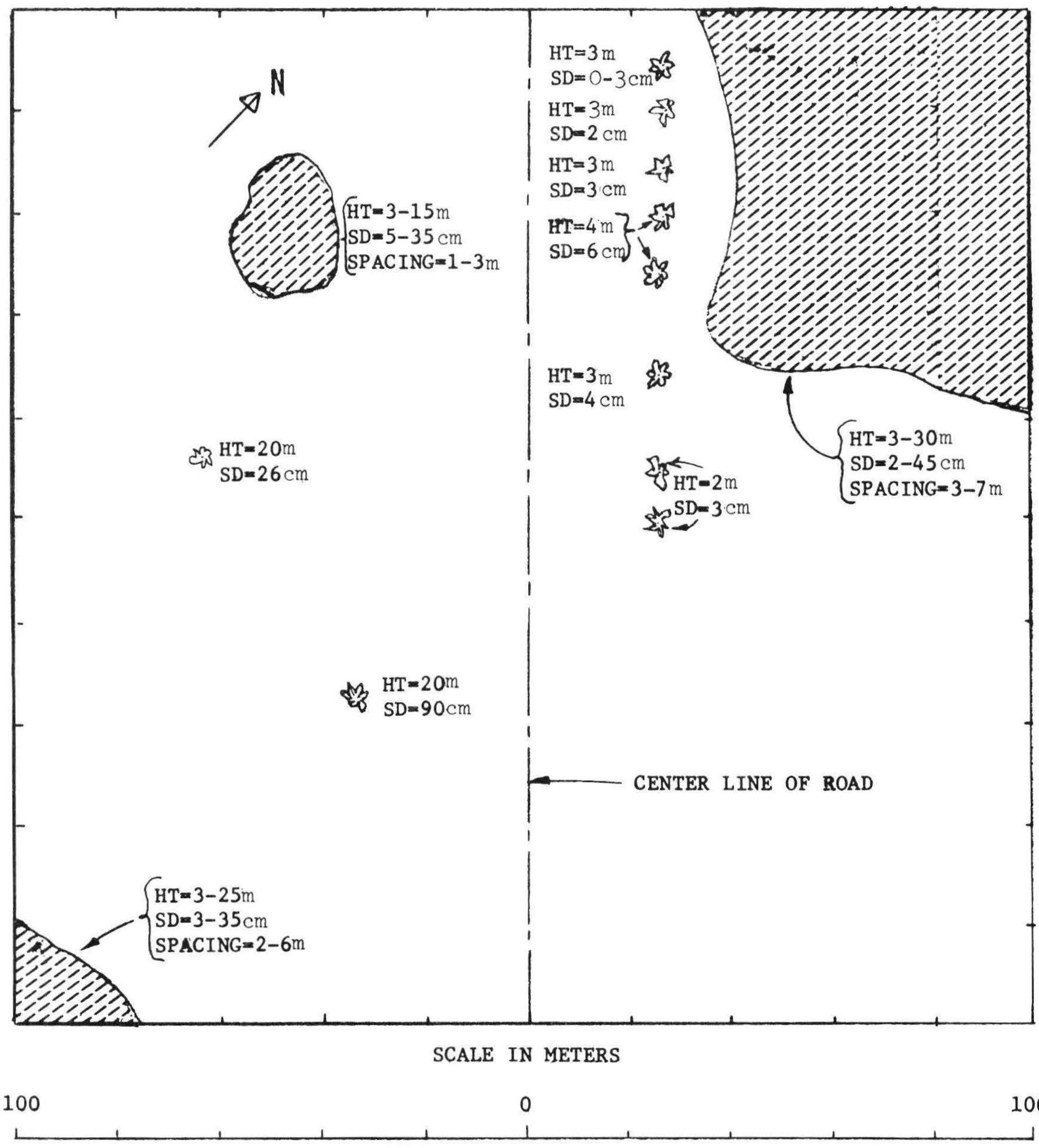
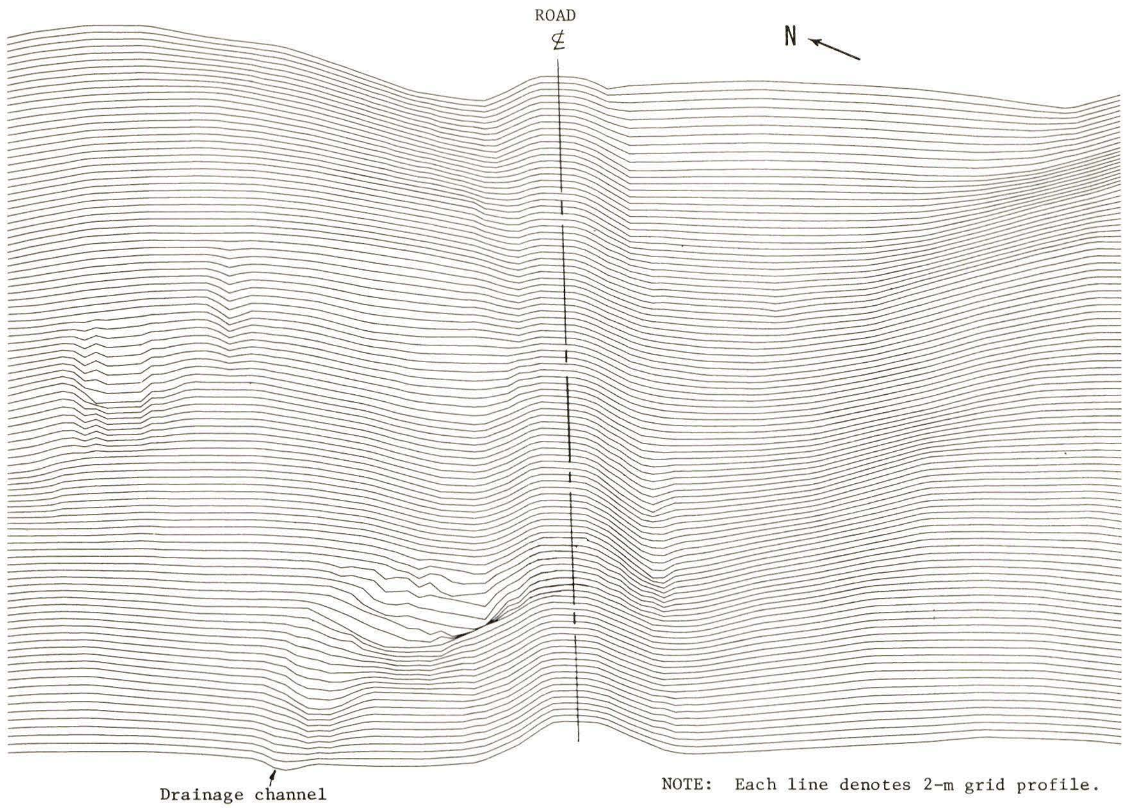
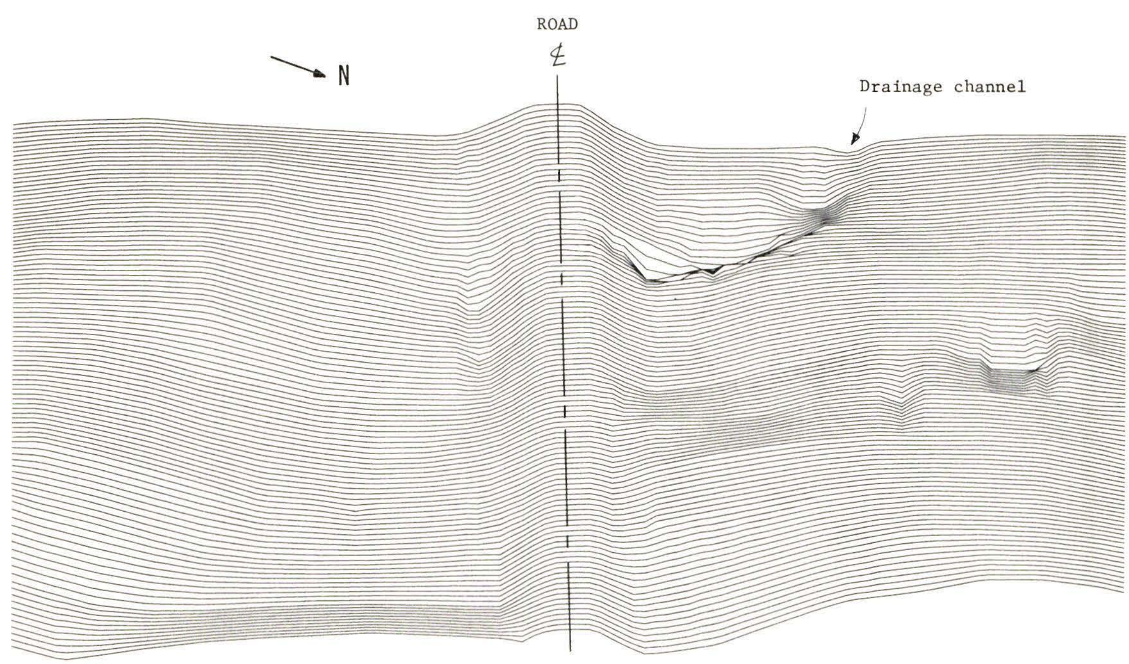


Fig. 7. Location of woody vegetation material on road site 1



a. Looking northeast



b. Looking southwest

Fig. 8. Perspectives, road site 2

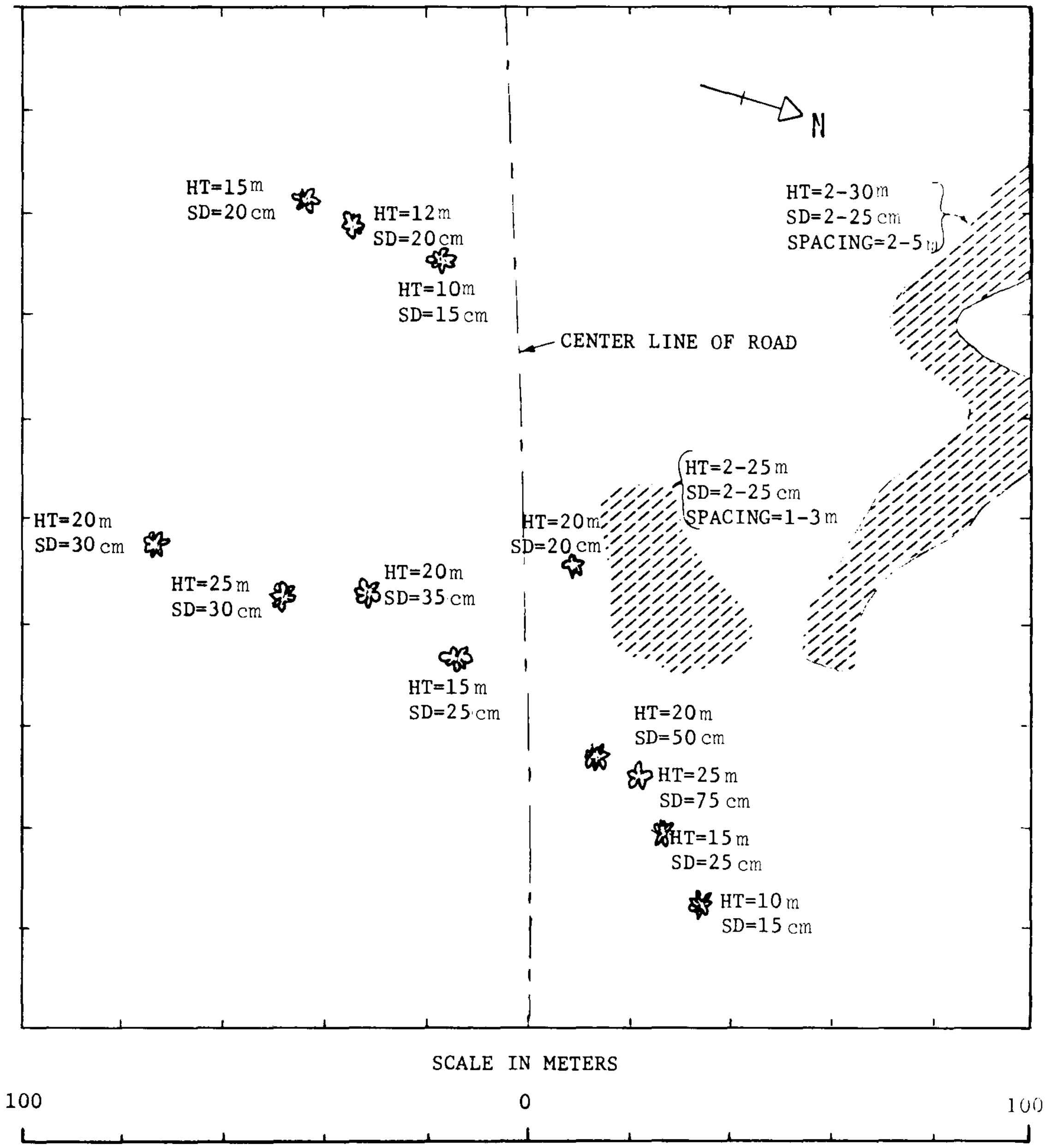
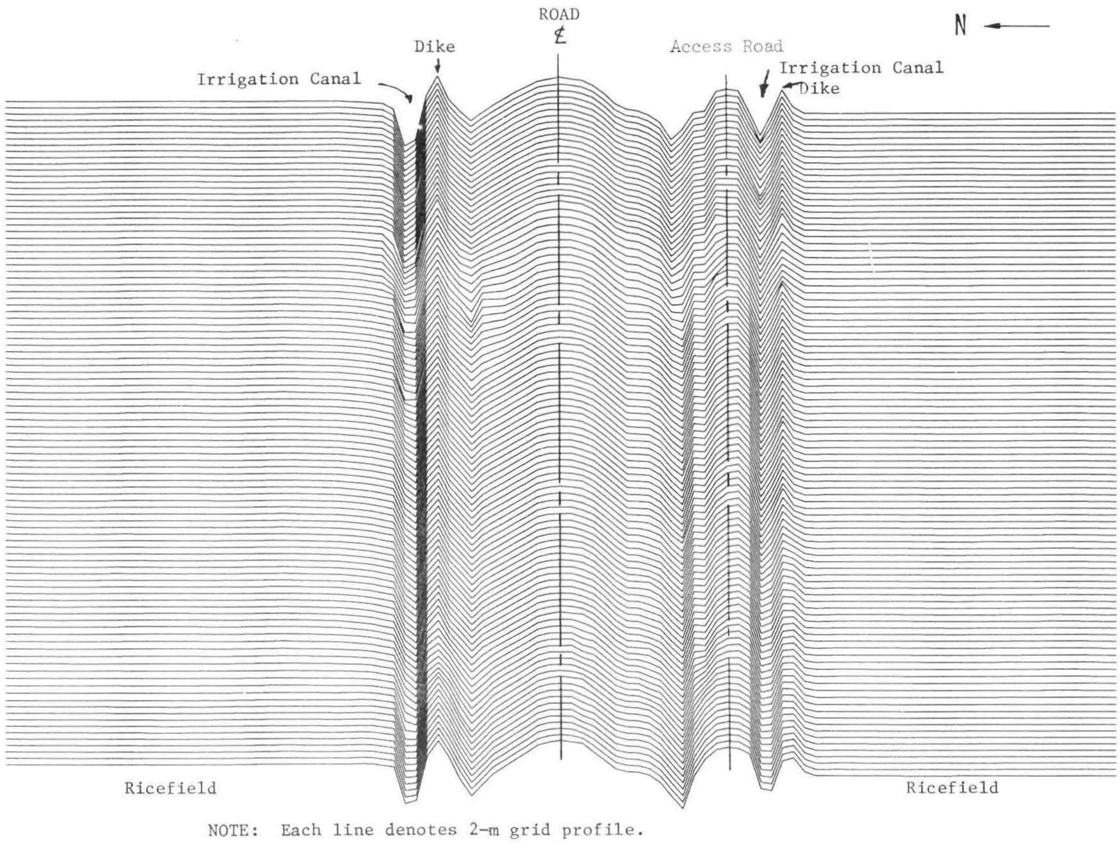


Fig. 9. Location of woody vegetation material on road site 2

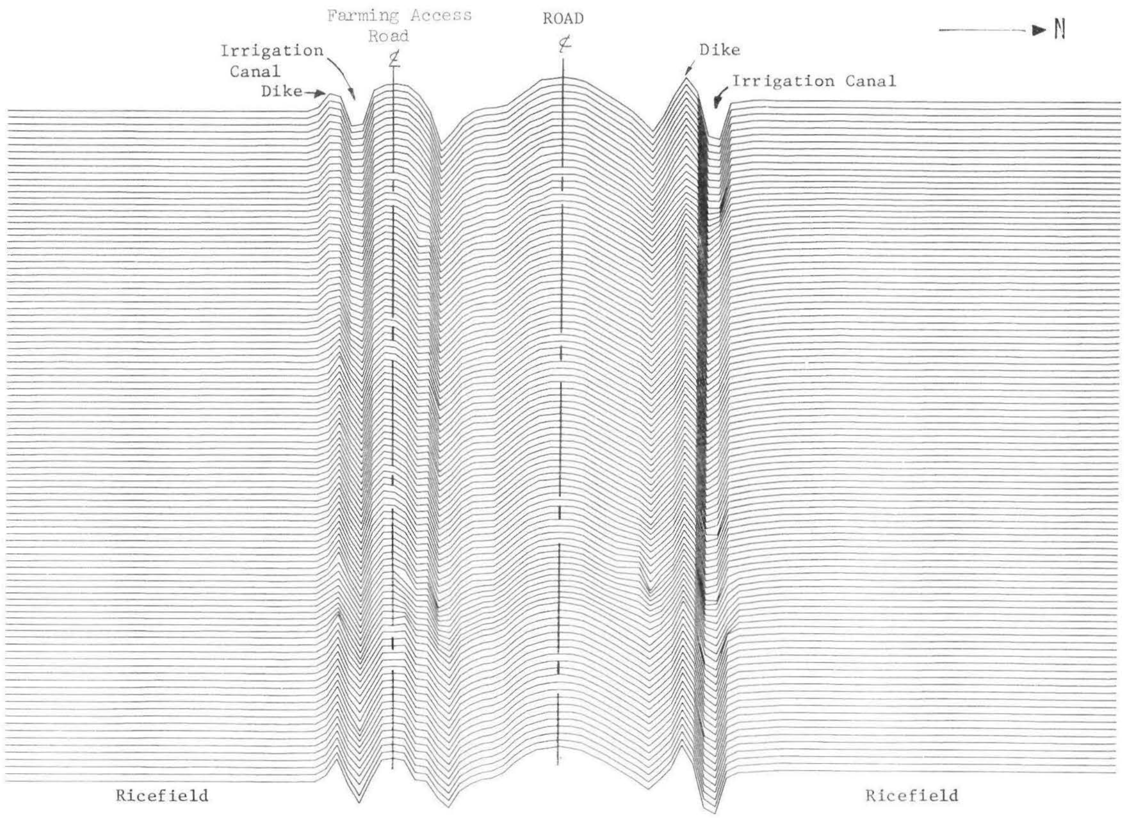
a. View west, road site 3

b. View north, road site 4

Fig. 10. Ground panoramic views of road sites 3 and 4

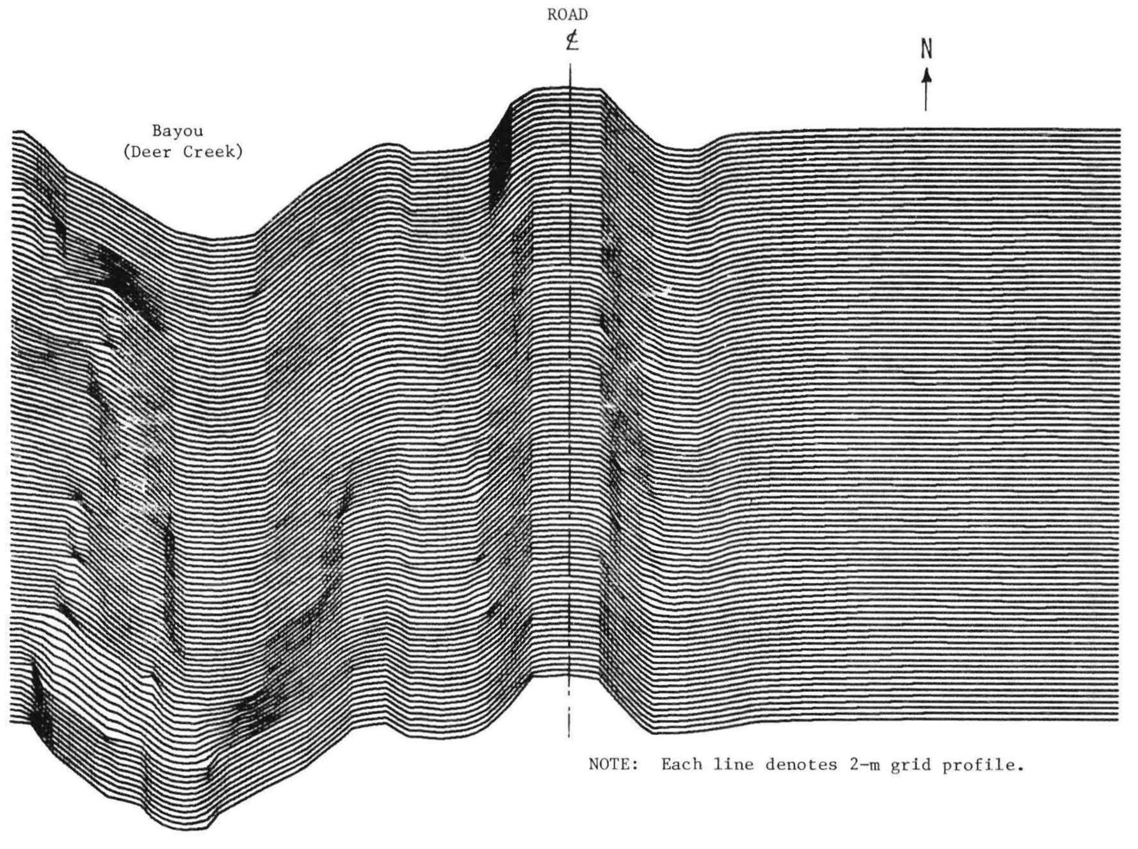


a. Looking east

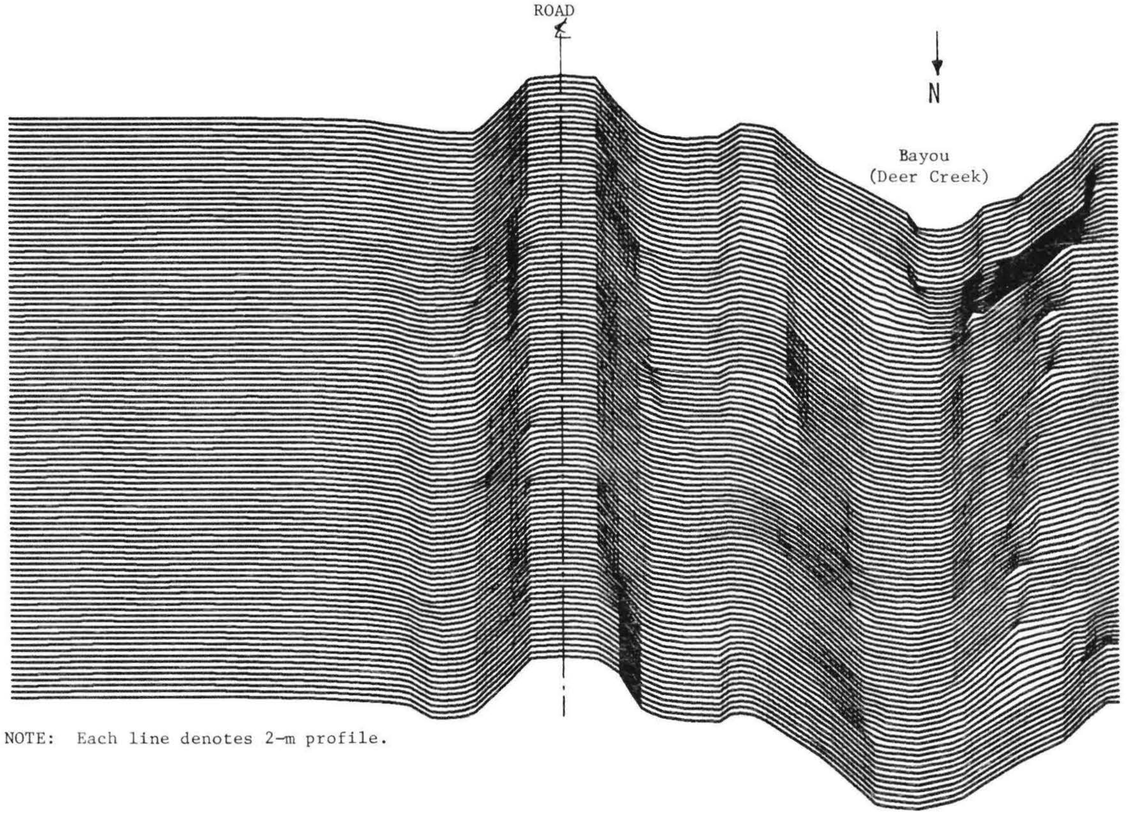


b. Looking west

Fig. 11. Perspectives, road site 3



a. Looking north



b. Looking south

Fig. 12. Perspectives, road site 4

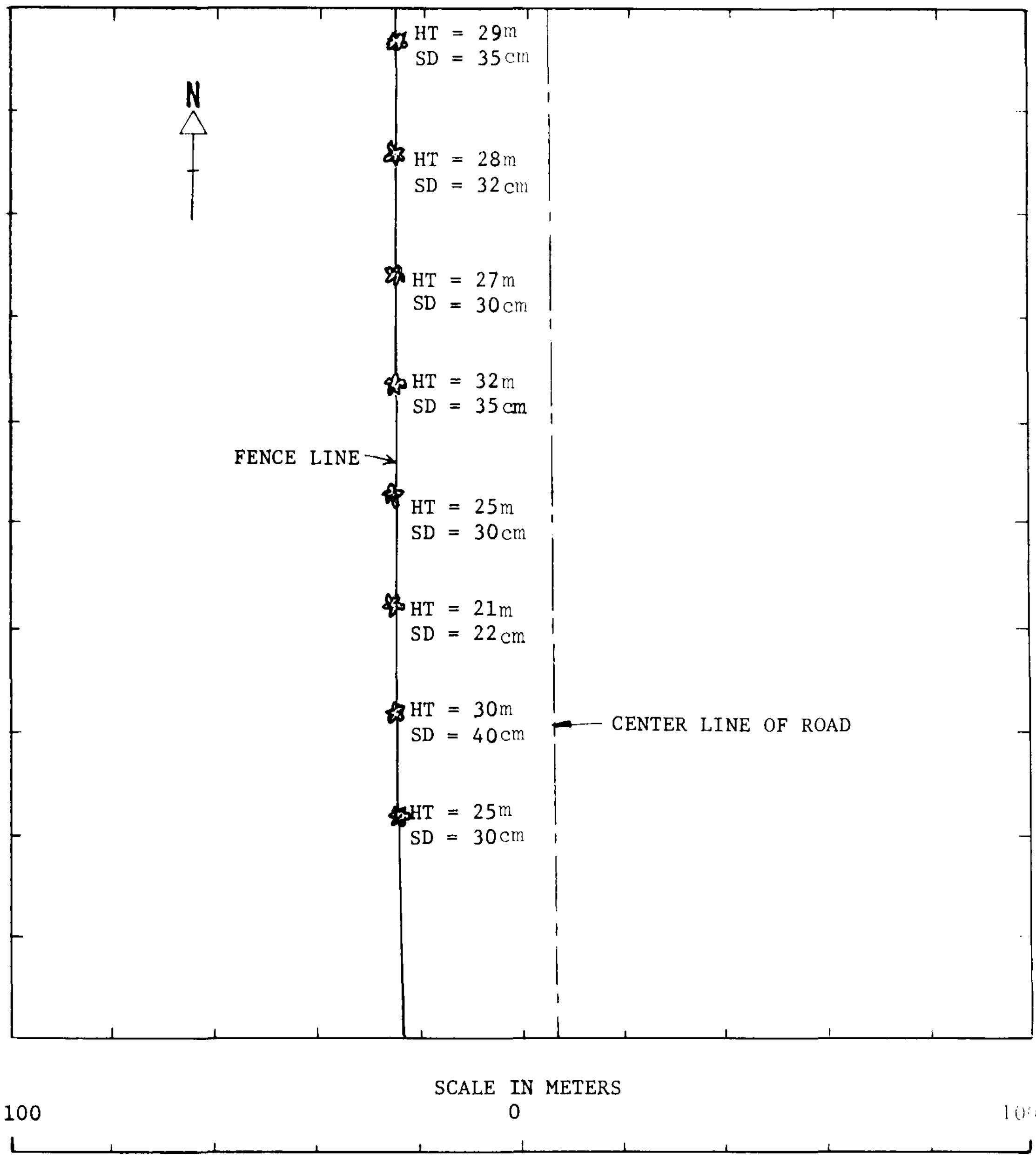
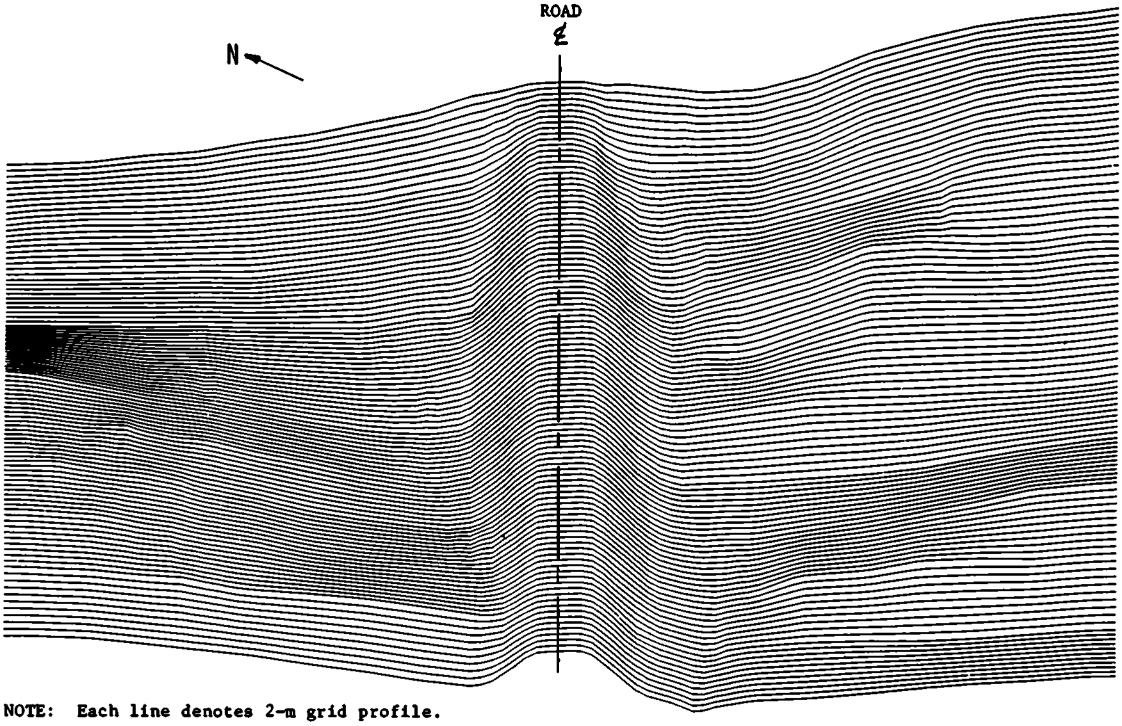


Fig. 13. Location of woody vegetation material on road site 4

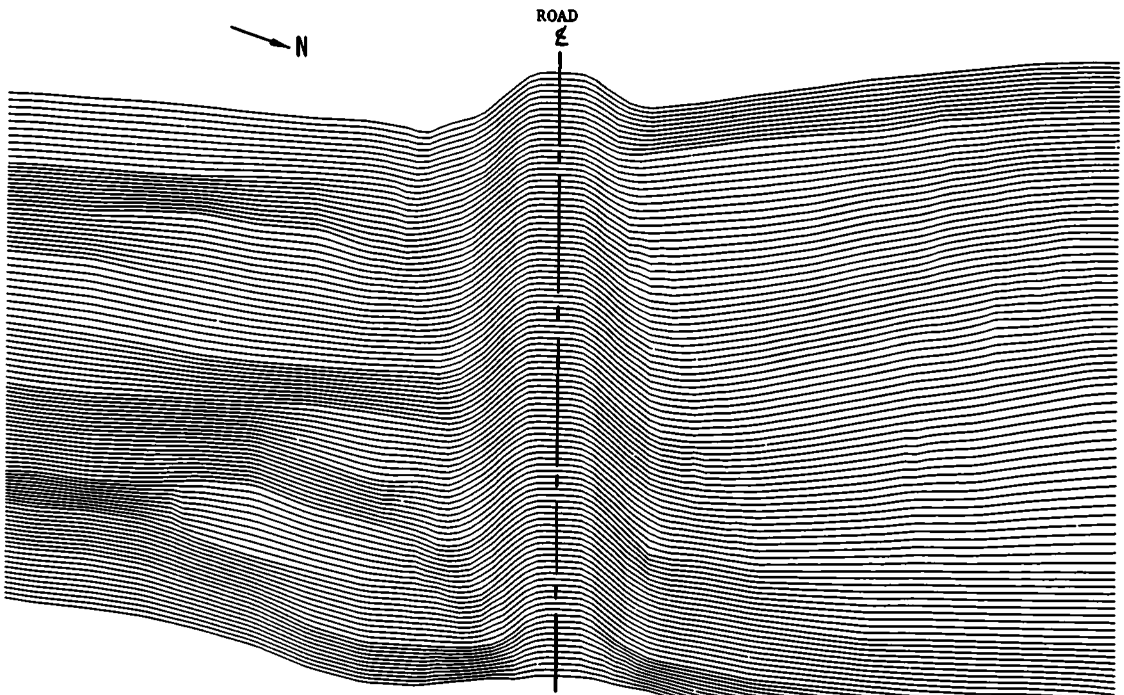
a. View northeast, road site 5

b. View northwest, road site 6

Fig. 14. Ground panoramic views of road sites 5 and 6



a. Looking north-northwest



b. Looking east-southeast

Fig. 15. Perspectives, road site 5

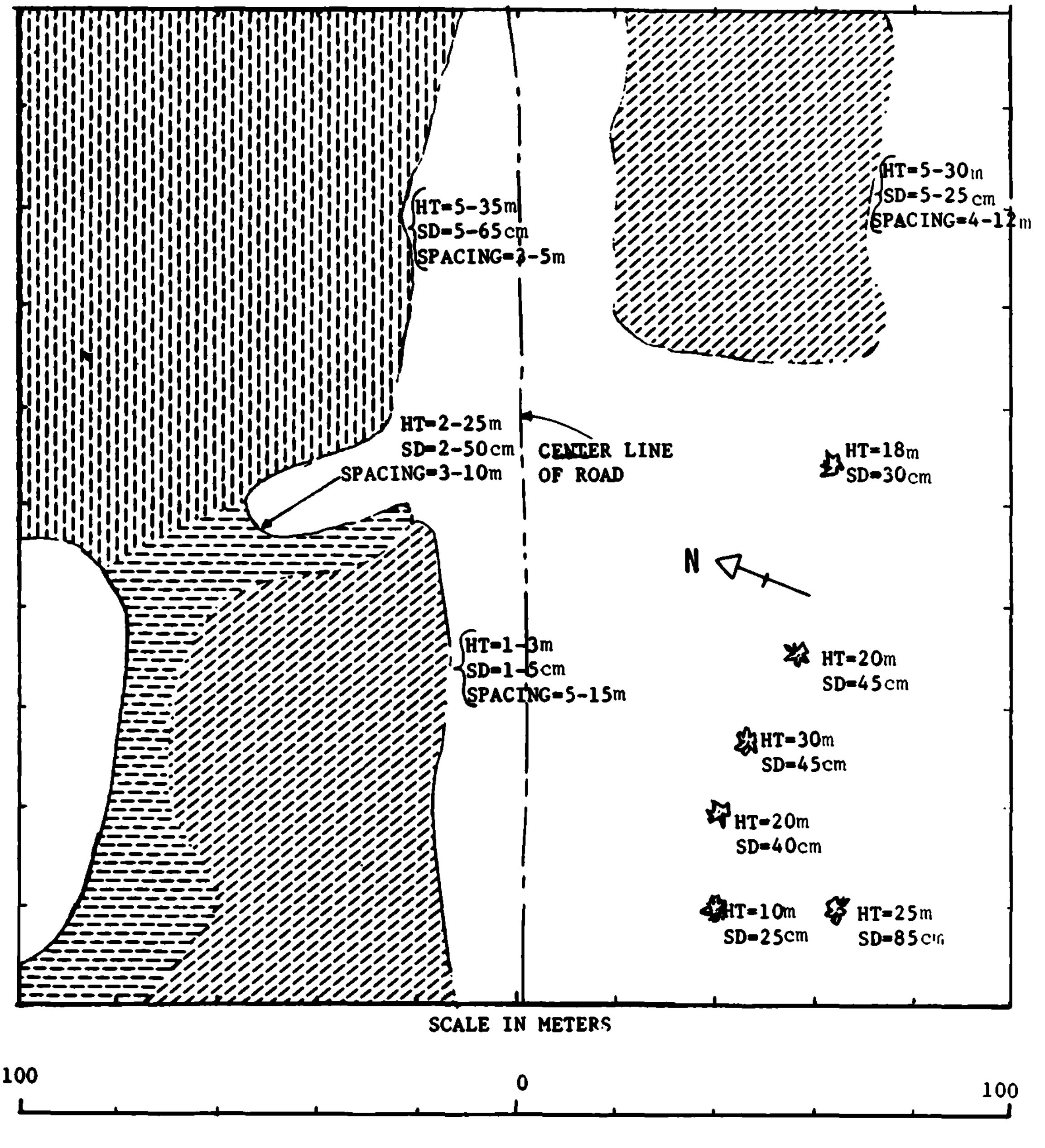
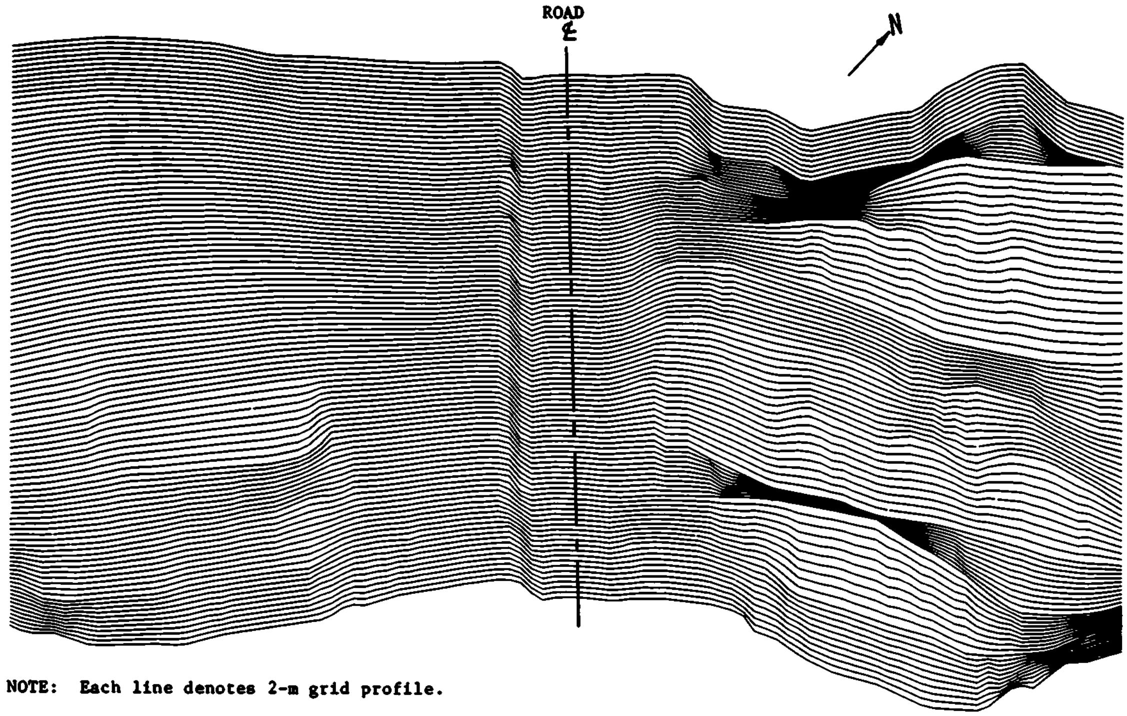
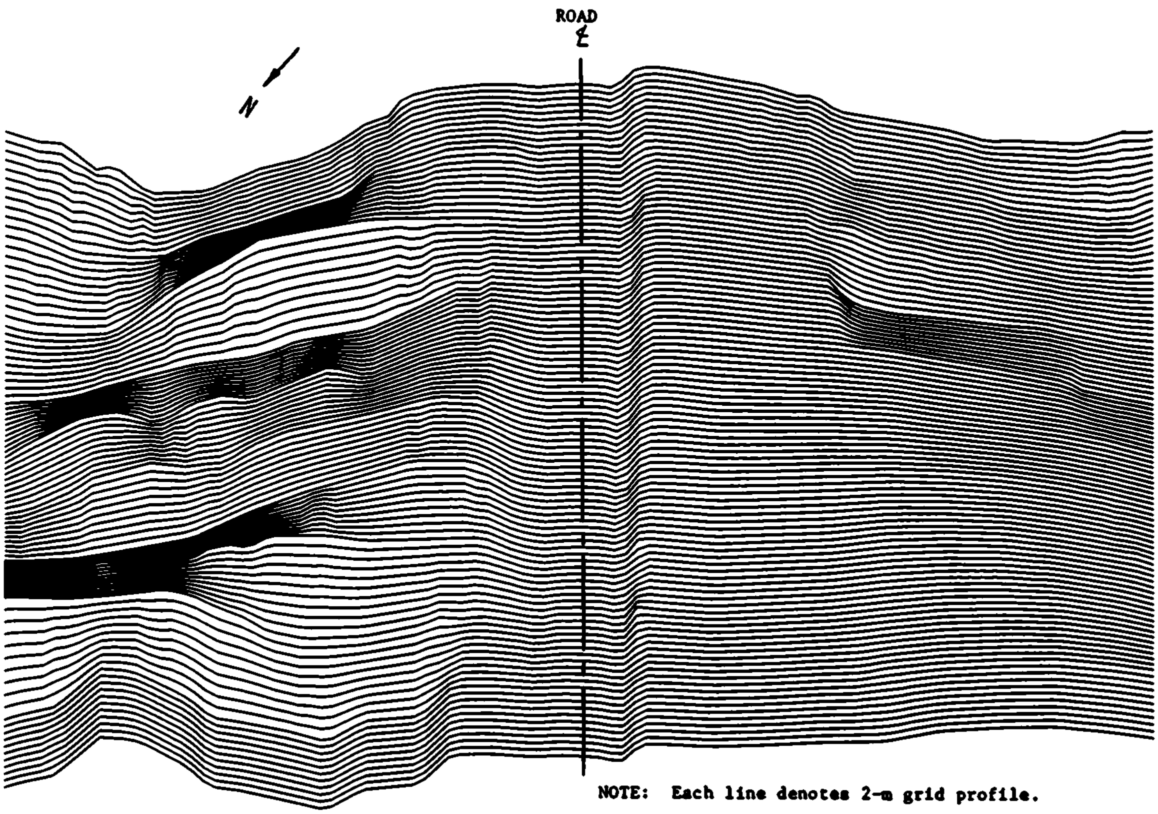


Fig. 16. Location of woody vegetation material on road site 5



a. Looking northwest



b. Looking southeast

Fig. 17. Perspectives, road site 6

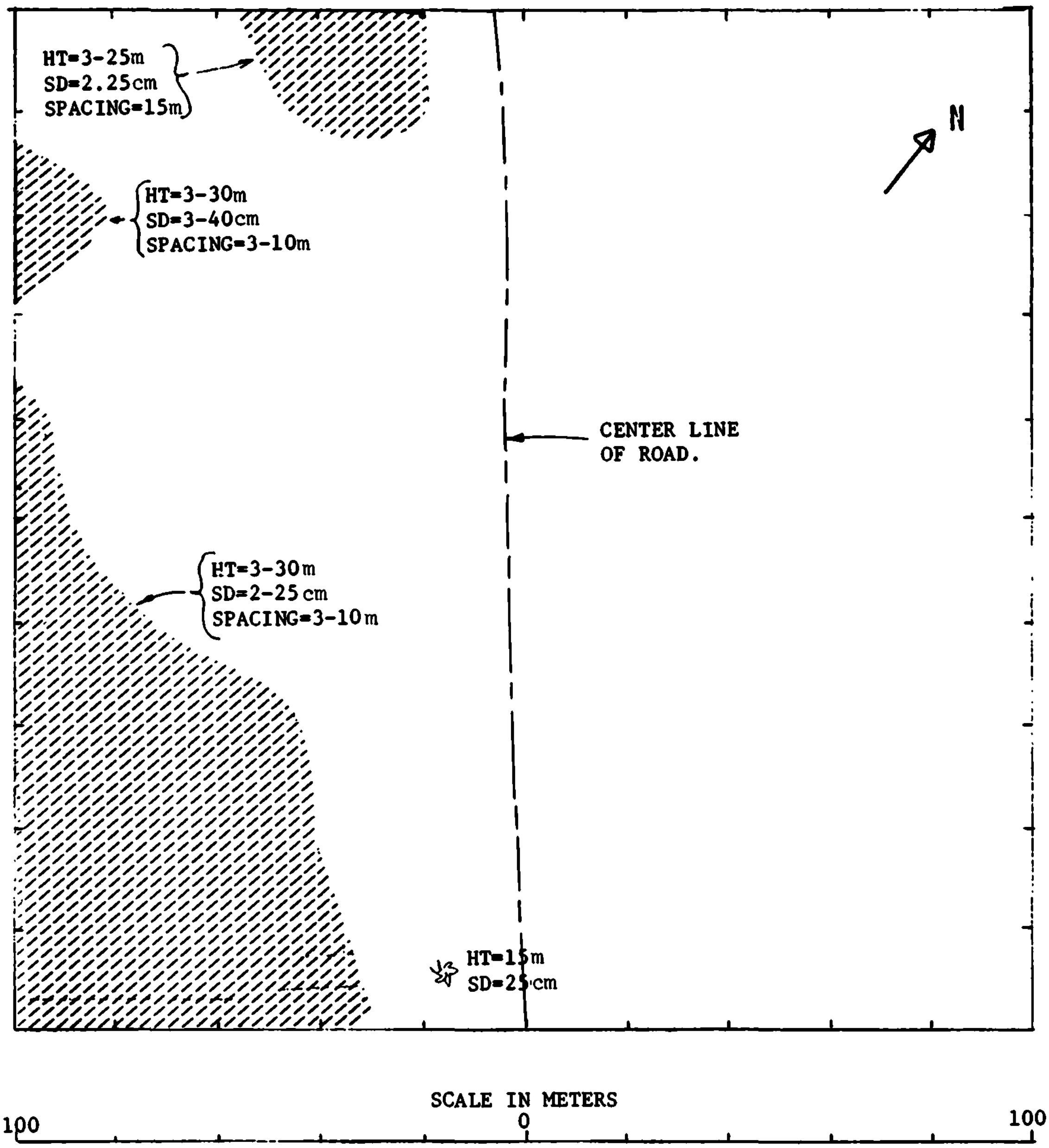
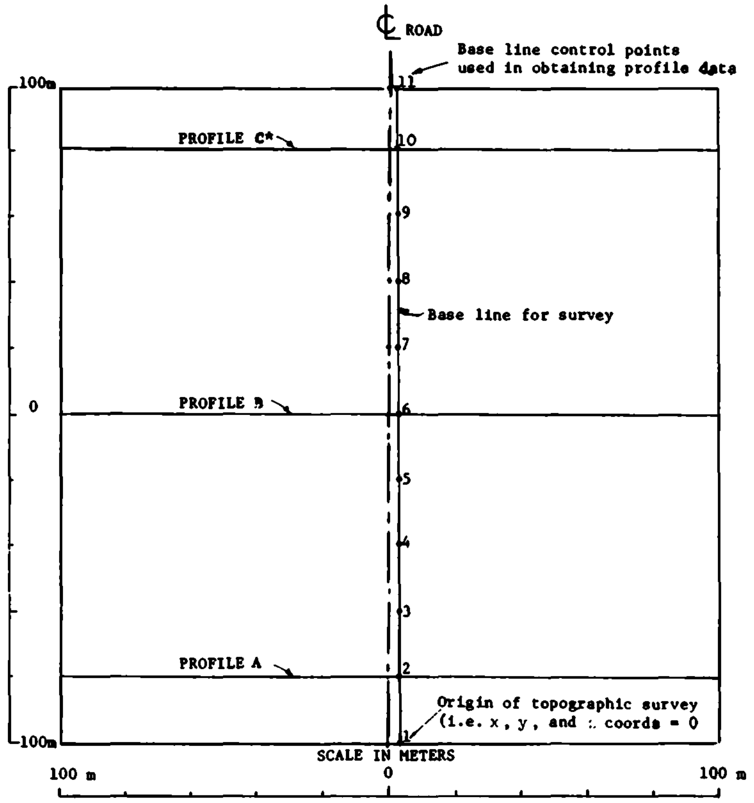
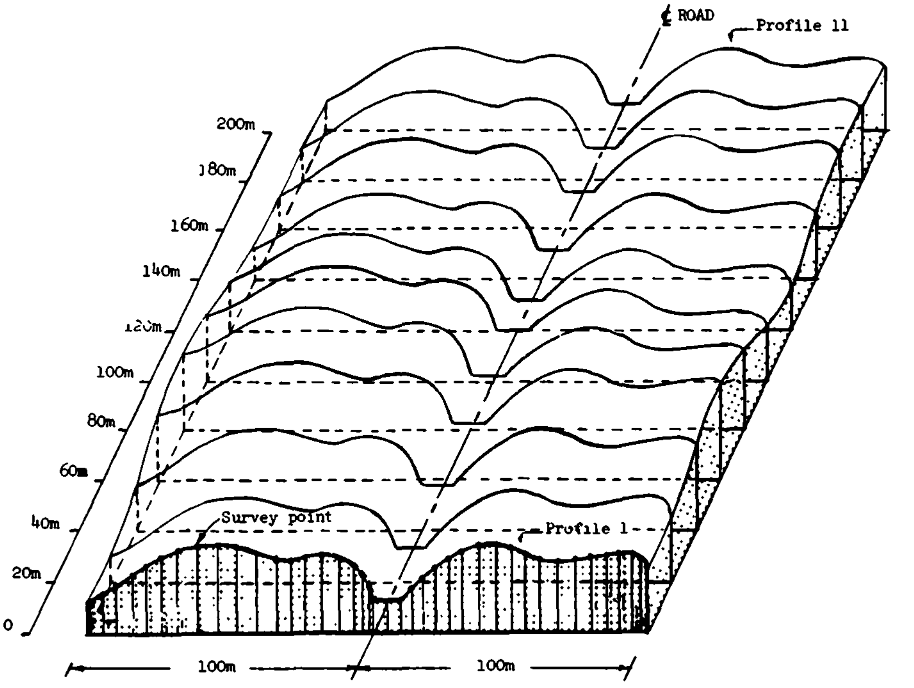


Fig. 18. Location of woody vegetation material on road site 6



* Profiles A, B, and C in figs. 22-27 are plotted from left to right.

a. Location of base-line control points



b. Location of surveyed profiles

Fig. 19. Topographic survey procedures

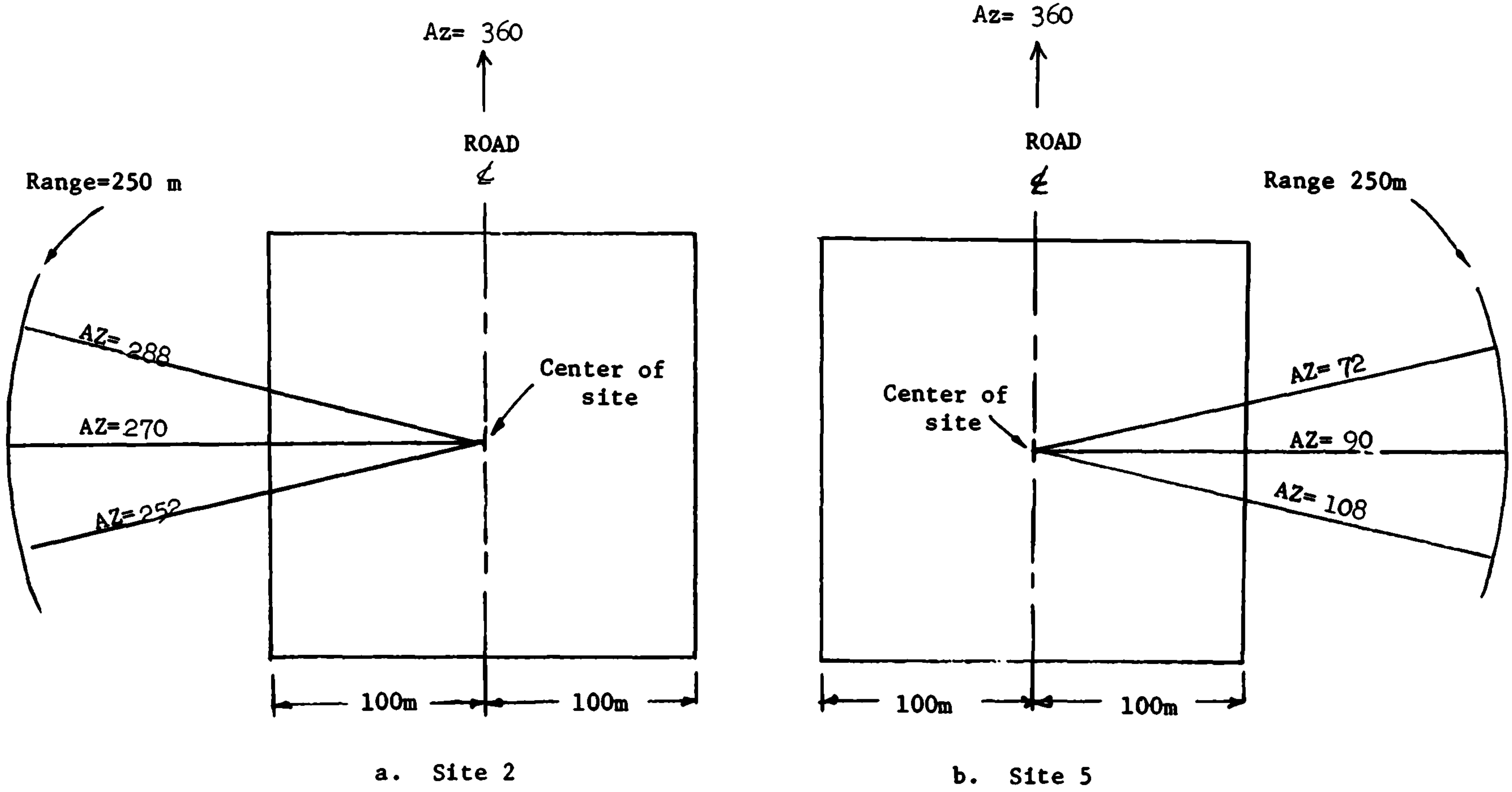


Fig. 20. Location of 250-m profiles, sites 2 and 5

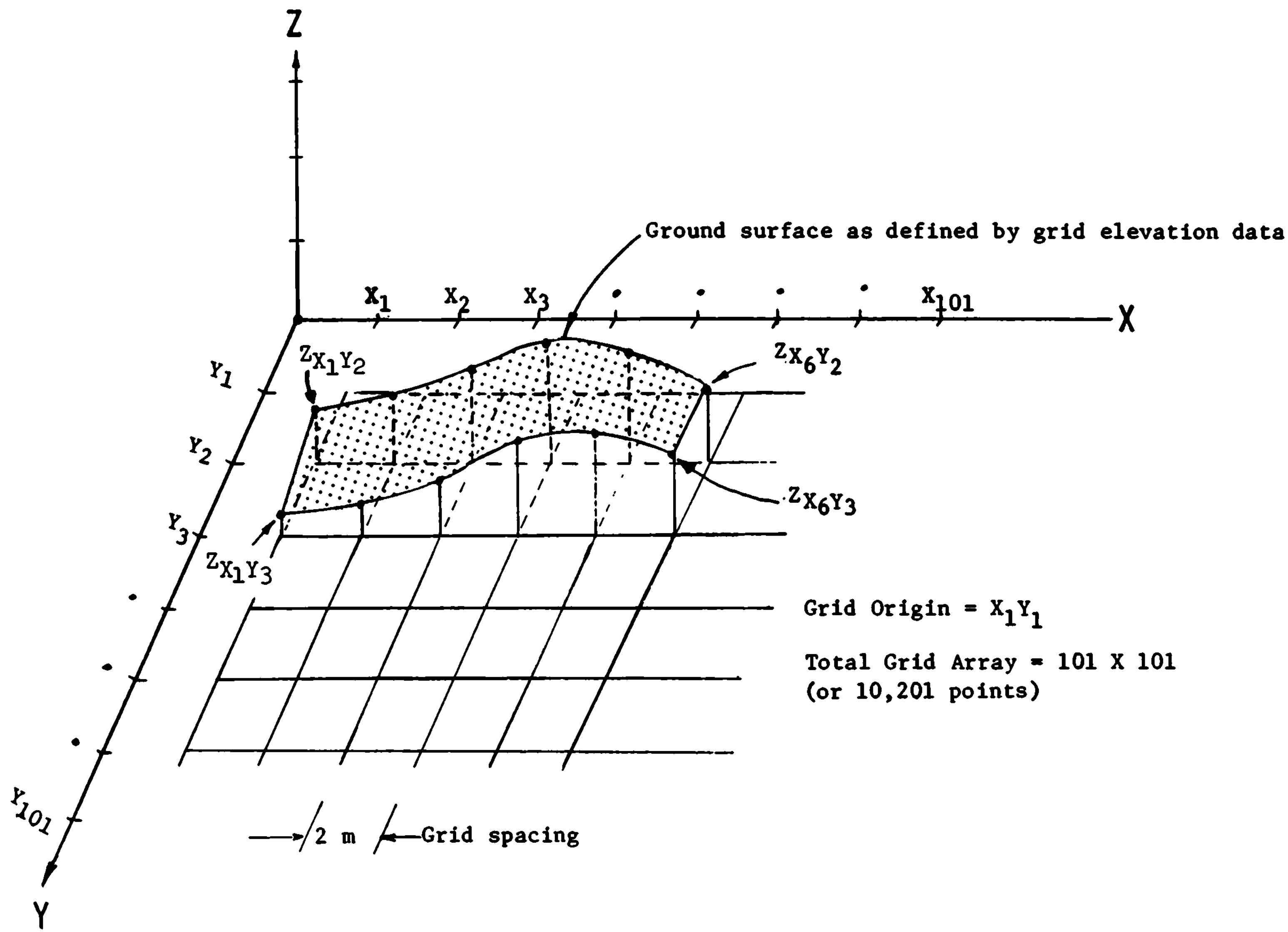
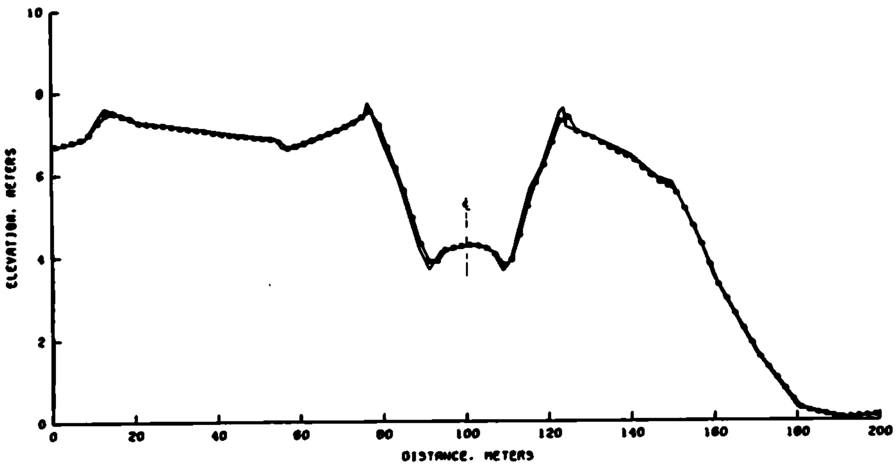
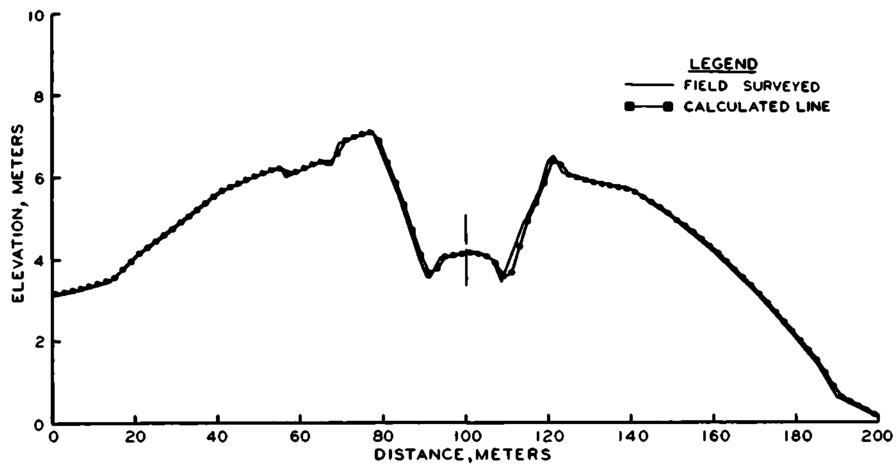


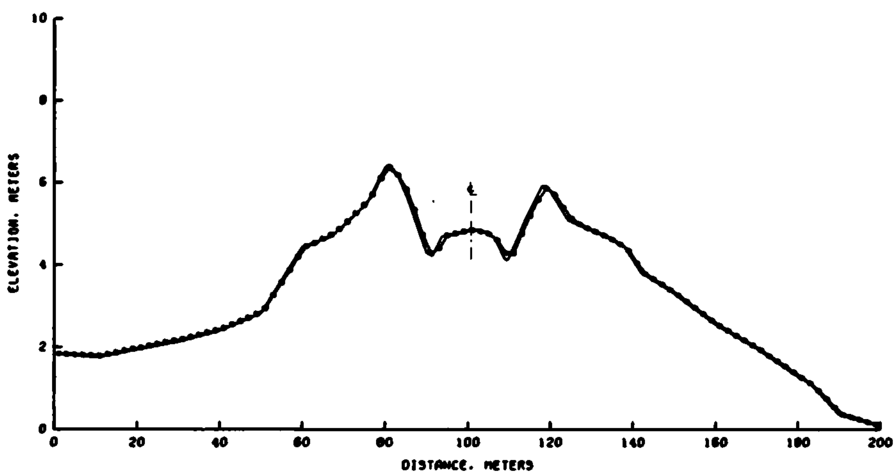
Fig. 21. Computer storage of grid elevation data for 200-m by 200-m road sites



a. PROFILE A



b PROFILE B



c. PROFILE C

Fig. 22. Comparison of field-surveyed and grid profile data, site 1

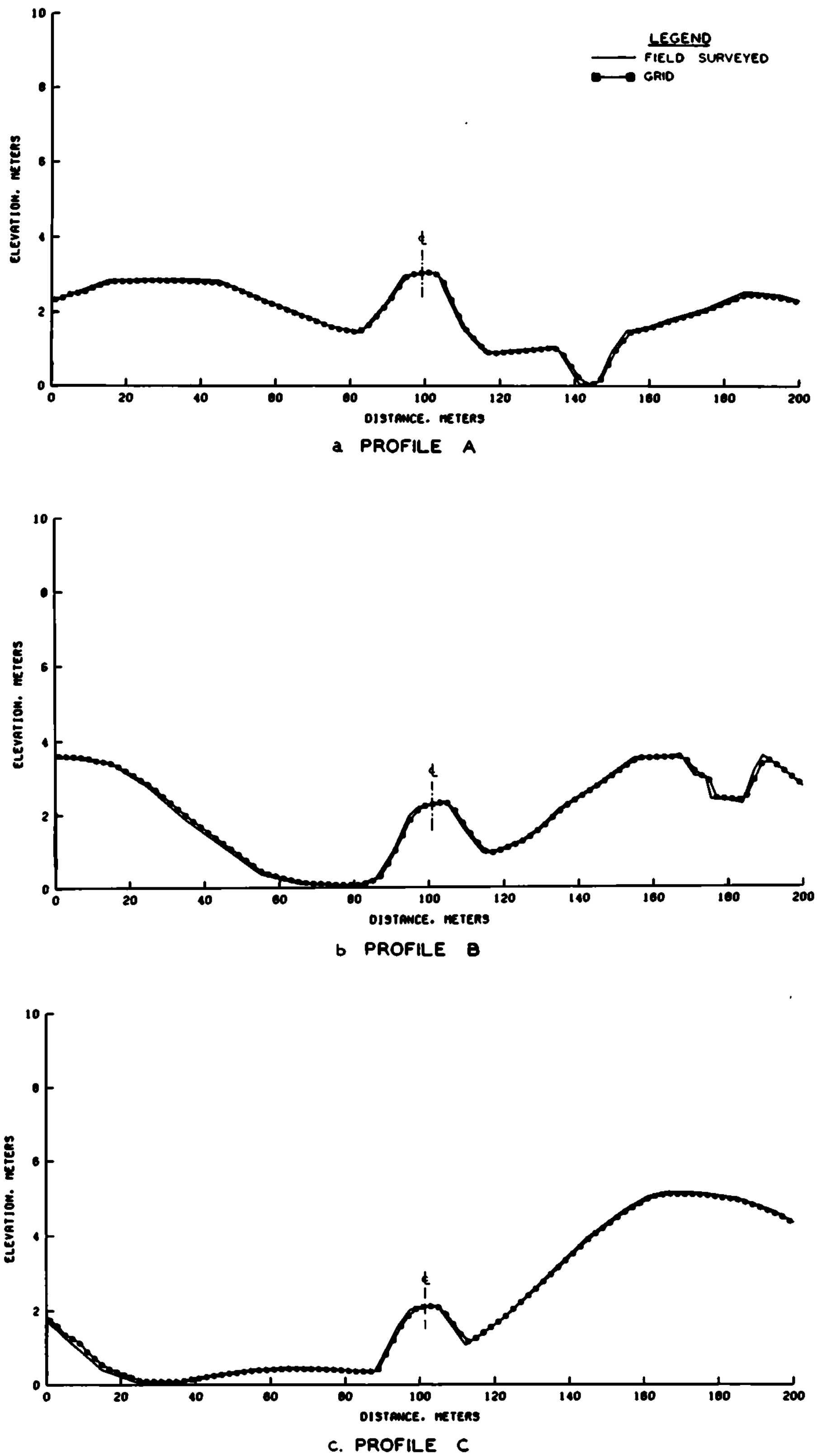


Fig. 23. Comparison of field-surveyed and grid profile data, site 2

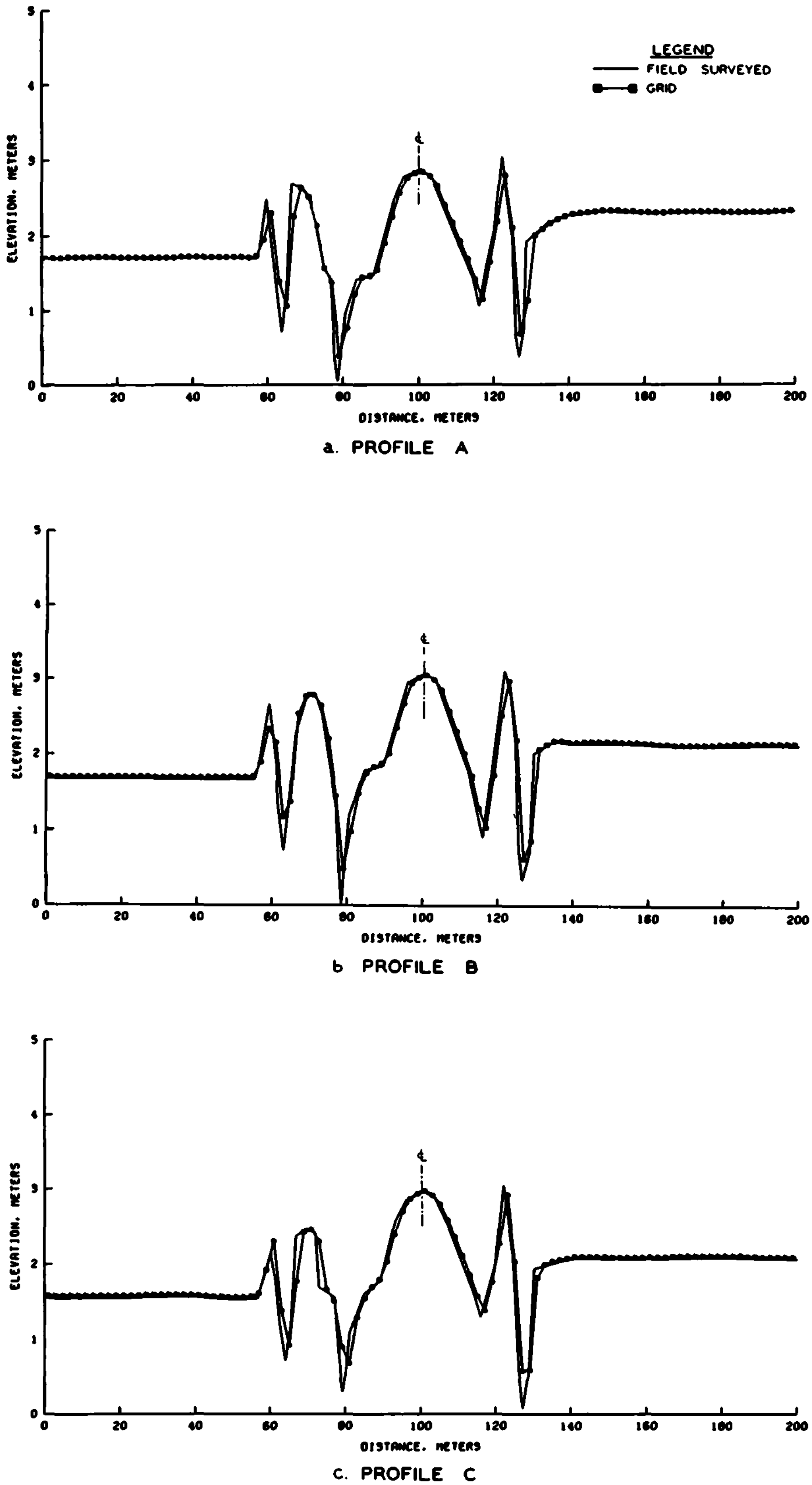
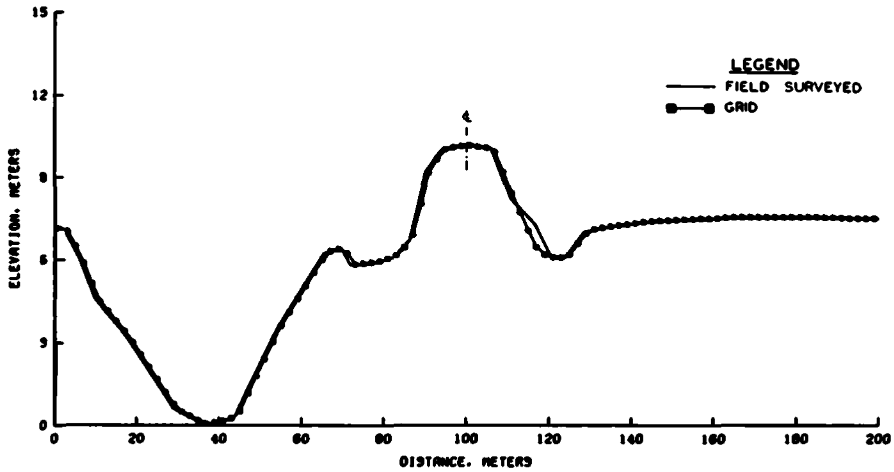
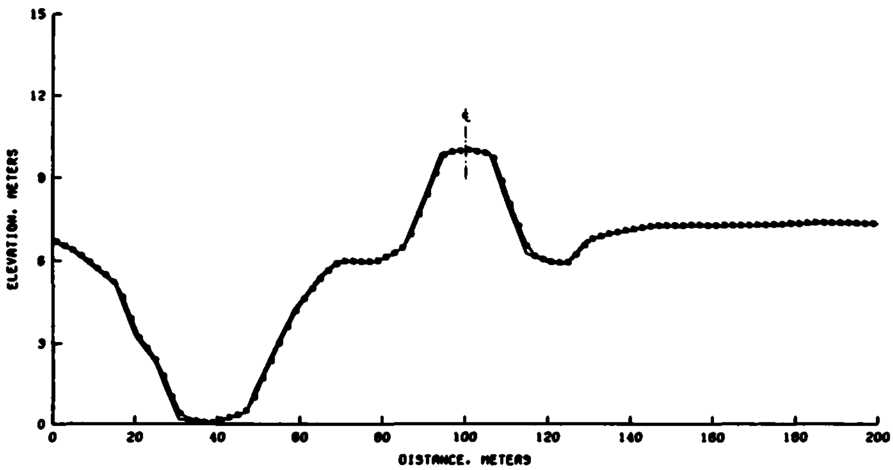


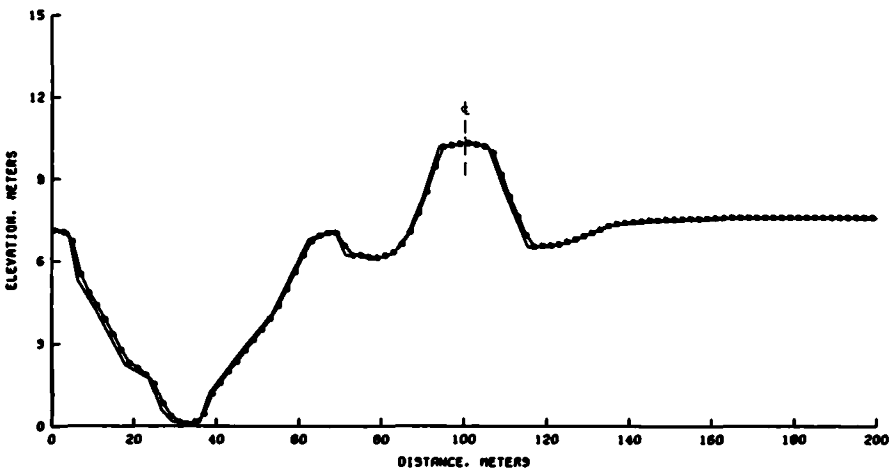
Fig. 24. Comparison of field-surveyed and grid profile data, site 3



a. PROFILE A

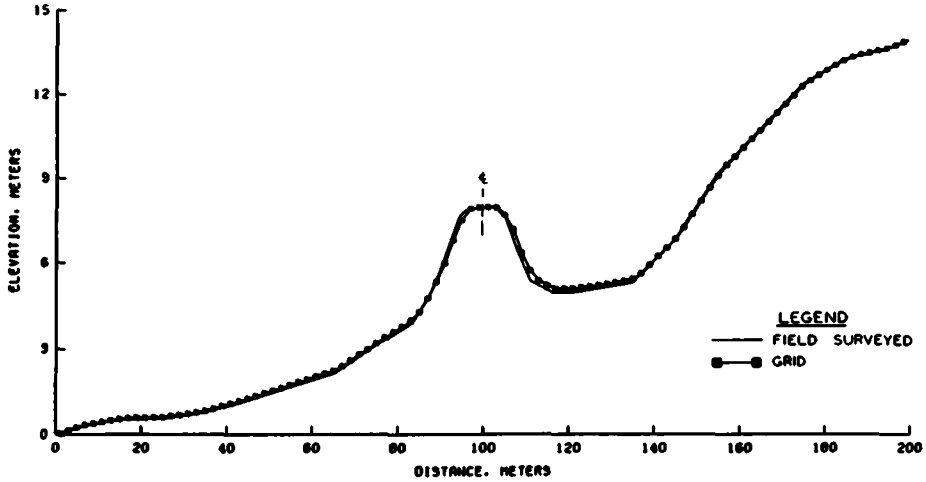


b PROFILE B

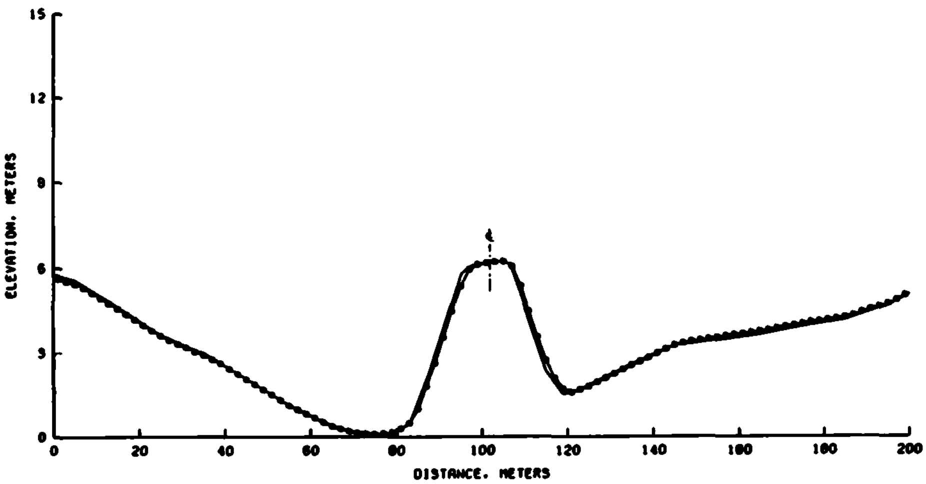


c. PROFILE C

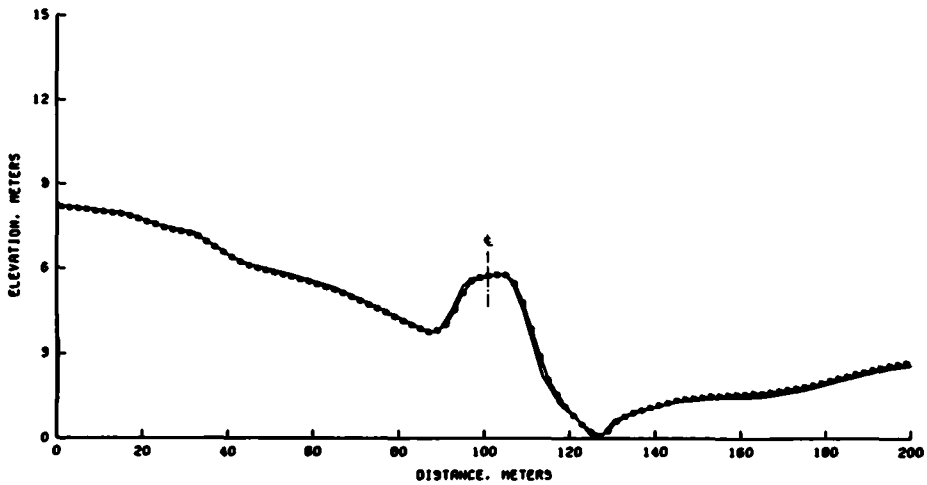
Fig. 25. Comparison of field-surveyed and grid profile data, site 4



a. PROFILE A

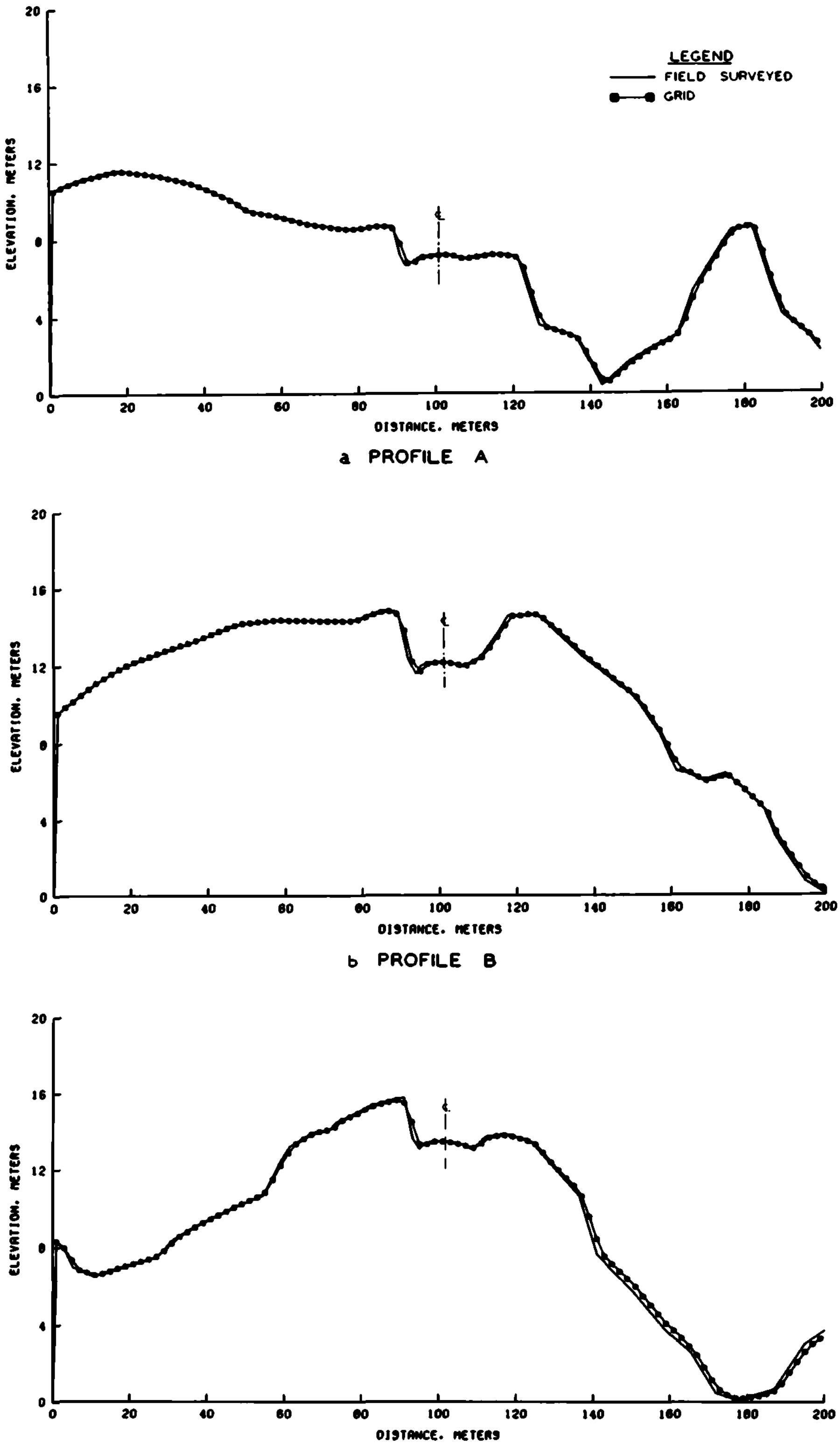


b. PROFILE B



c. PROFILE C

Fig. 26. Comparison of field-surveyed and grid profile data, site 5



a PROFILE A

b PROFILE B

c. PROFILE C

Fig. 27. Comparison of field-surveyed and grid profile data, site 6

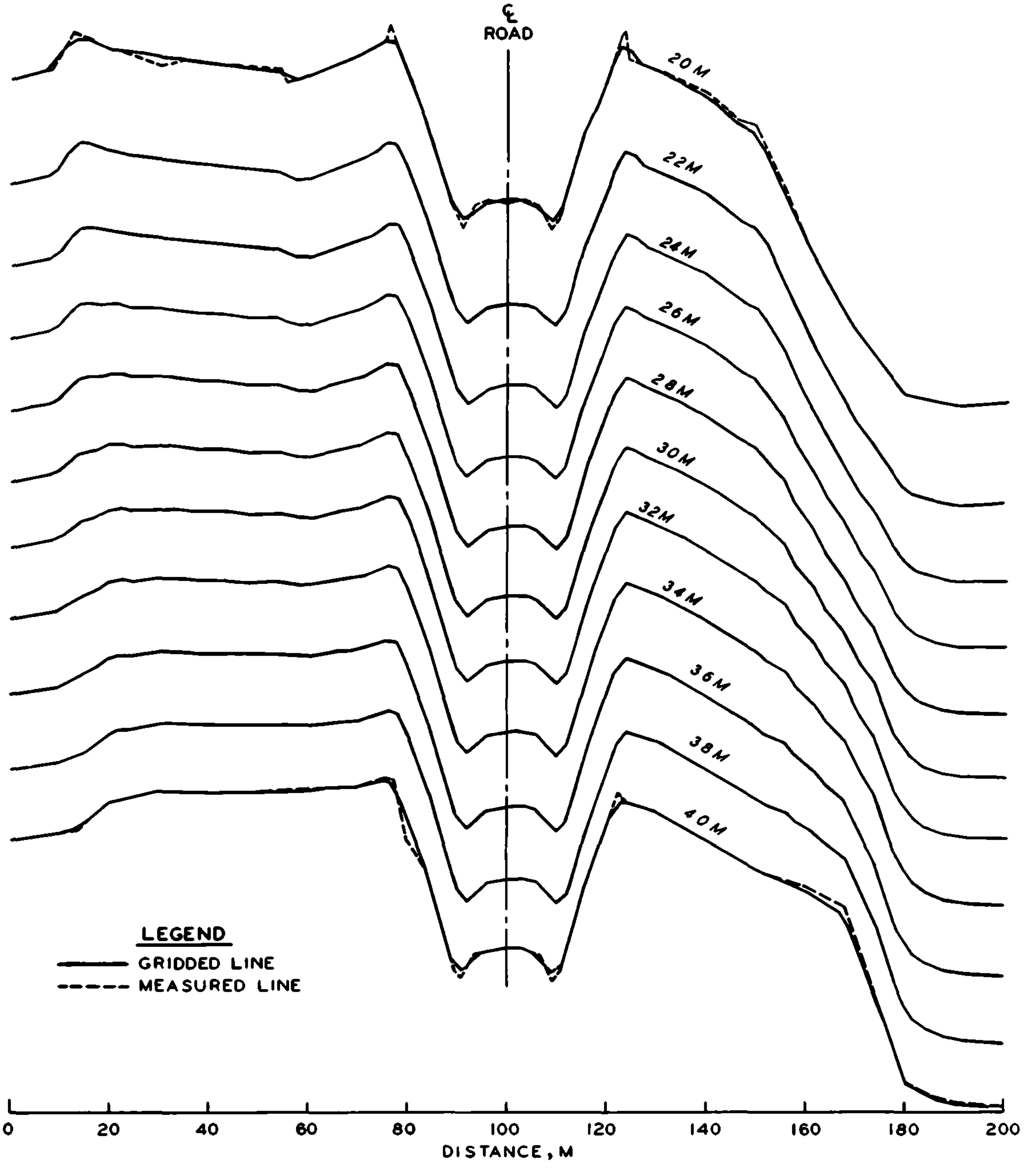


Fig. 28. Comparison of field-surveyed and grid data generated between surveyed profiles

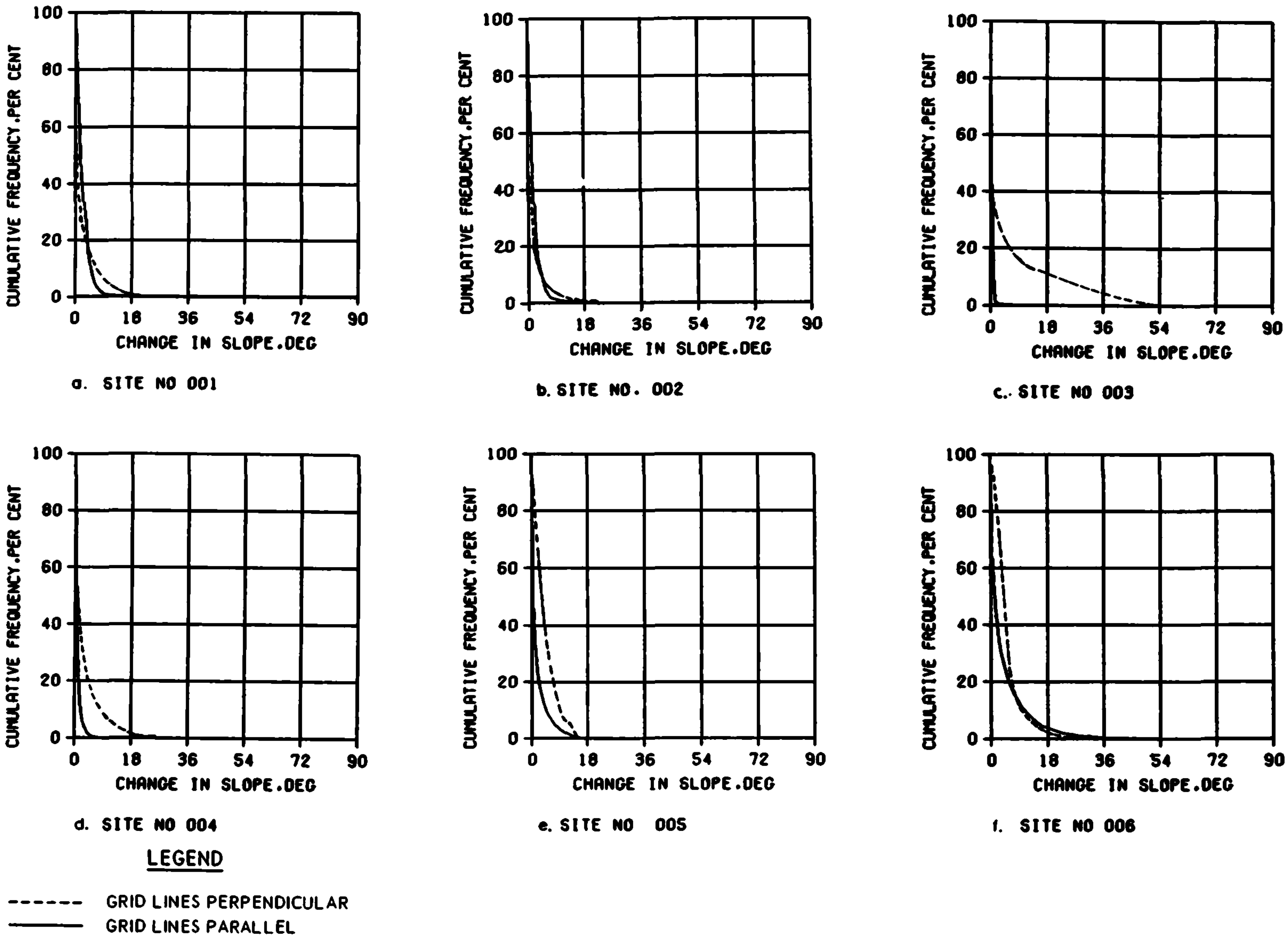
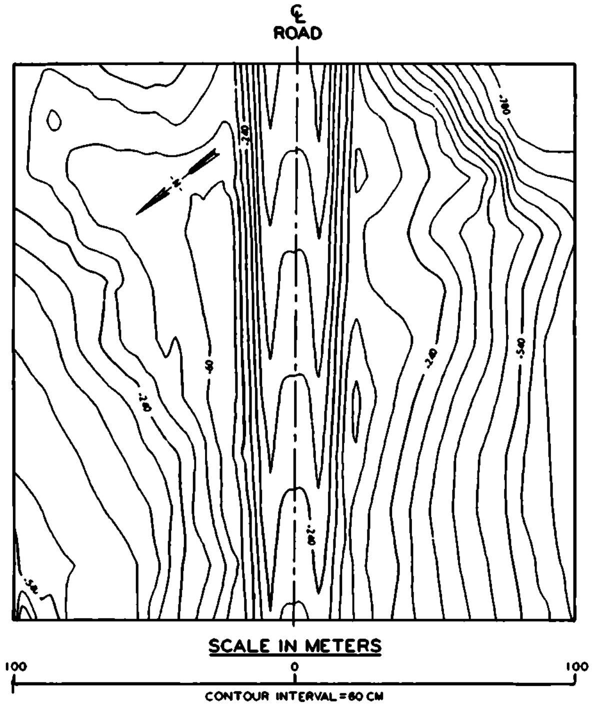
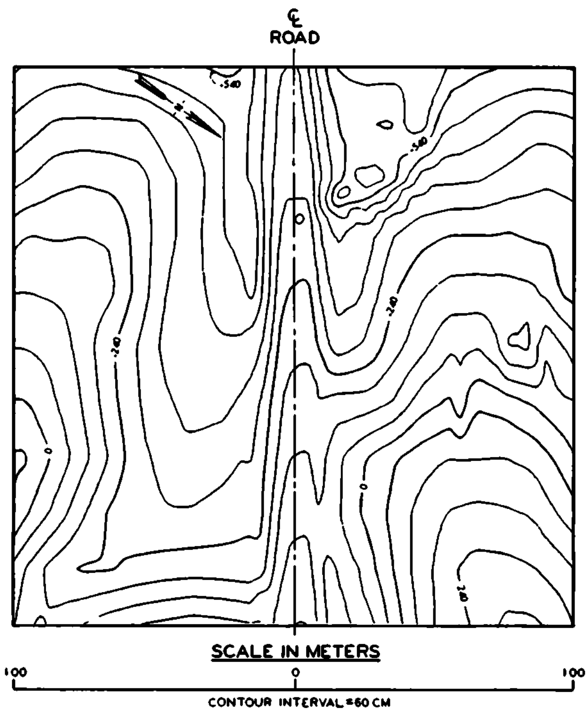


Fig. 29. Comparison of slope changes along 2-m grid profiles for grid lines approximately perpendicular and parallel to road center line

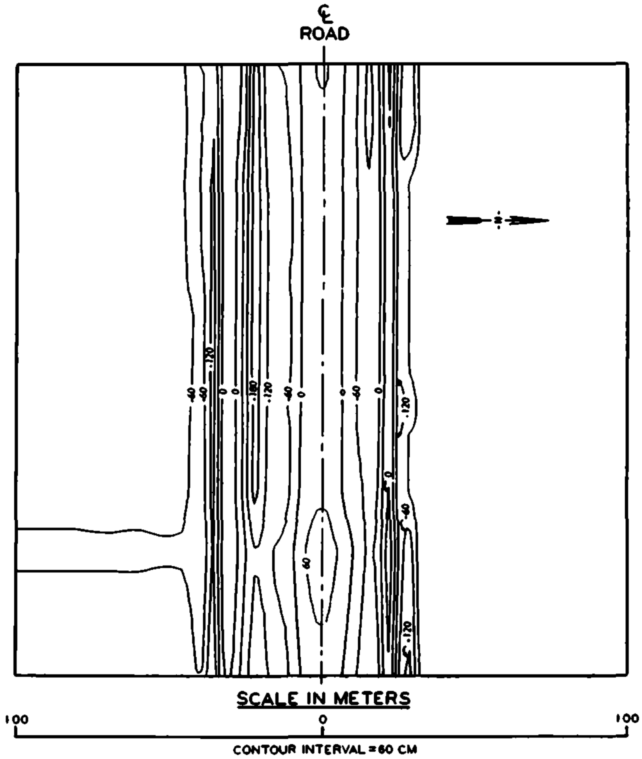


a. Road site 1

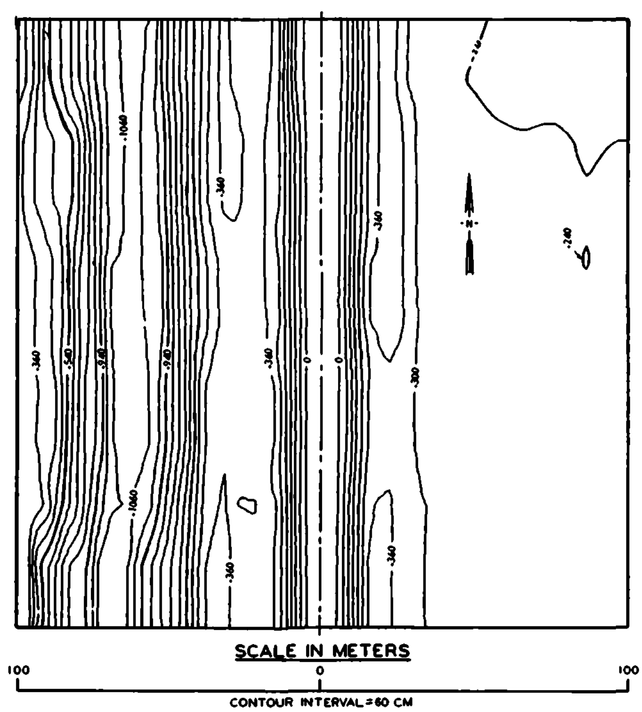


b. Road site 2

Fig. 30. Contour maps, sites 1-6
(sheet 1 of 3)

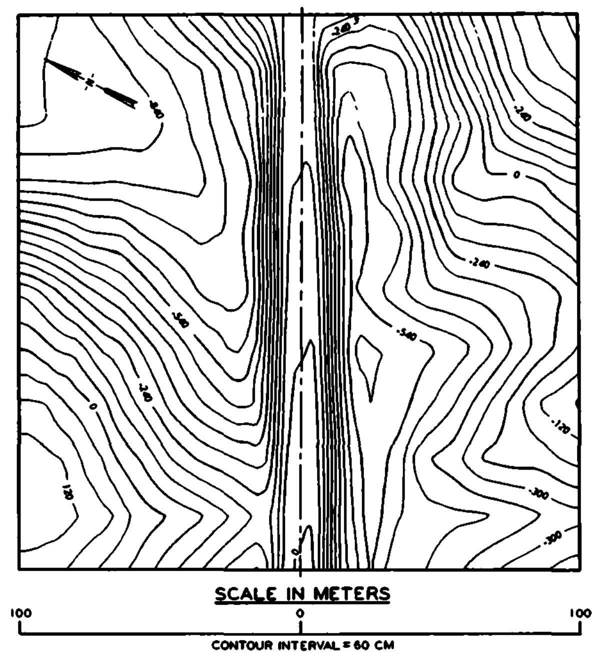


c. Road site 3

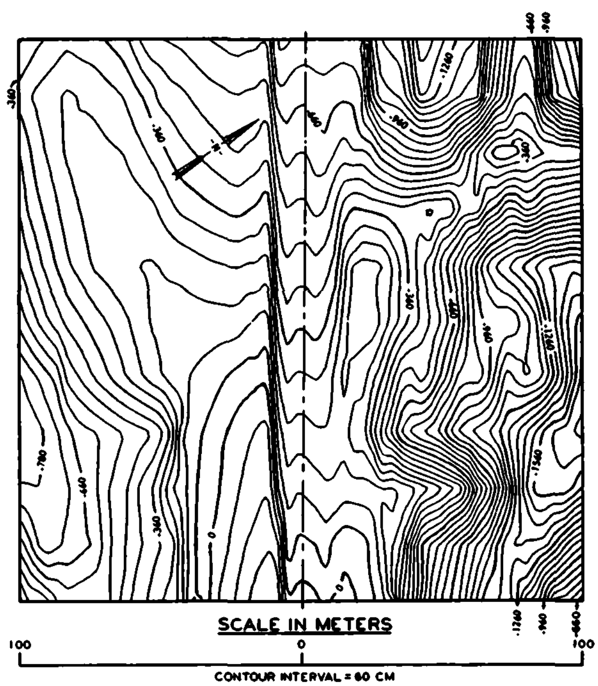


d. Road site 4

Fig. 30 (sheet 2 of 3)

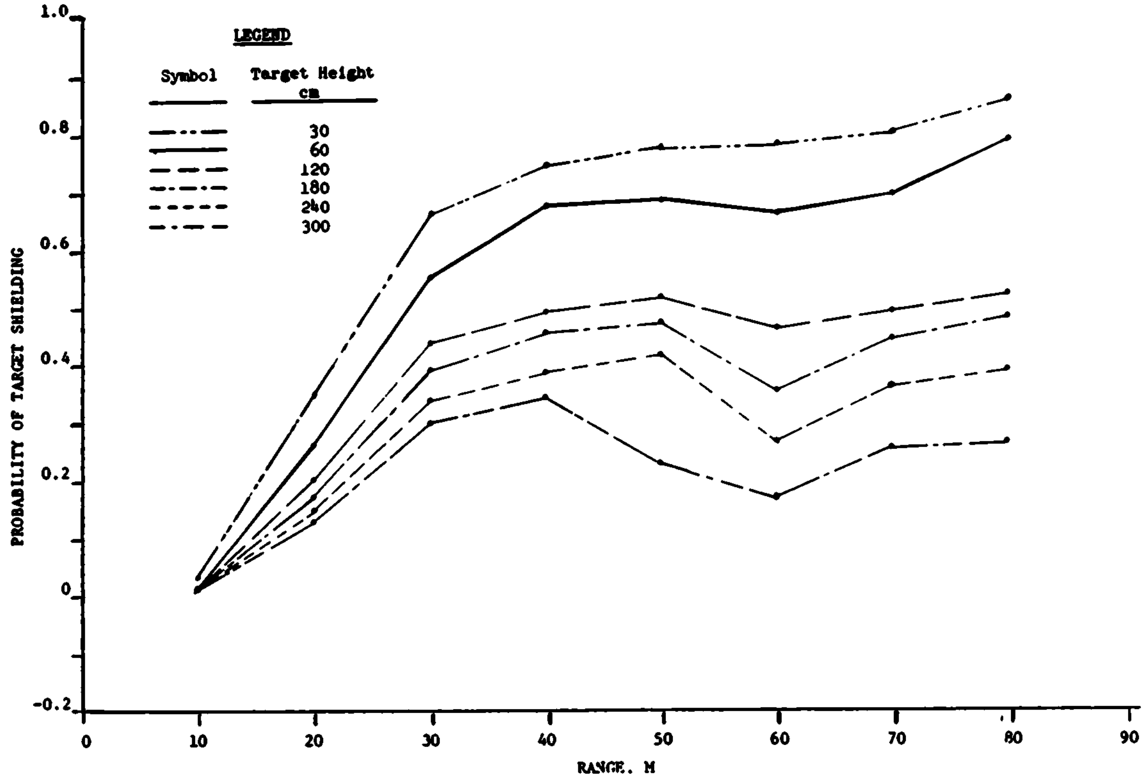


e. Road site 5

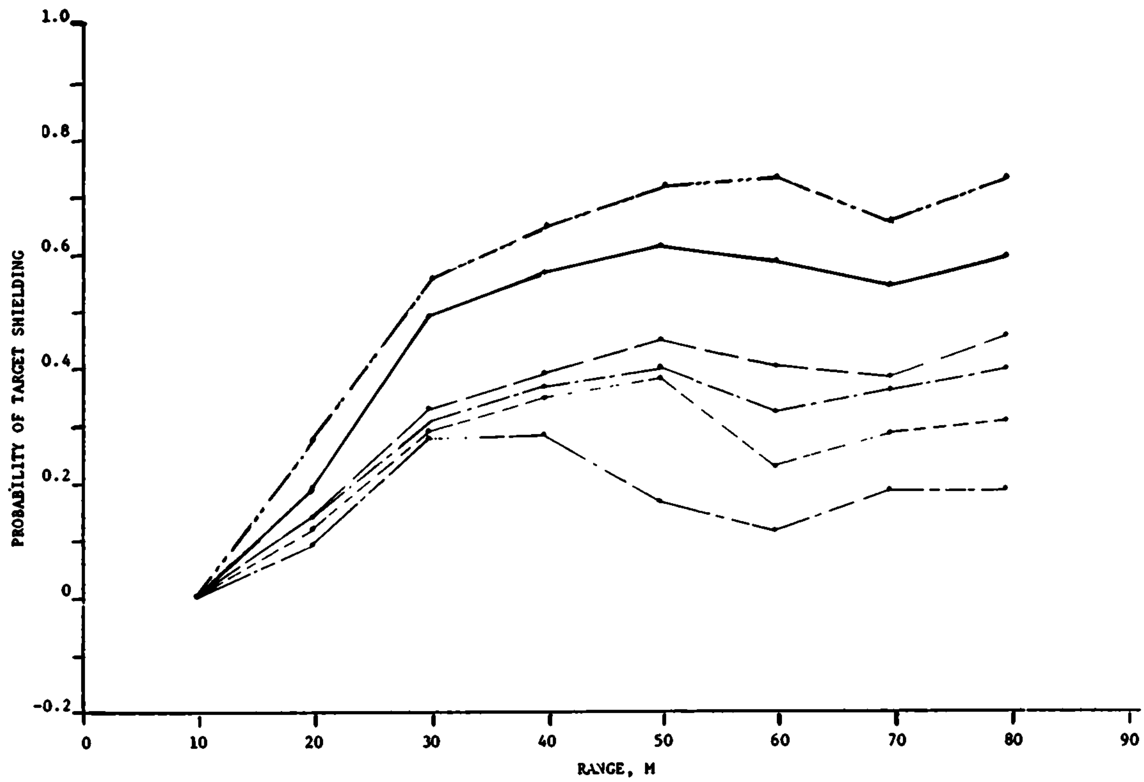


f. Road site 6

Fig. 30 (sheet 3 of 3)

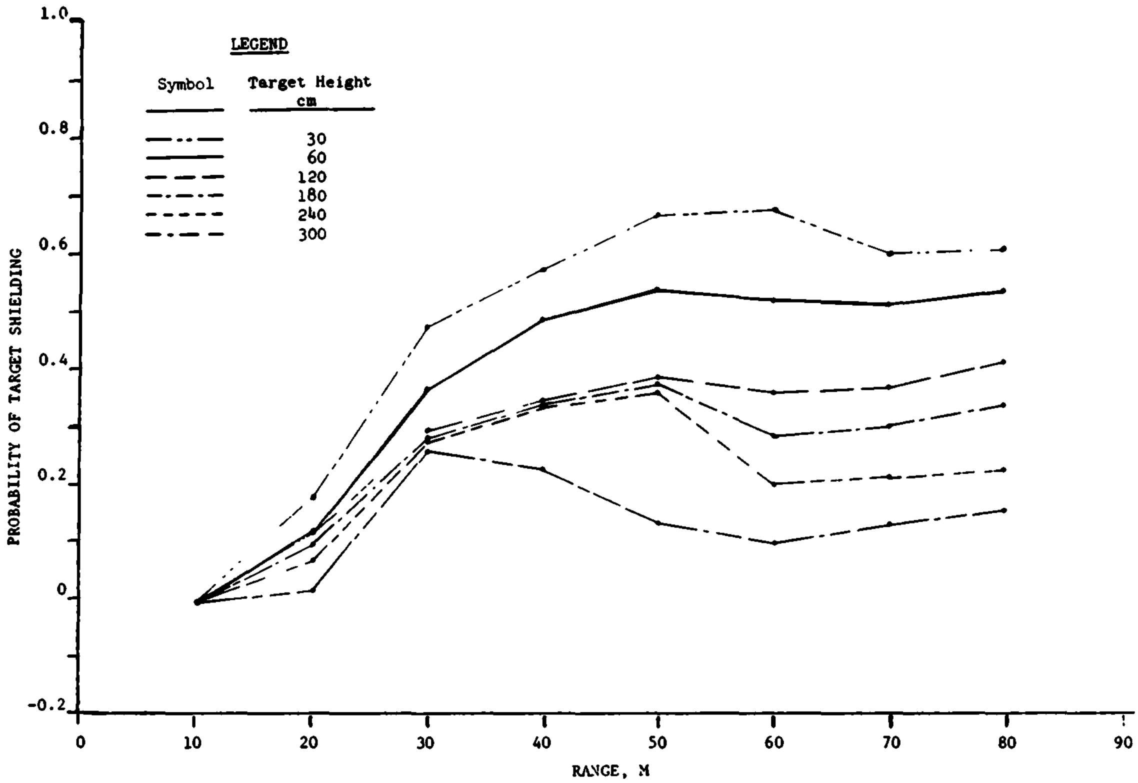


a. HOB = 0 cm

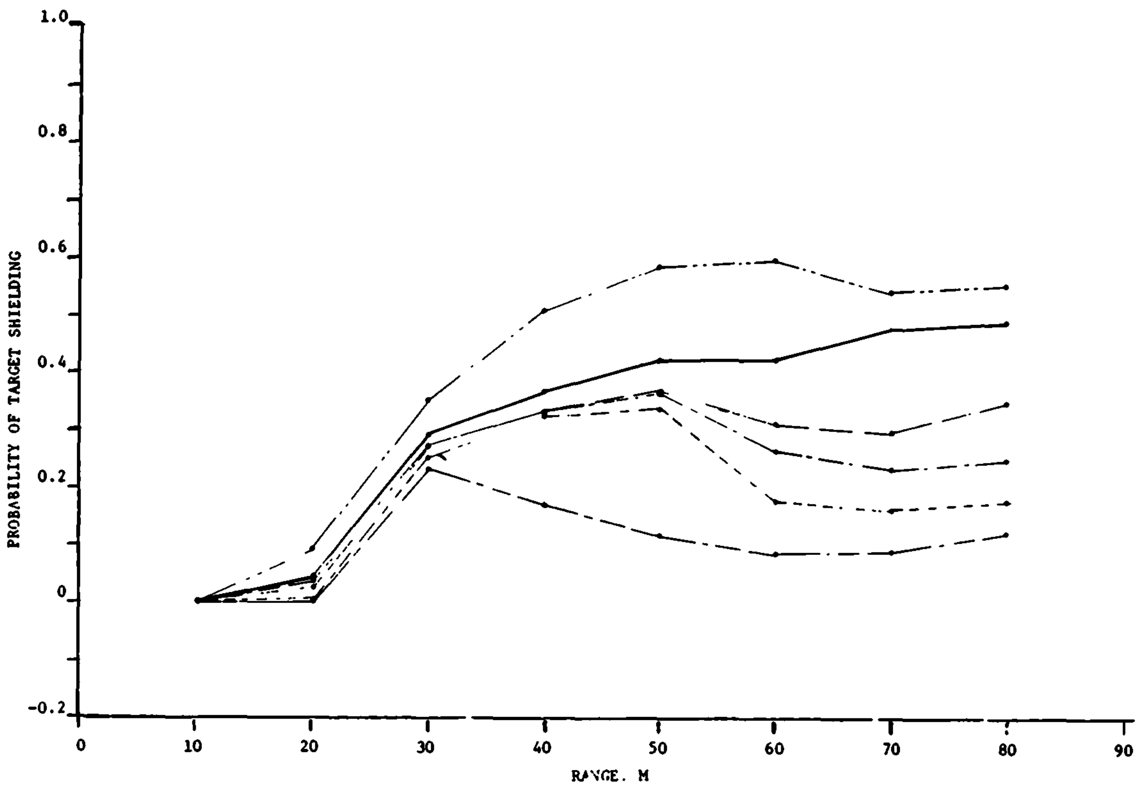


b. HOB = 10 cm

Fig. 31. Probability of shielding for different target heights, site 1 (sheet 1 of 5)

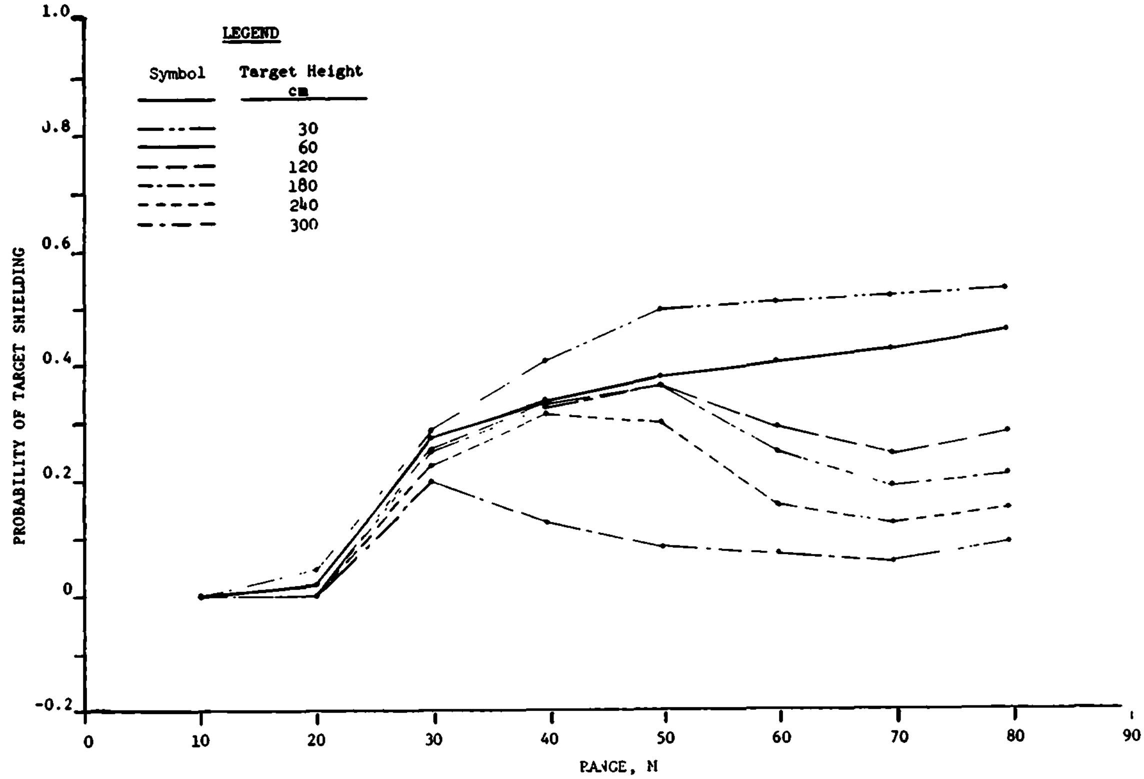


c. HOB = 25 cm

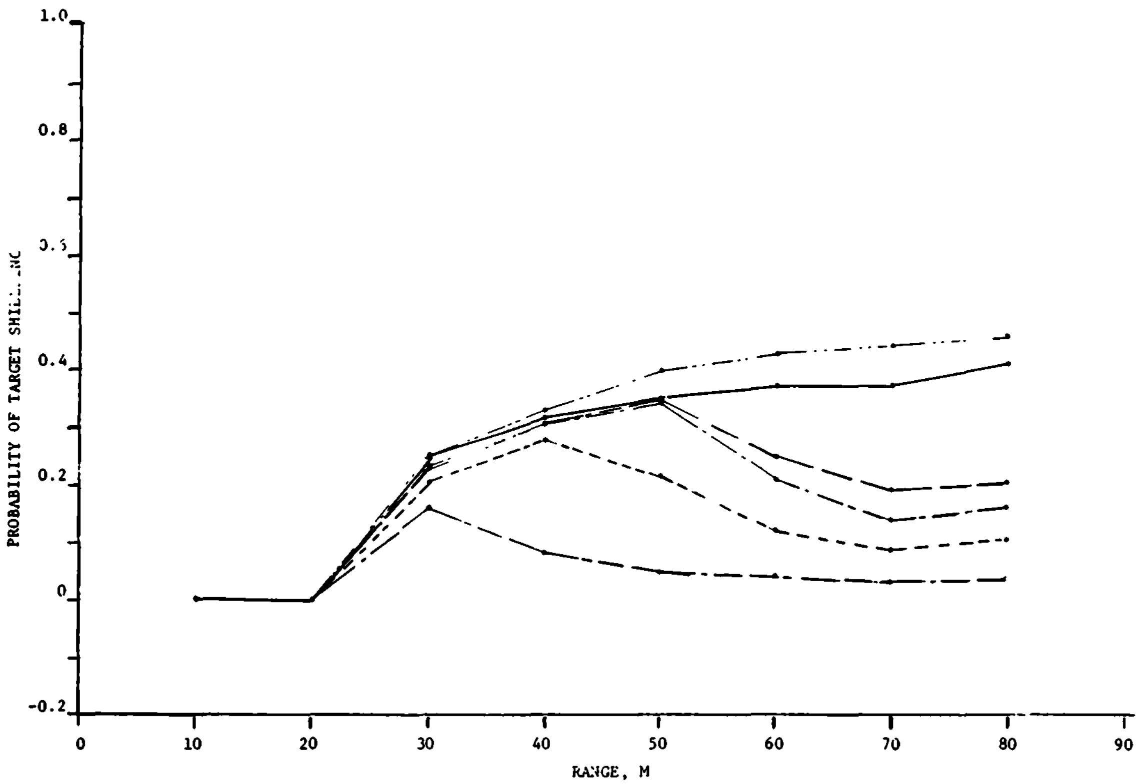


d. HOB = 50 cm

Fig. 31 (sheet 2 of 5)

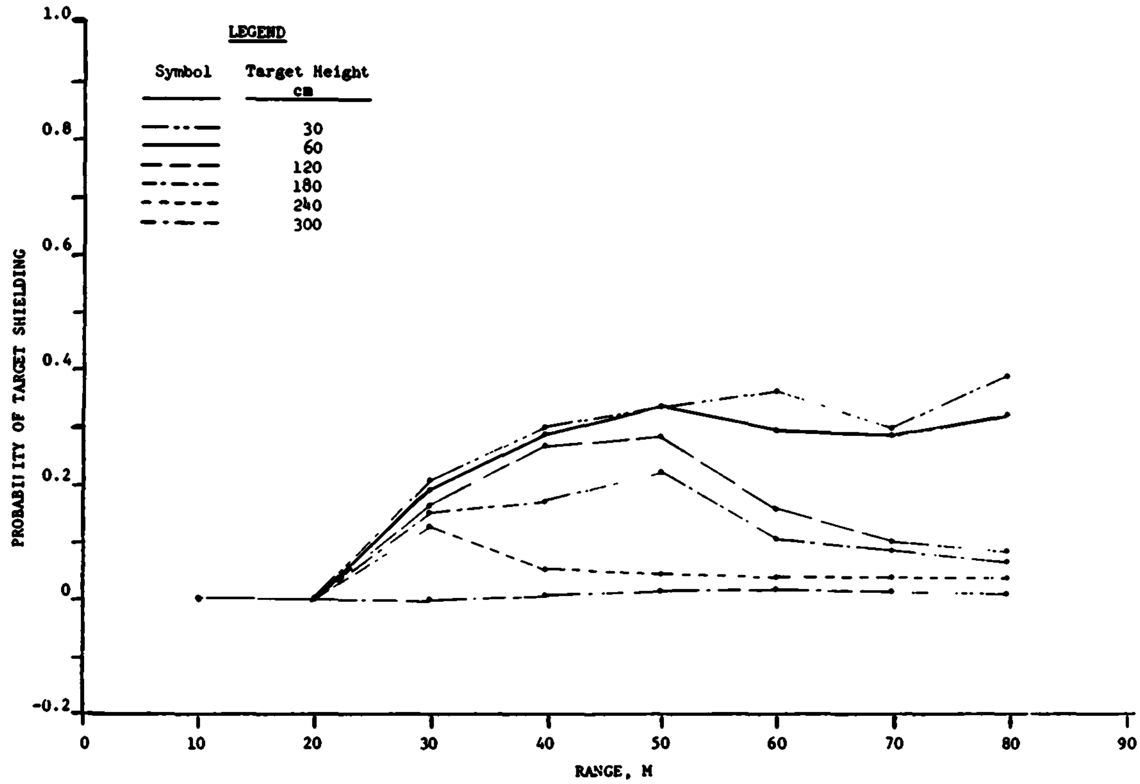


e. HOB = 75 cm

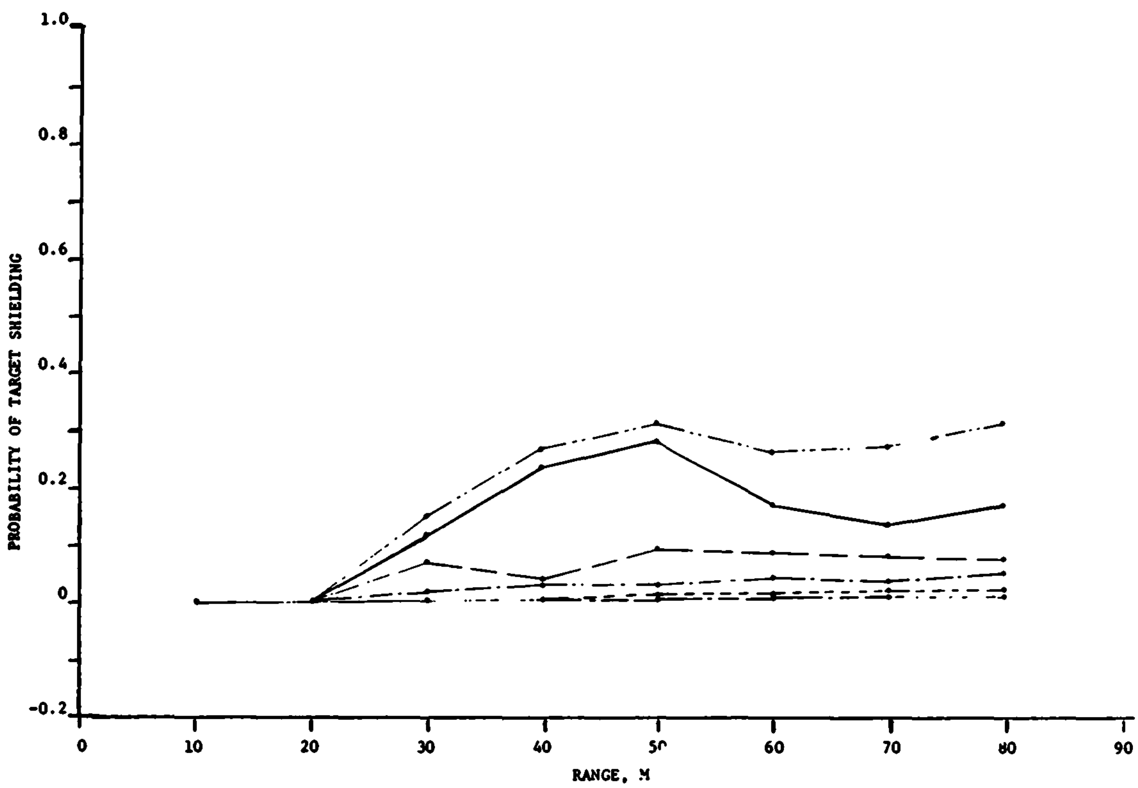


f. HOB = 100 cm

Fig. 31 (sheet 3 of 5)

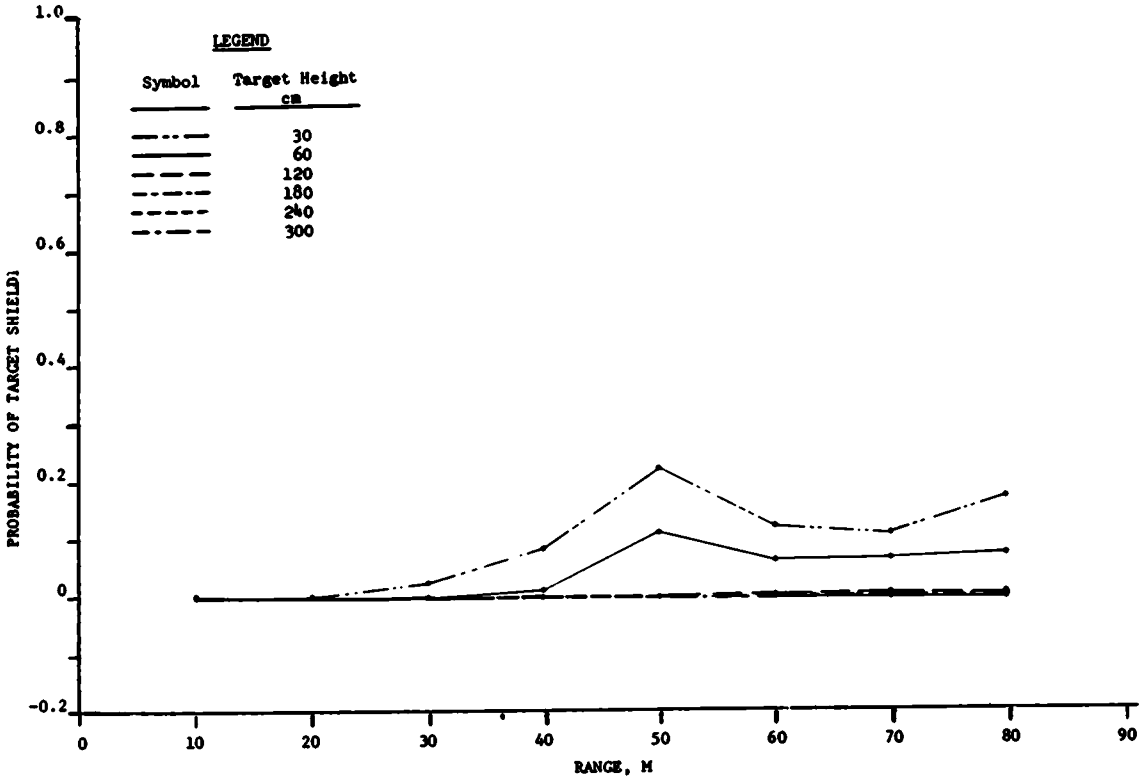


g. HOB = 200 cm

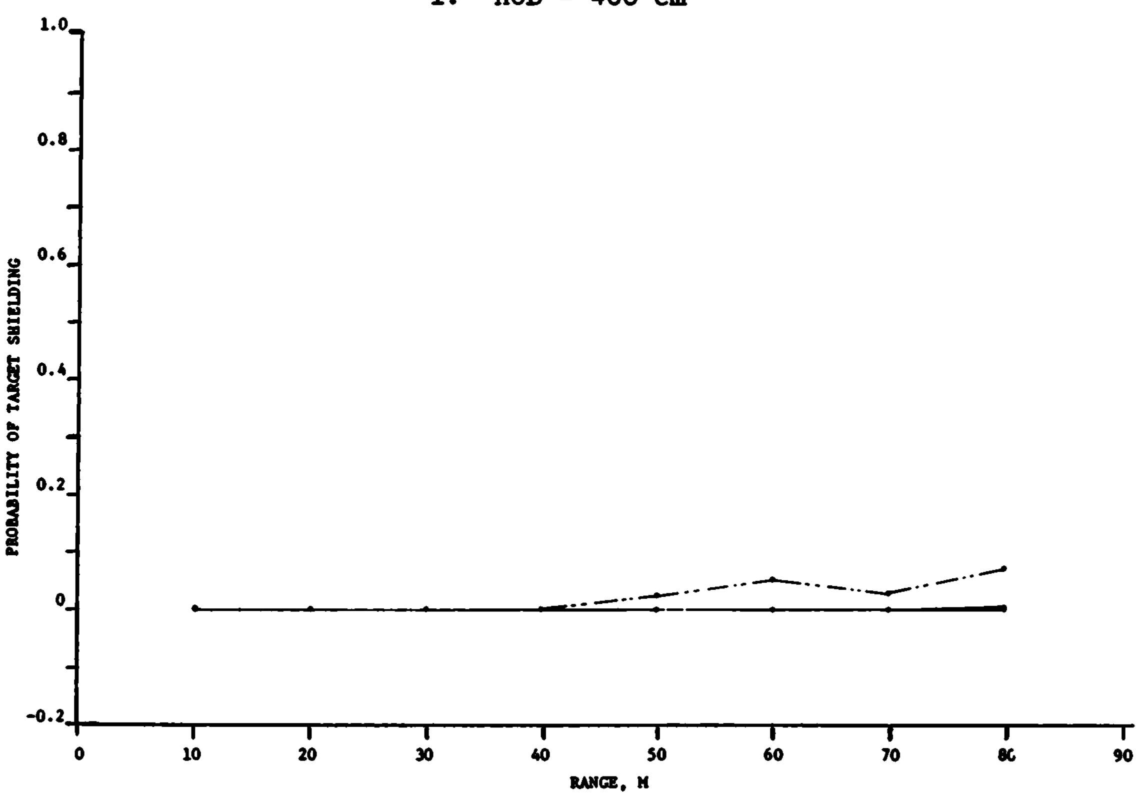


h. HOB = 300 cm

Fig. 31 (sheet 4 of 5)

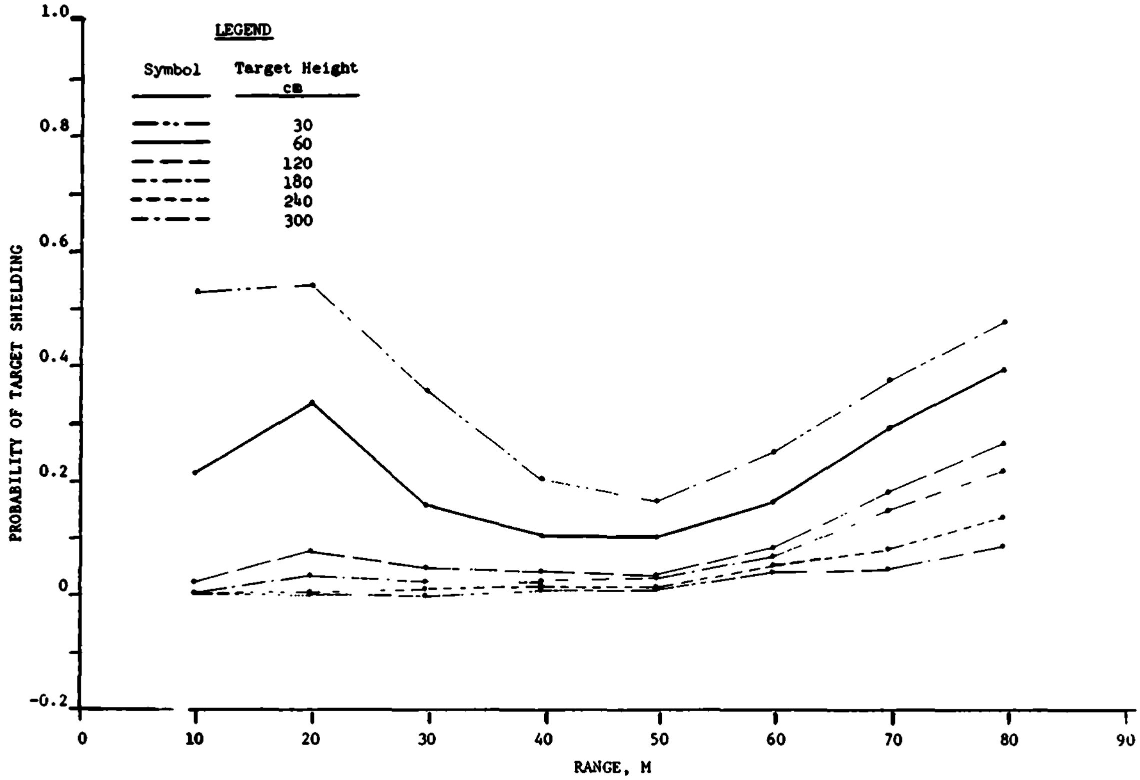


i. HOB = 400 cm

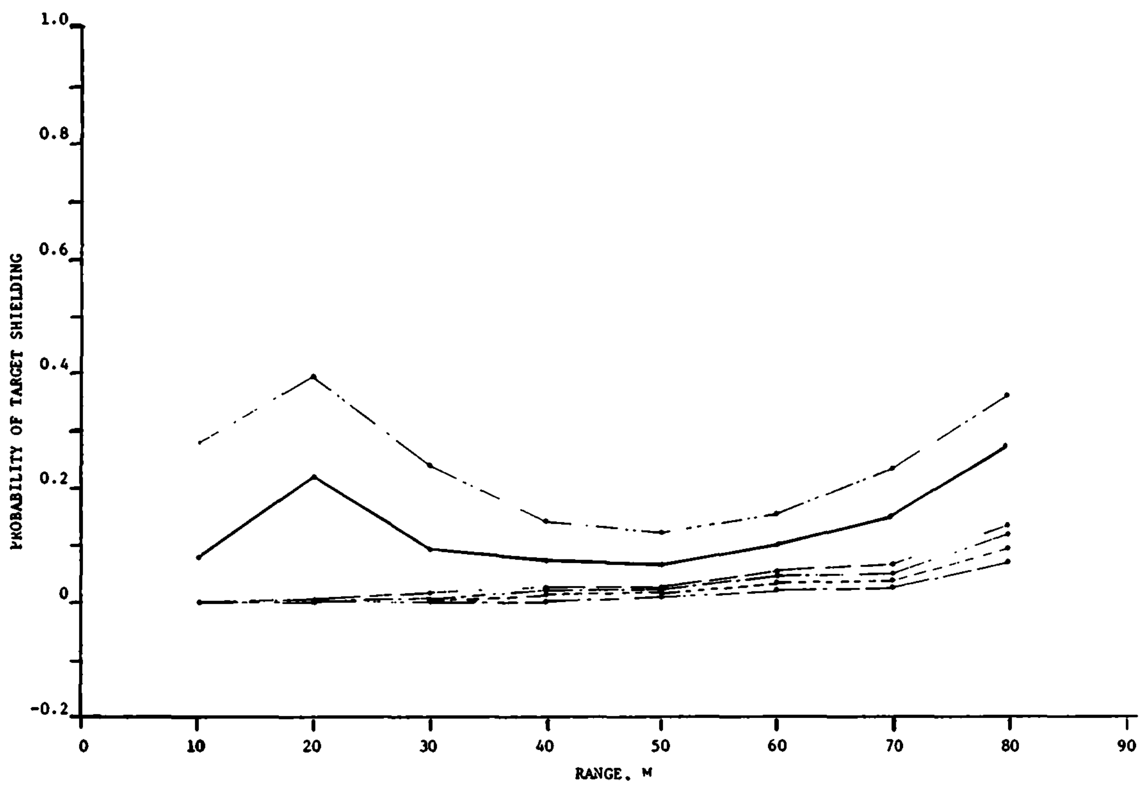


j. HOB = 500 cm

Fig. 31 (sheet 5 of 5)

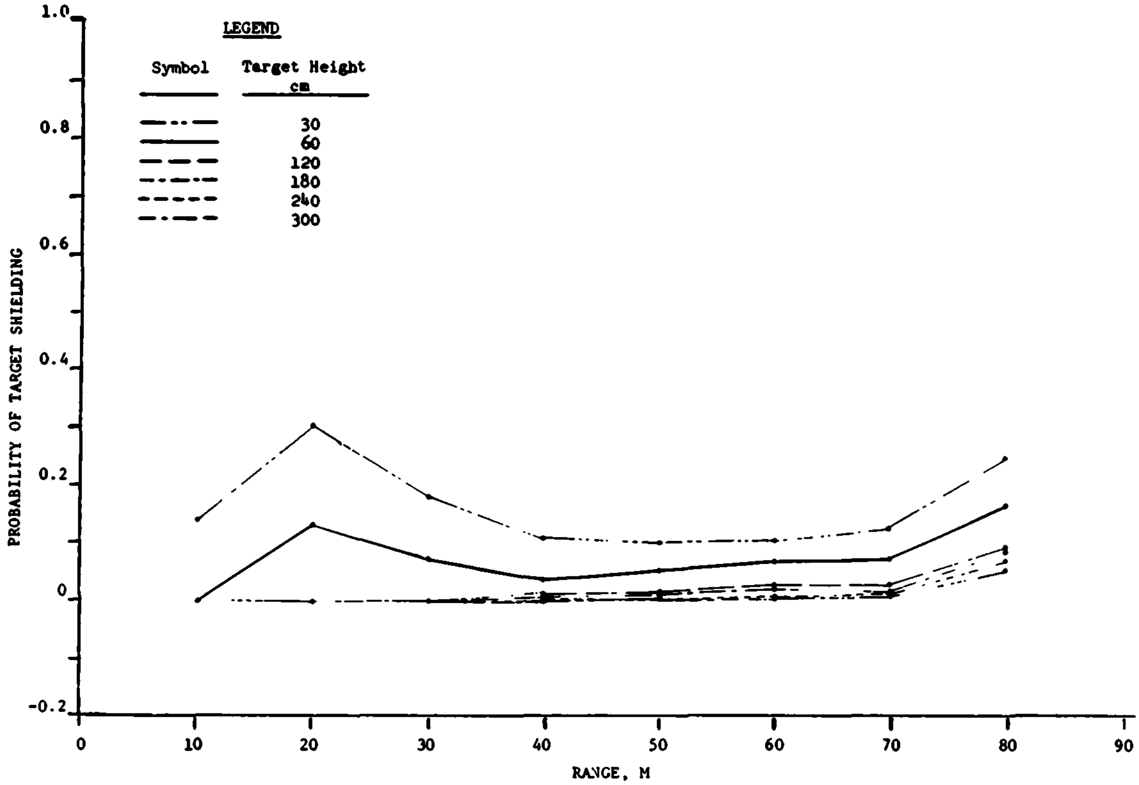


a. HOB = 0 cm

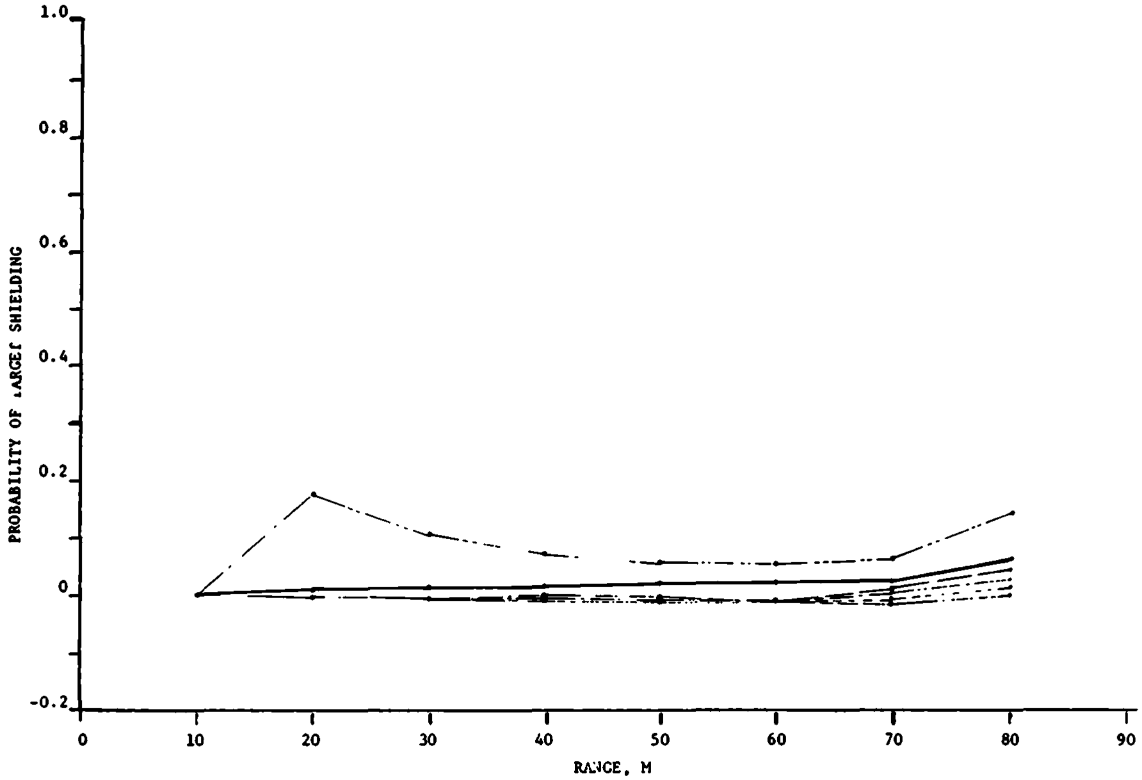


b. HOB = 10 cm

Fig. 32. Probability of shielding for different target heights, site 2 (sheet 1 of 5)

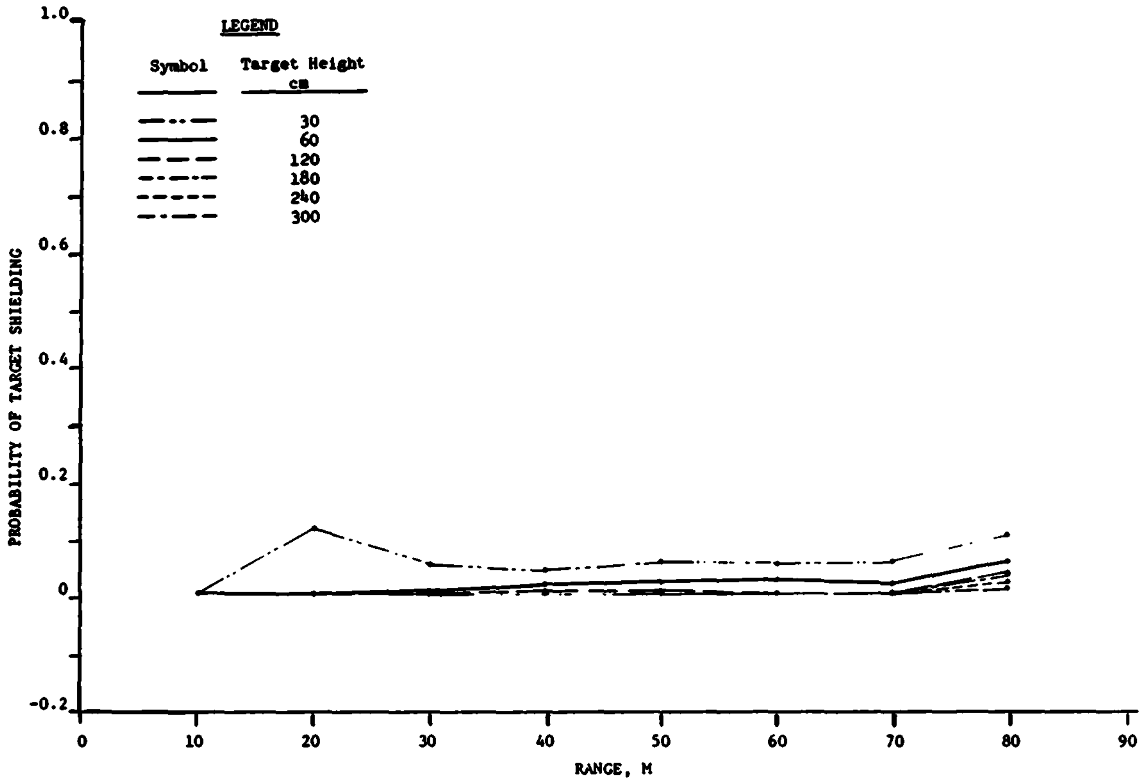


c. HOB = 25 cm

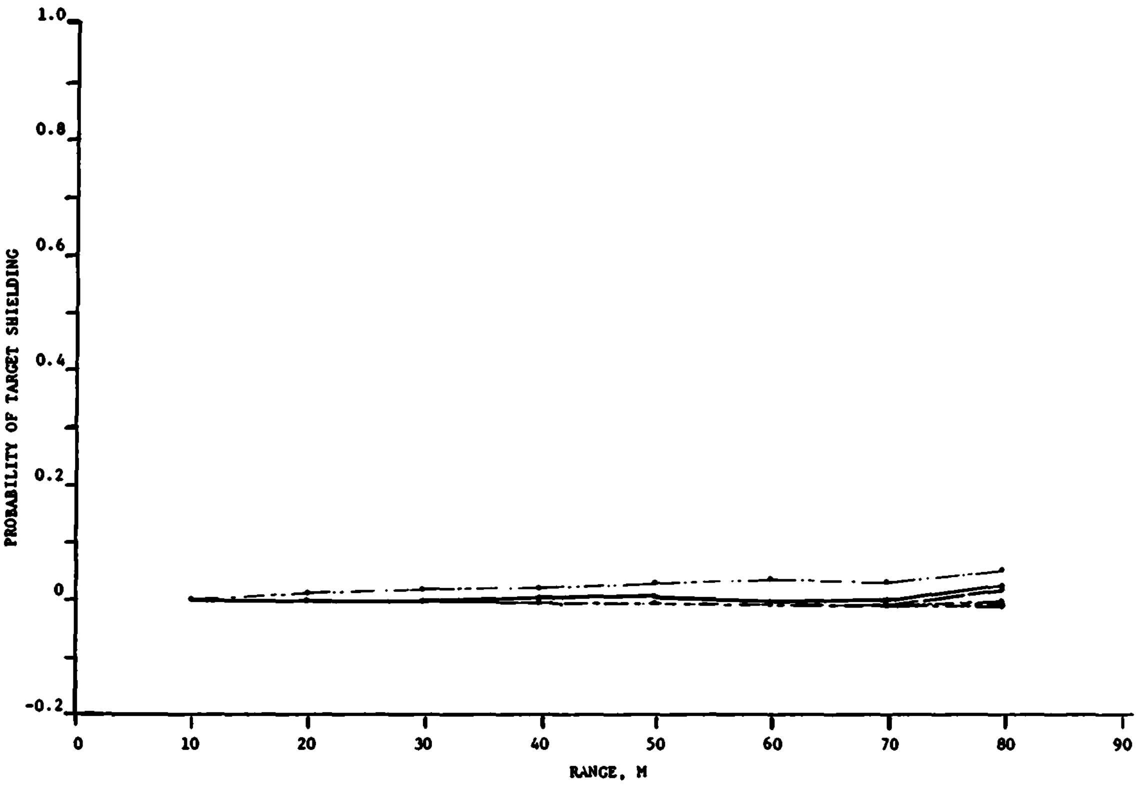


d. HOB = 50 cm

Fig. 32 (sheet 2 of 5)

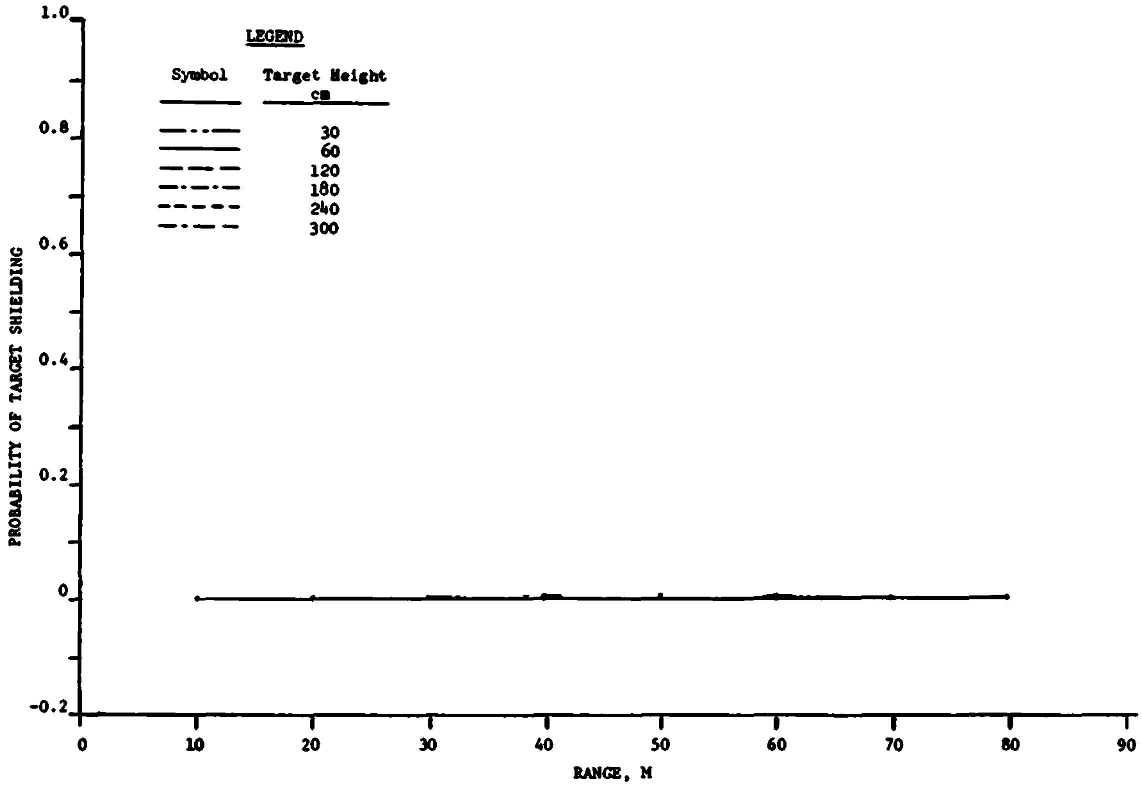


e. HOB = 75 cm

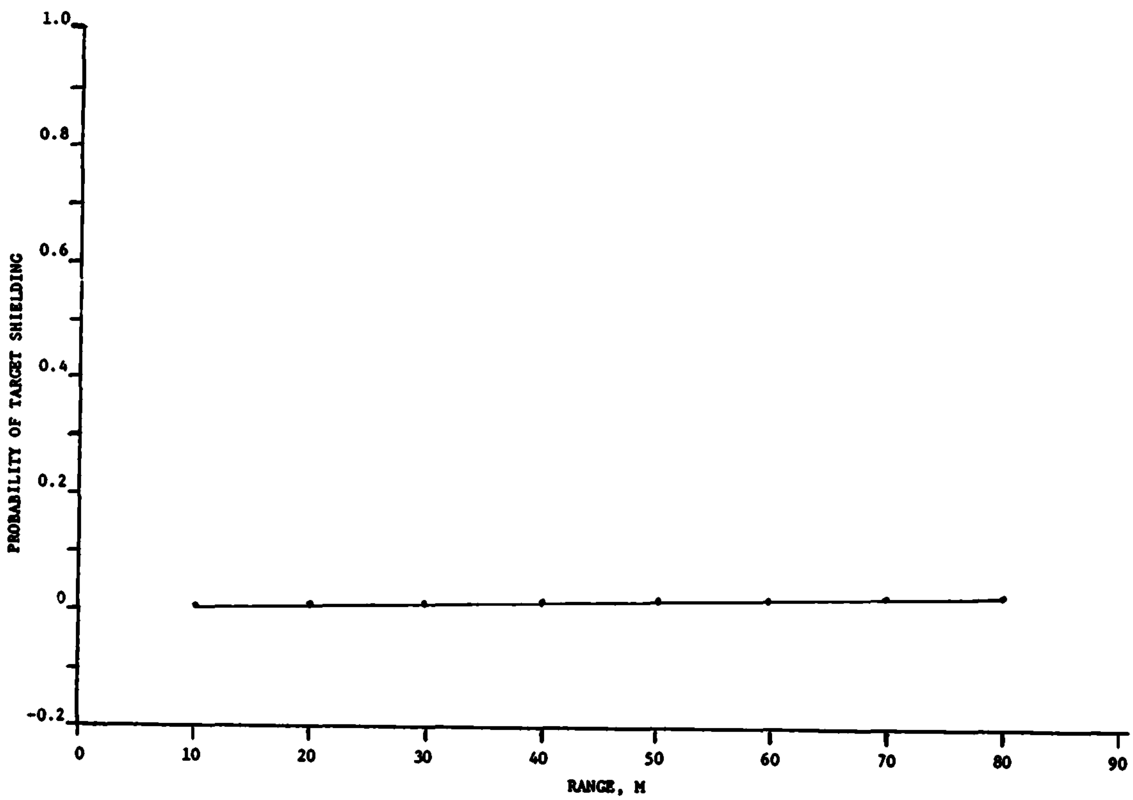


f. HOB = 100 cm

Fig. 32 (sheet 3 of 5)

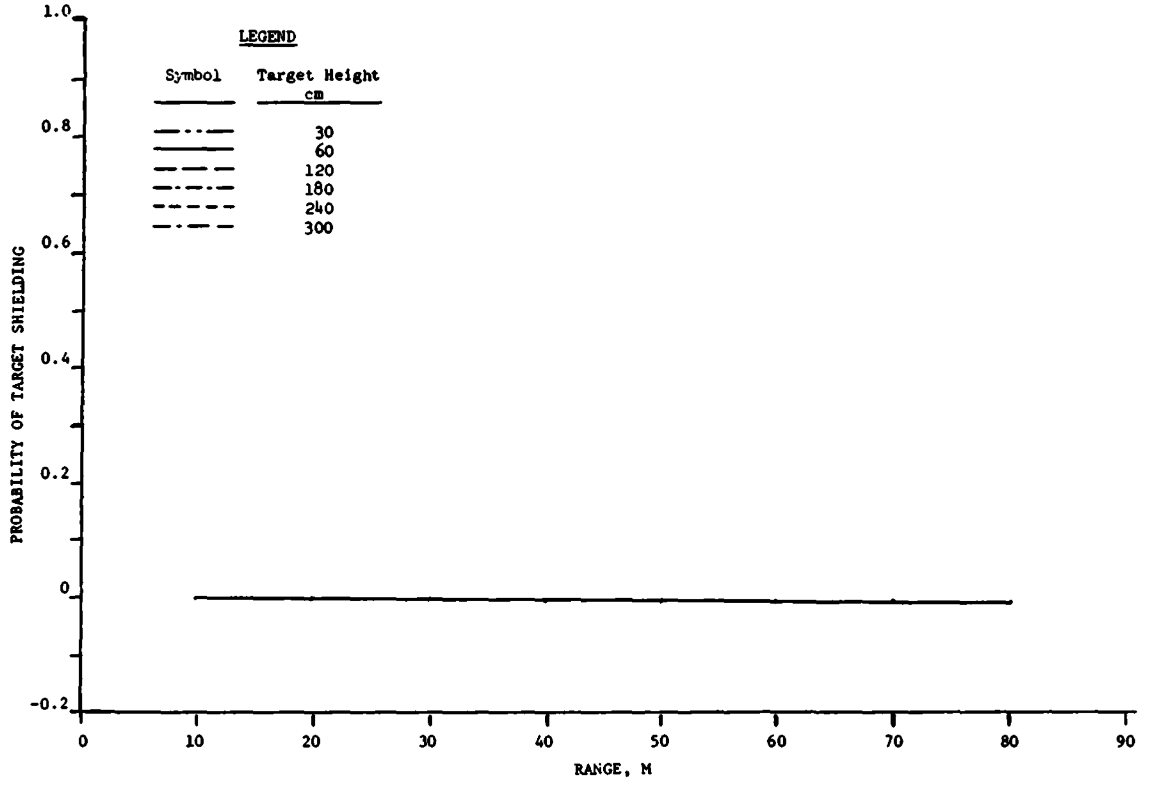


g. HOB = 200 cm

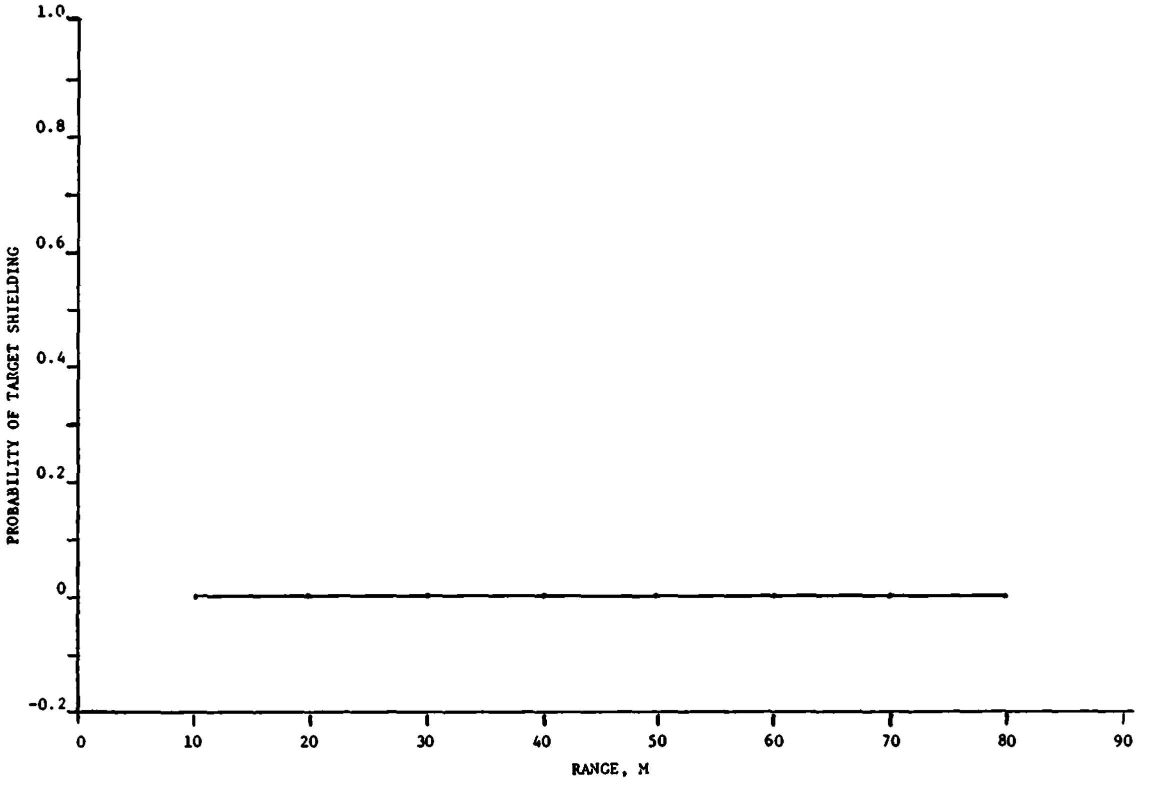


h. HOB = 300 cm

Fig. 32 (sheet 4 of 5)

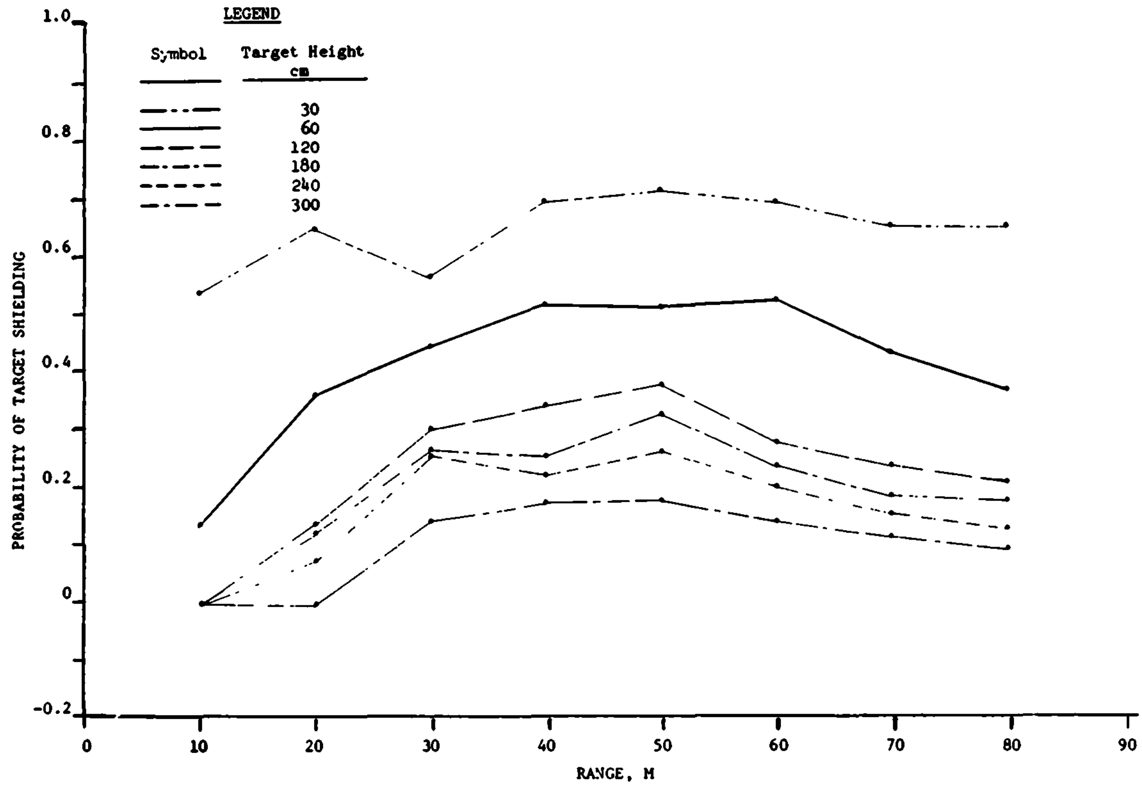


i. HOB = 400 cm

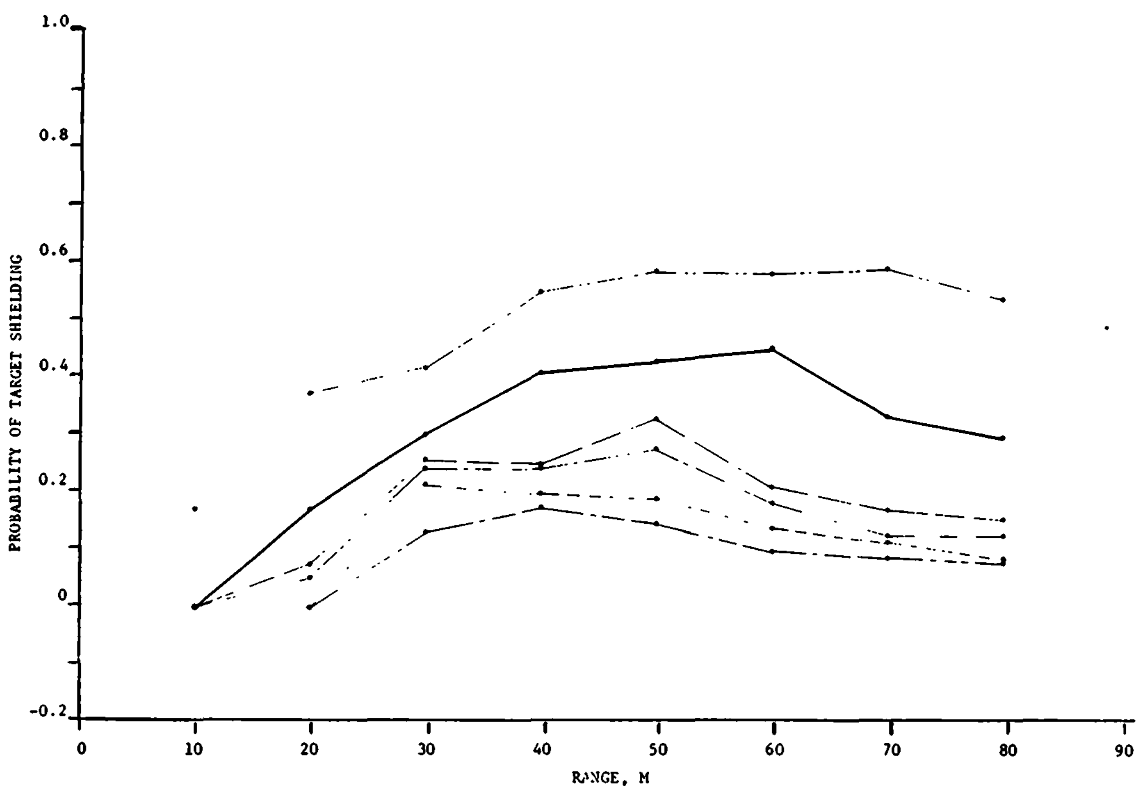


j. HOB = 500 cm

Fig. 32 (sheet 5 of 5)

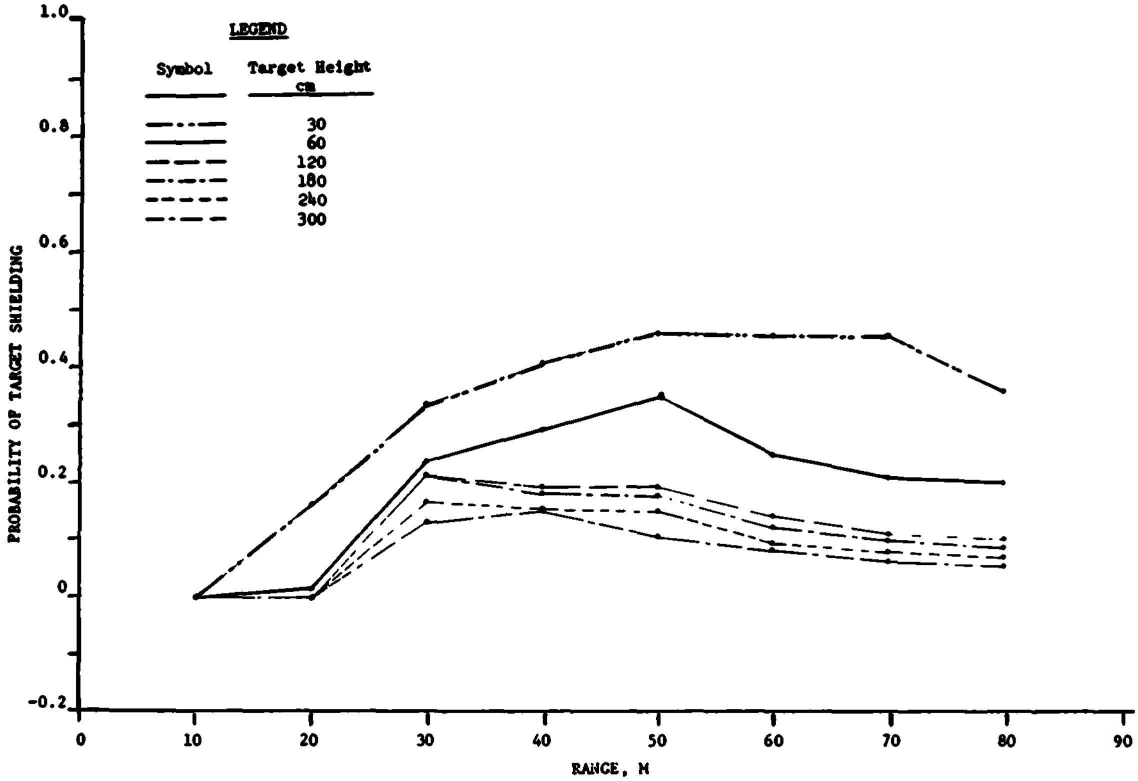


a. HOB = 0 cm

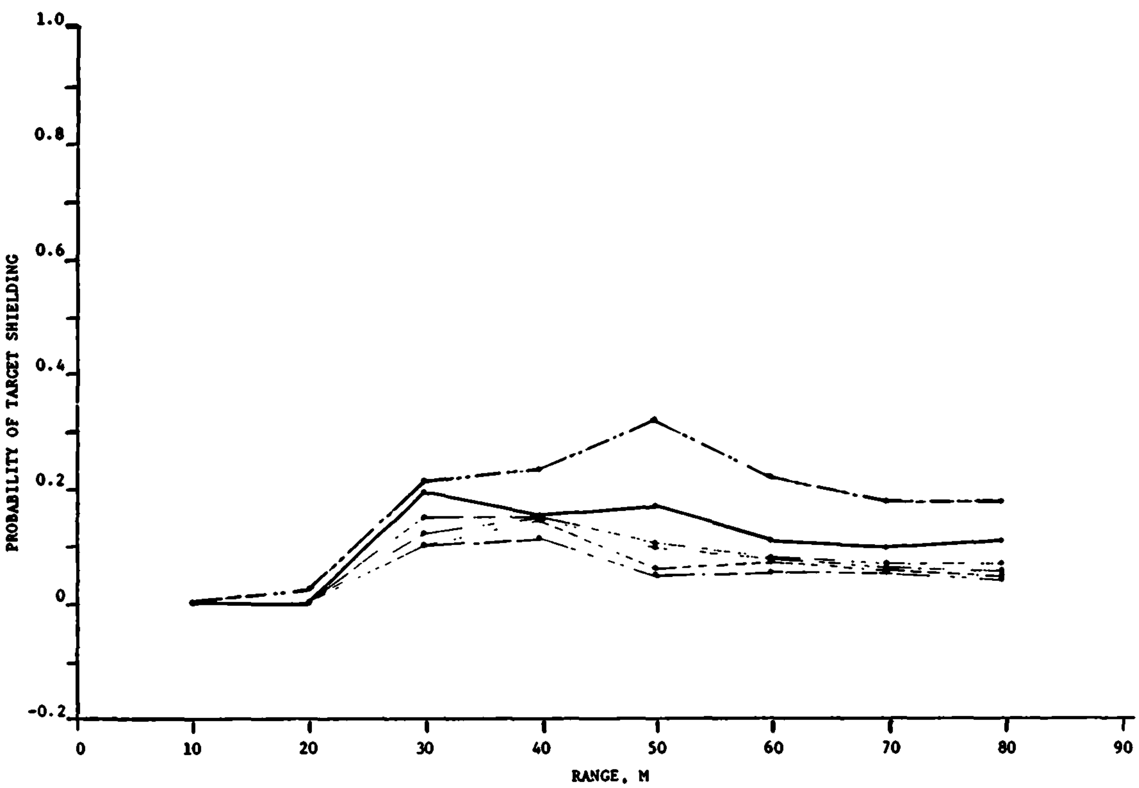


b. HOB = 10 cm

Fig. 33. Probability of shielding for different target heights, site 3 (sheet 1 of 5)

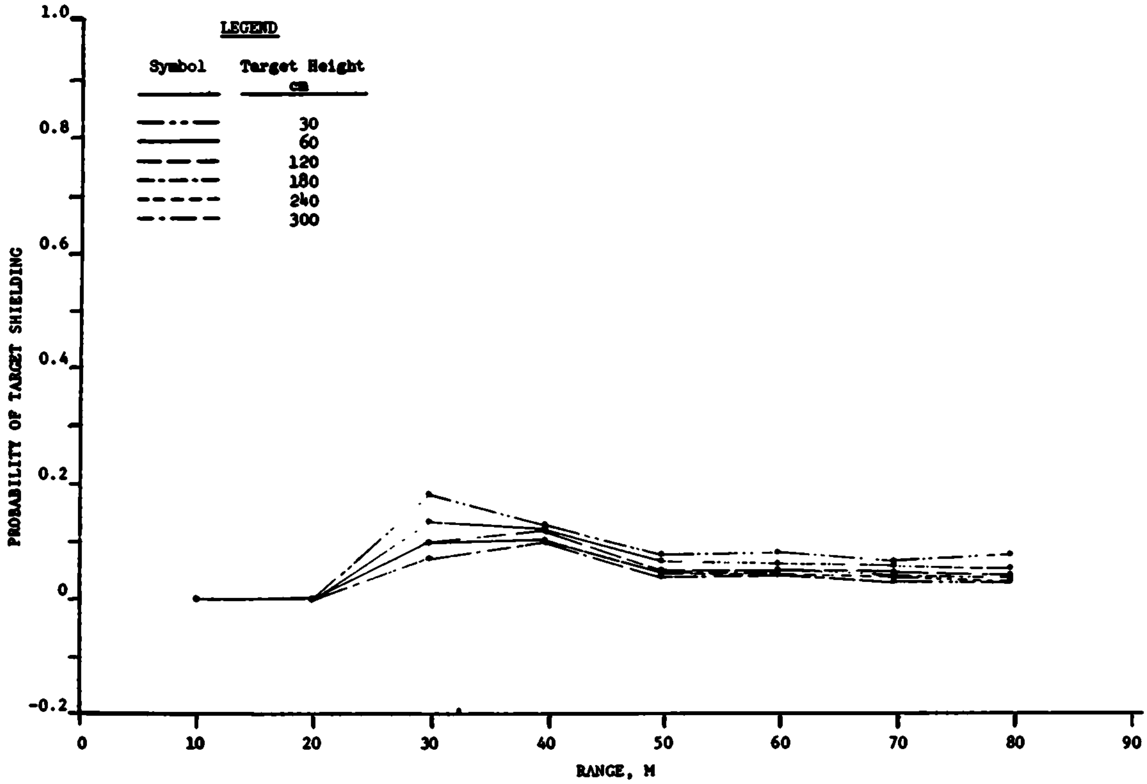


c. HOB = 25 cm

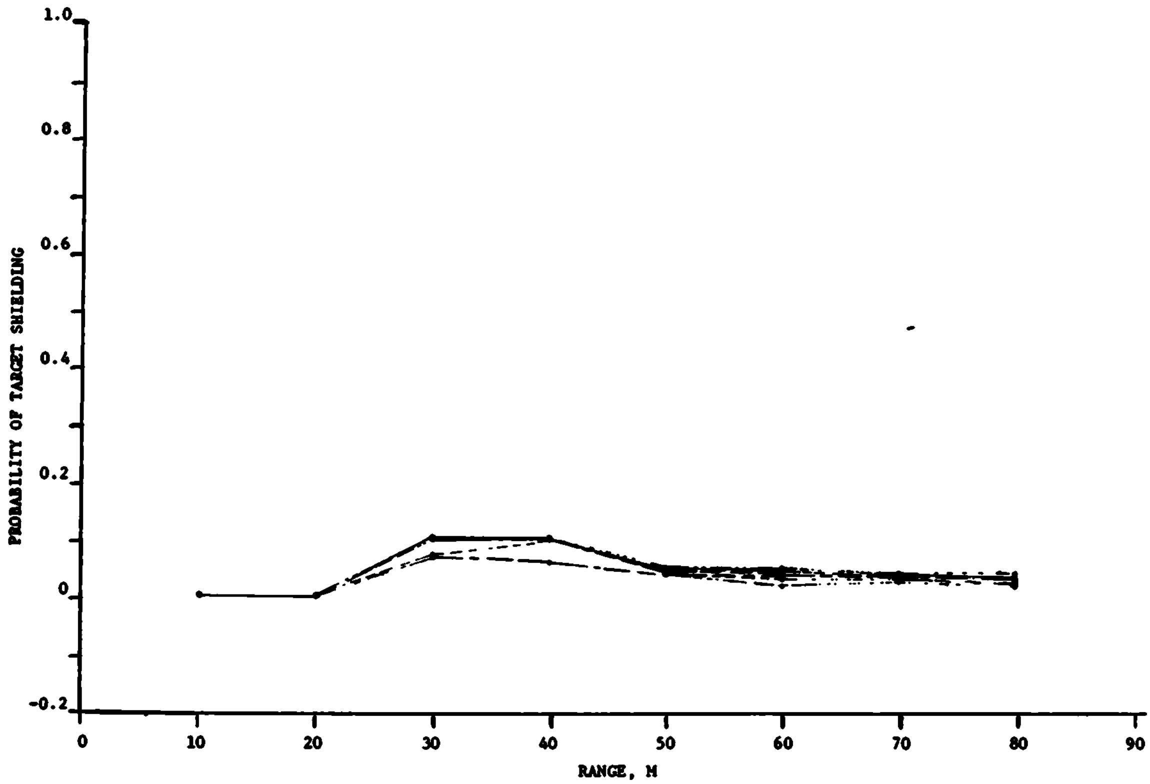


d. HOB = 50 cm

Fig. 33 (sheet 2 of 5)

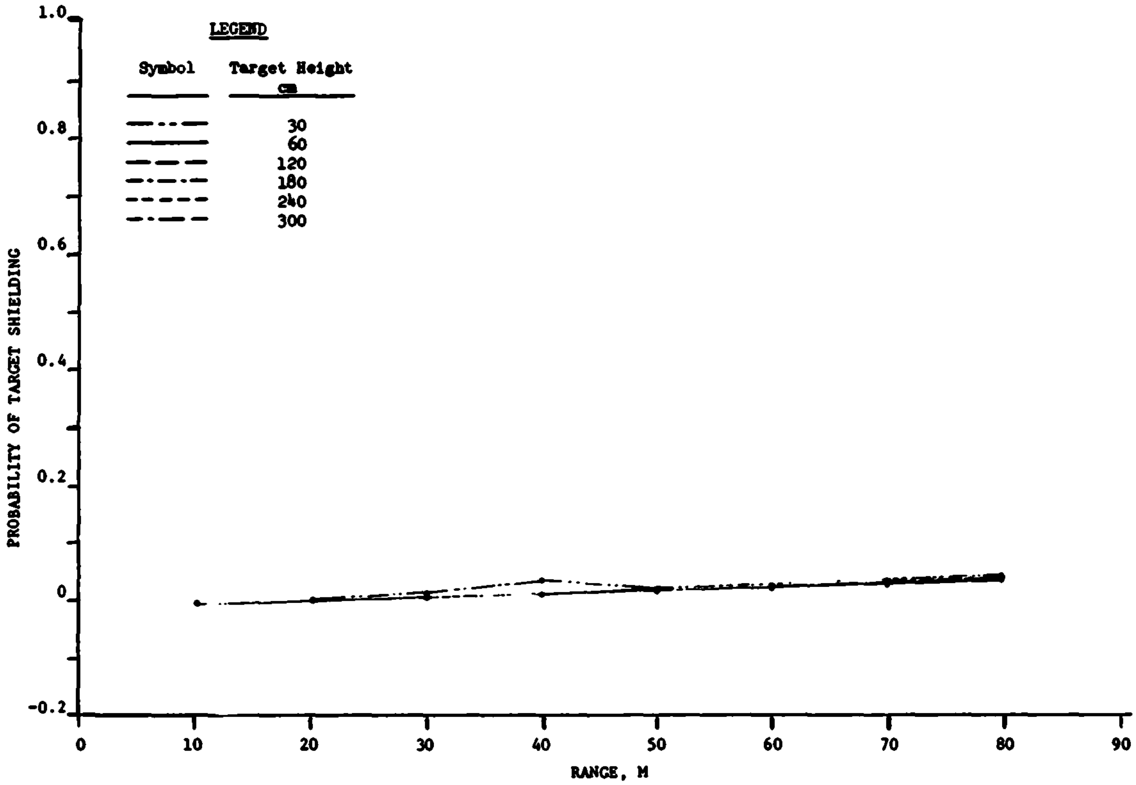


e. HOB = 75 m

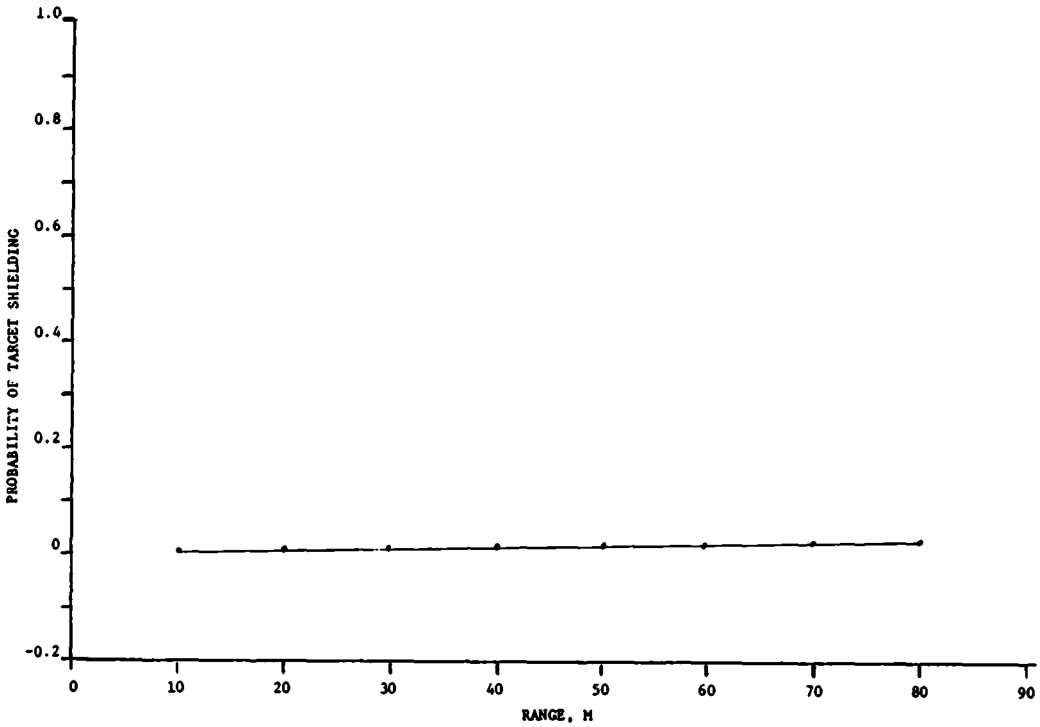


f. HOB = 100 cm

Fig. 33 (sheet 3 of 5)

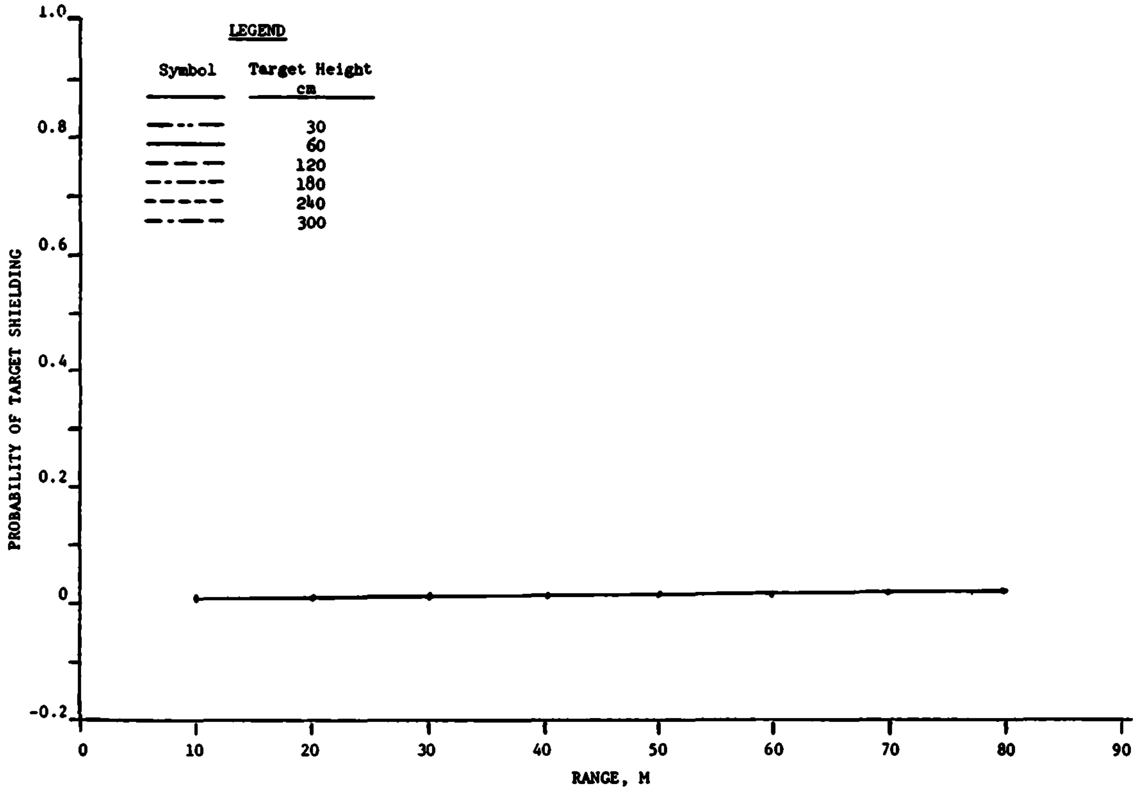


g. HOB = 200 cm

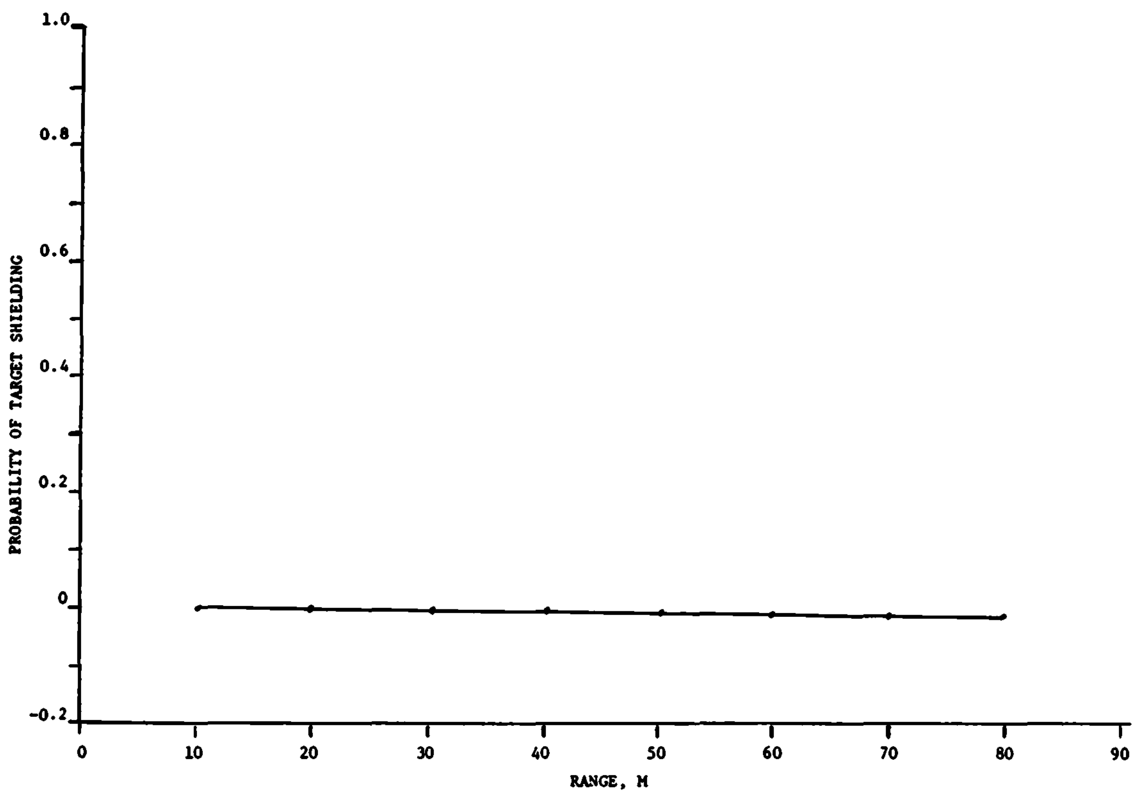


h. HOB = 300 cm

Fig. 33 (sheet 4 of 5)

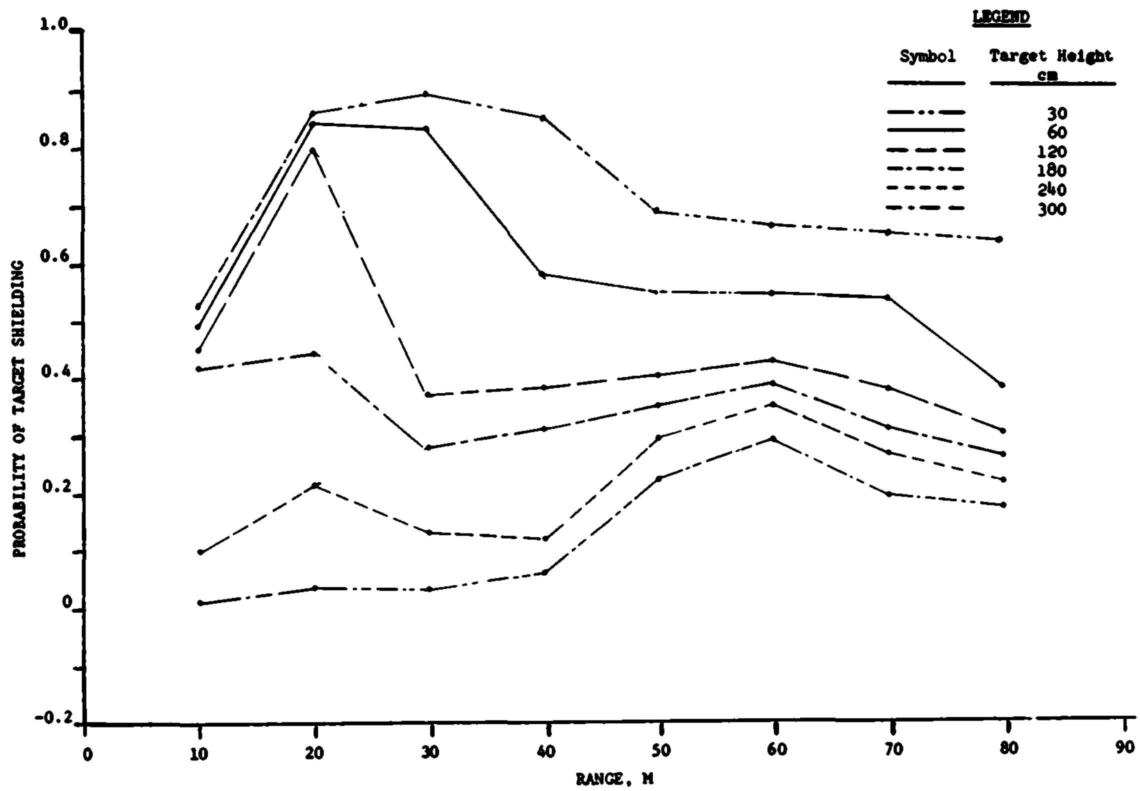


i. HOB = 400 cm

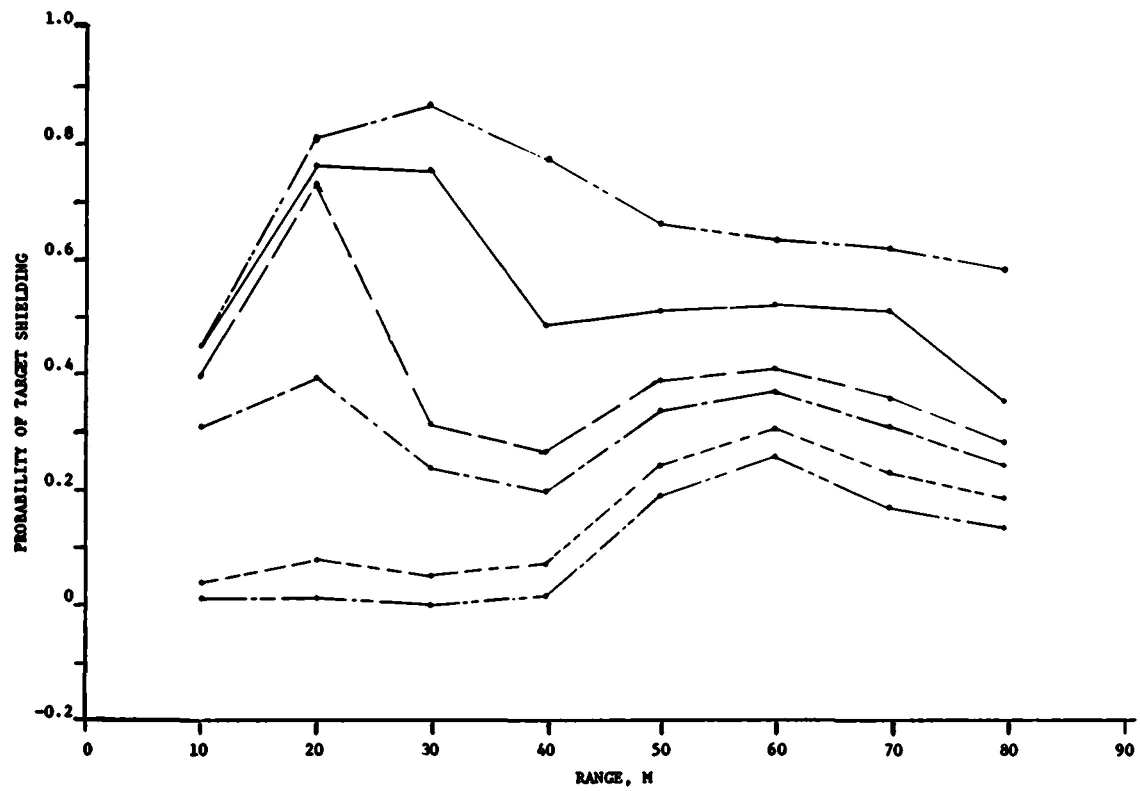


j. HOB = 500 cm

Fig. 33 (sheet 5 of 5)

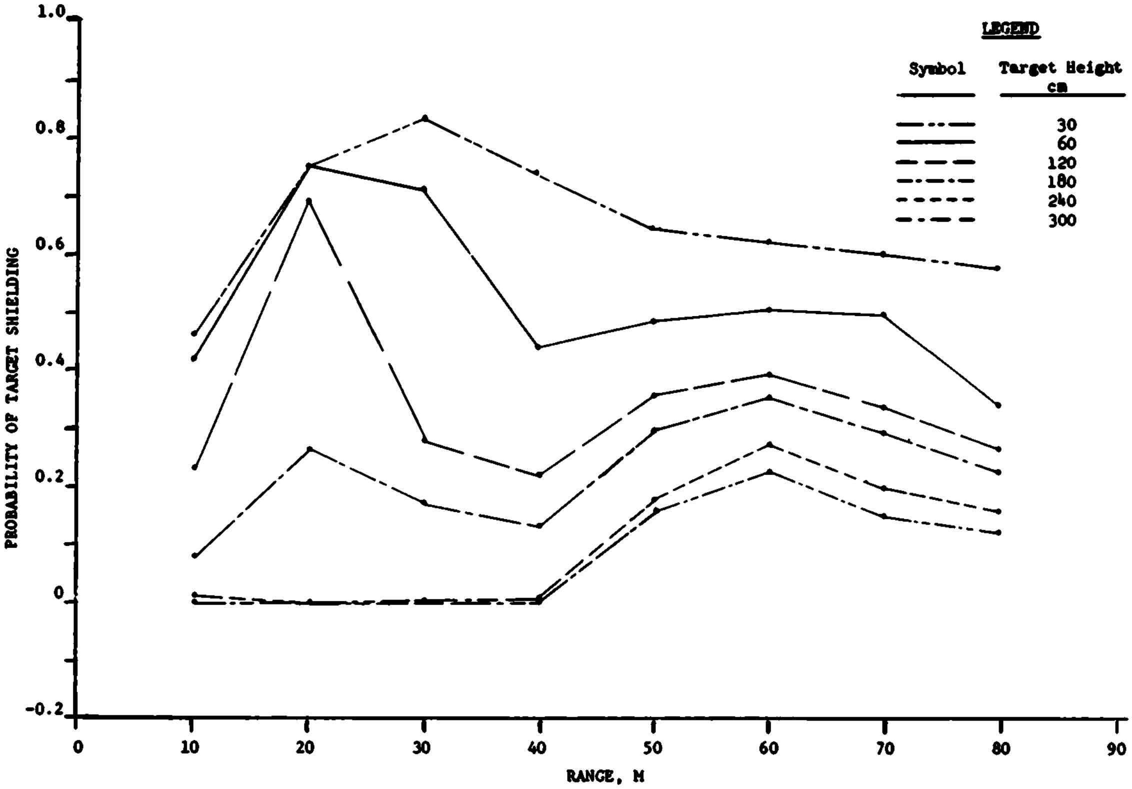


a. HOB = 0 cm

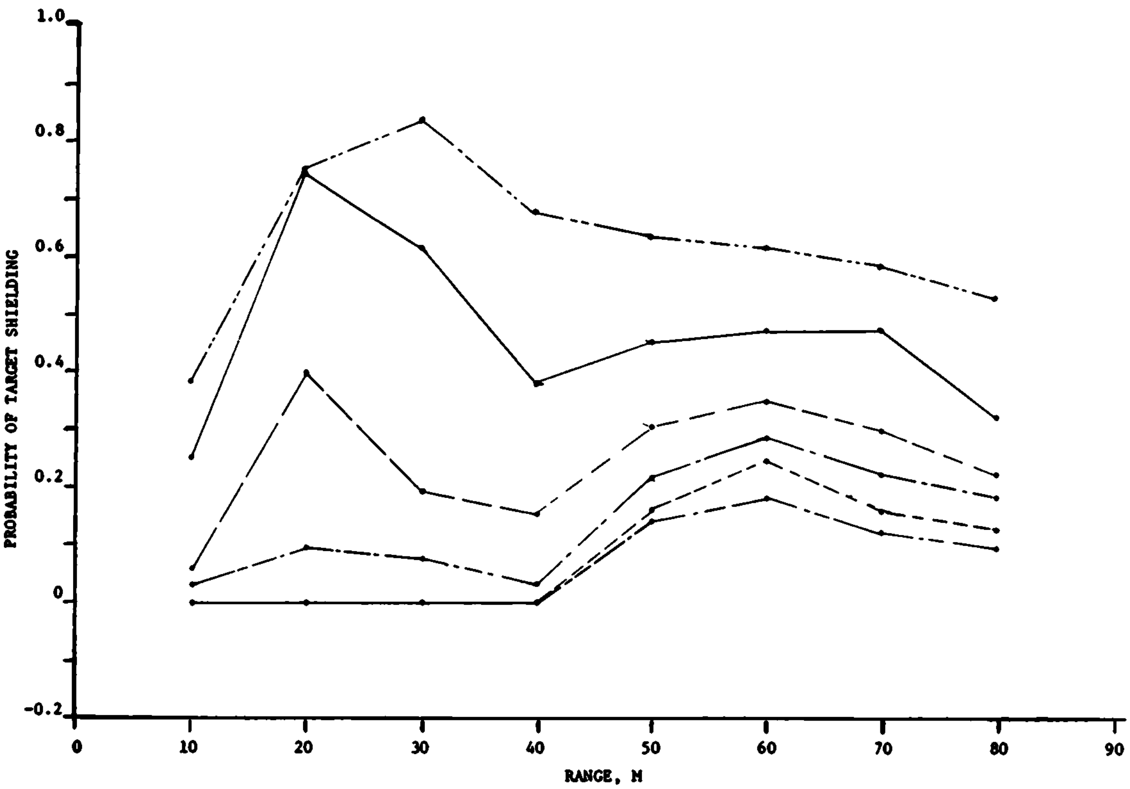


b. HOB = 10 cm

Fig. 34. Probability of shielding for different target heights, site 4 (sheet 1 of 5)

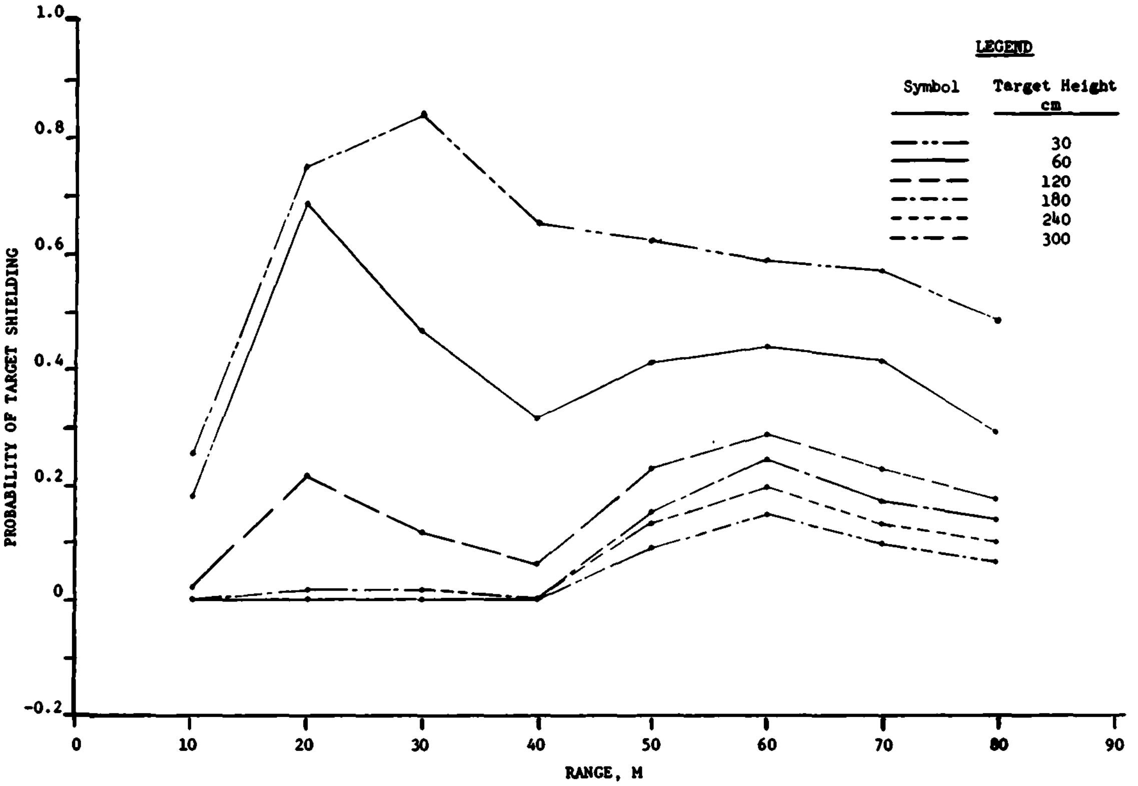


c. HOB = 25 cm

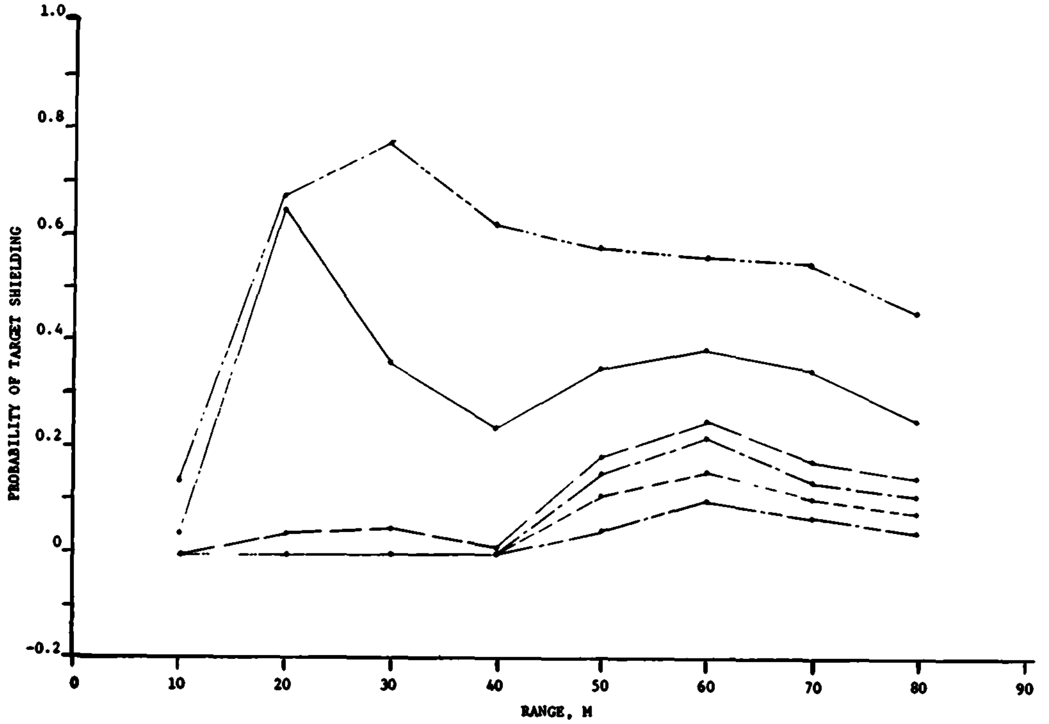


d. HOB = 50 cm

Fig. 34 (sheet 2 of 5)

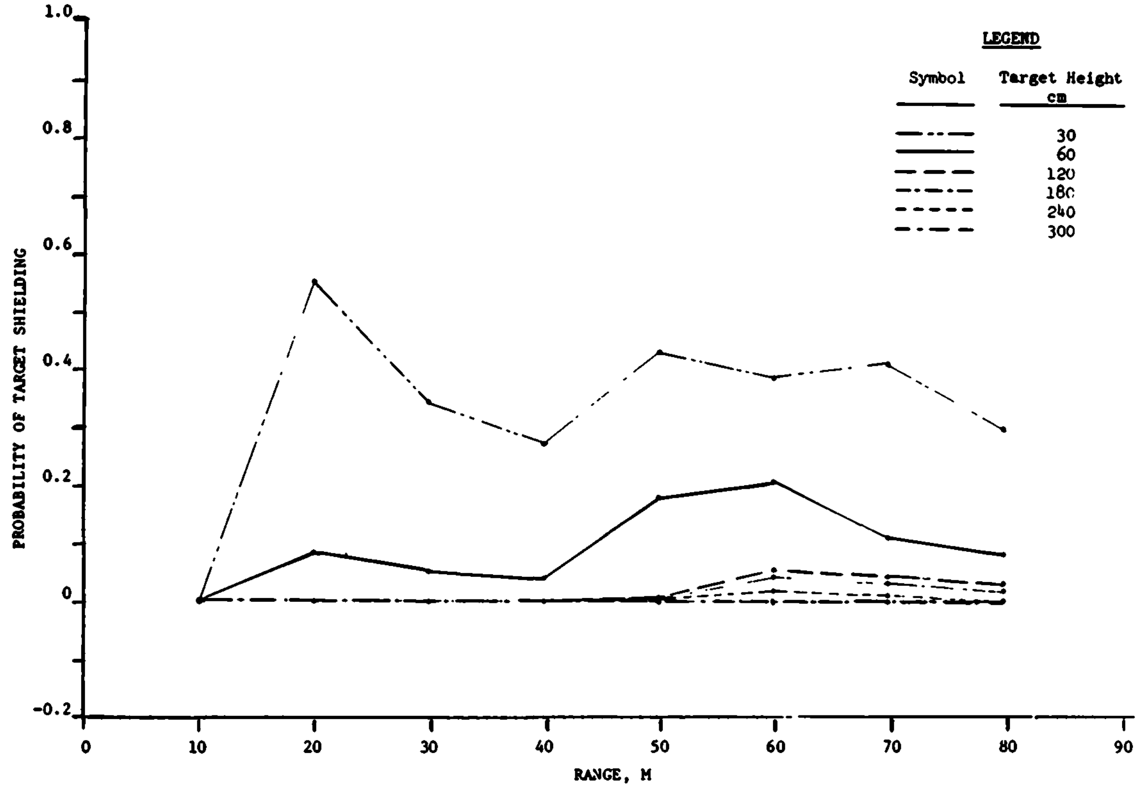


e. HOB = 75 cm

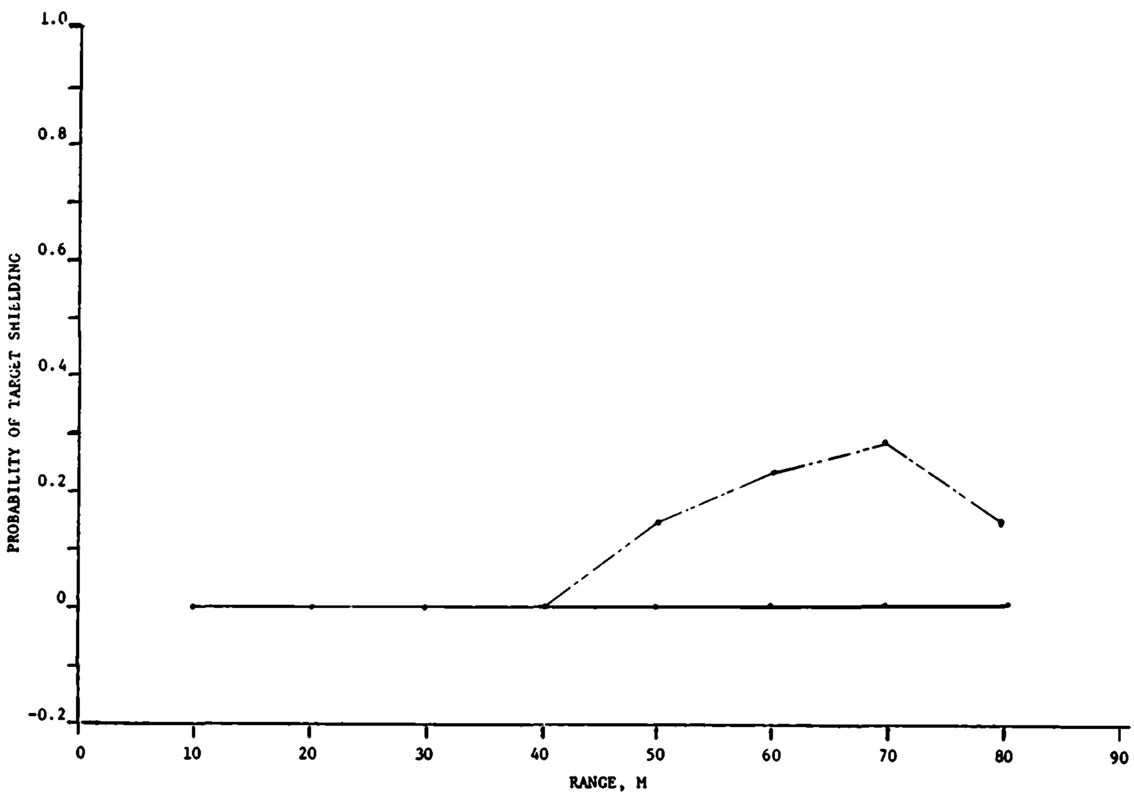


f. HOB = 100 cm

Fig. 34 (sheet 3 of 5)

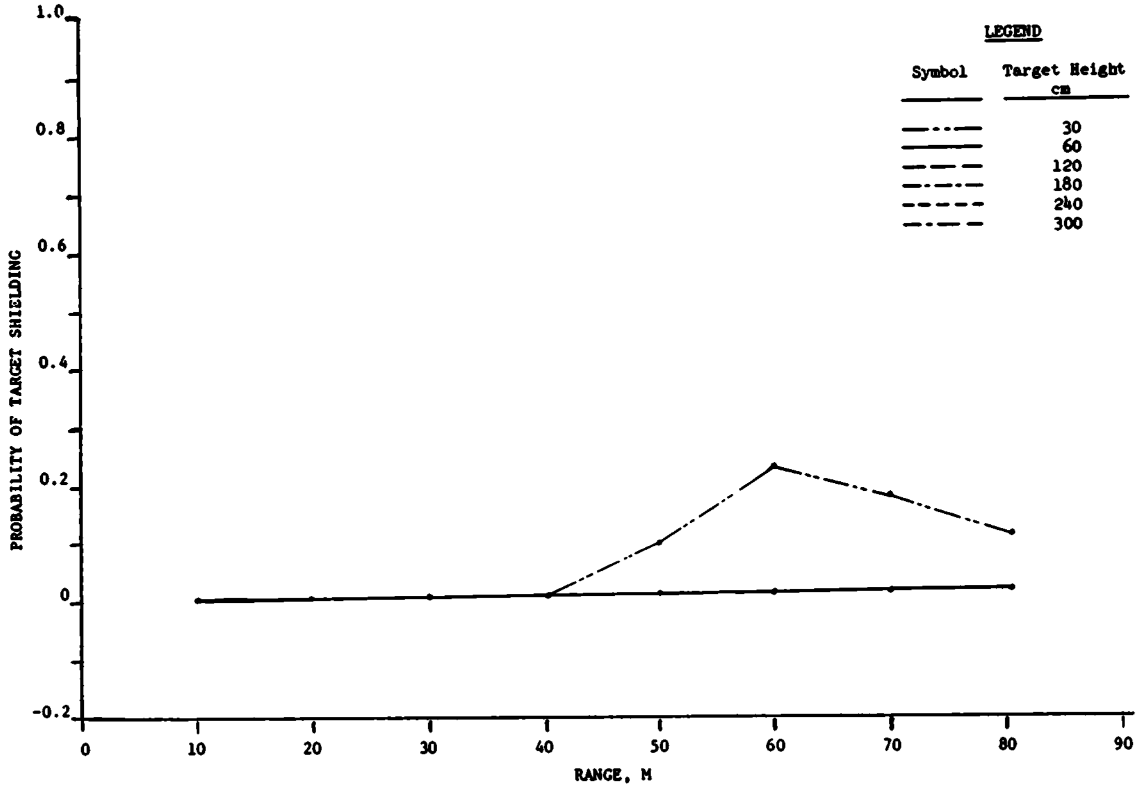


g. HOB = 200 cm

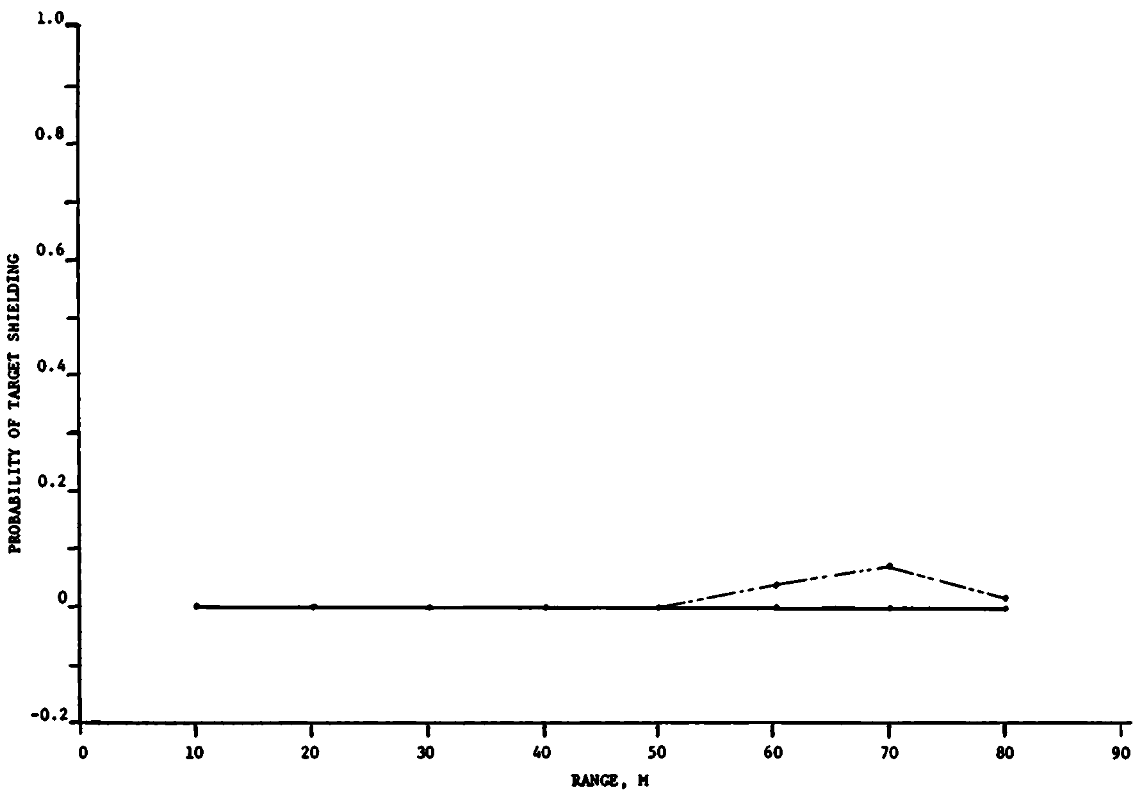


h. HOB = 300 cm

Fig. 34 (sheet 4 of 5)

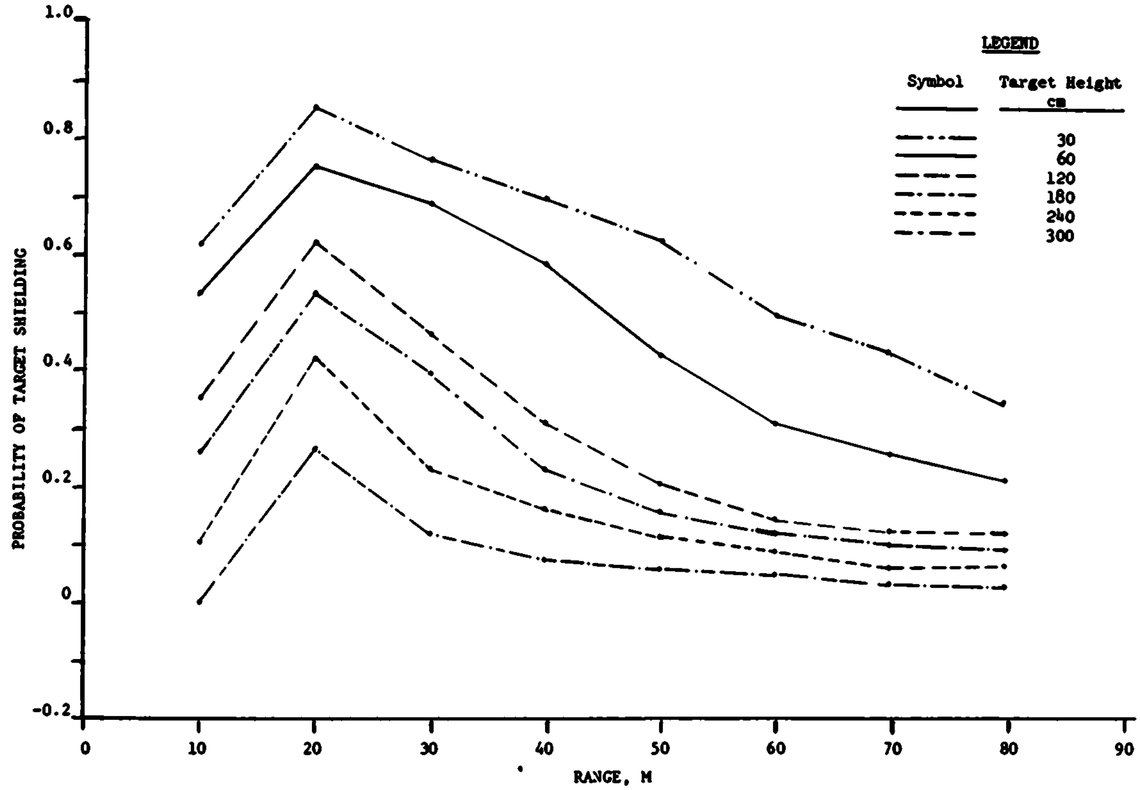


i. HOB = 400 cm

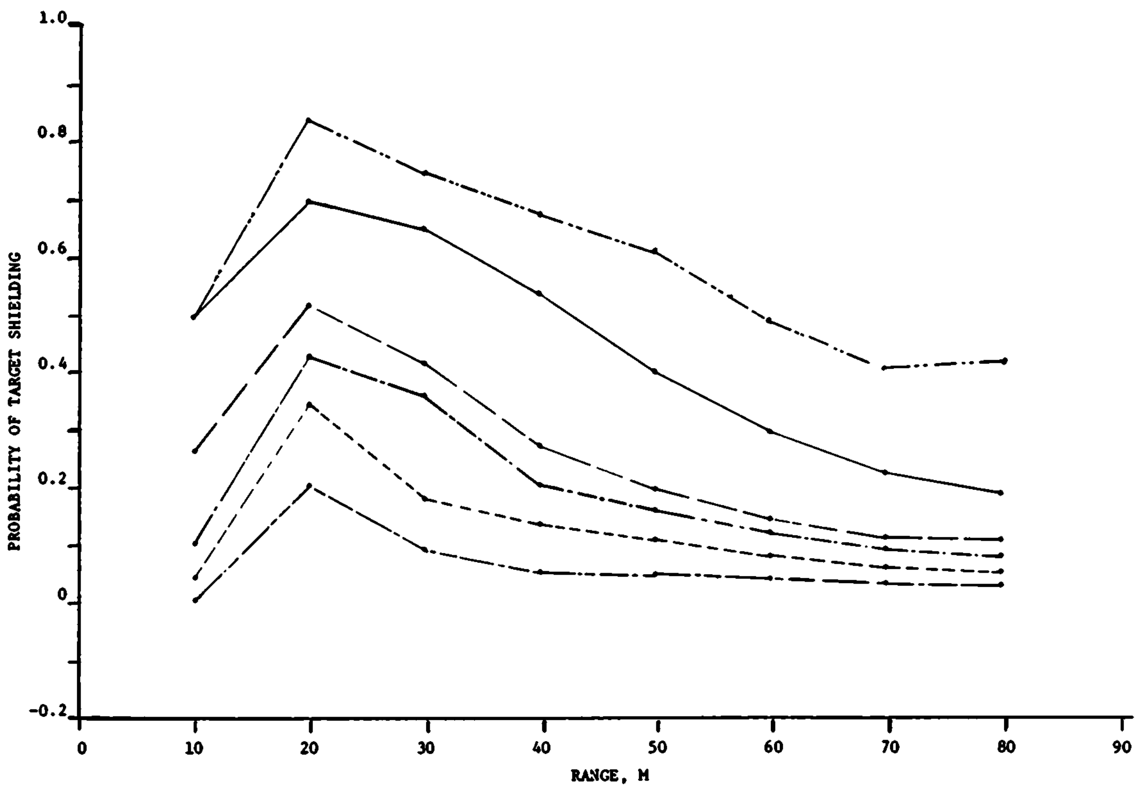


j. HOB = 500 cm

Fig. 34 (sheet 5 of 5)

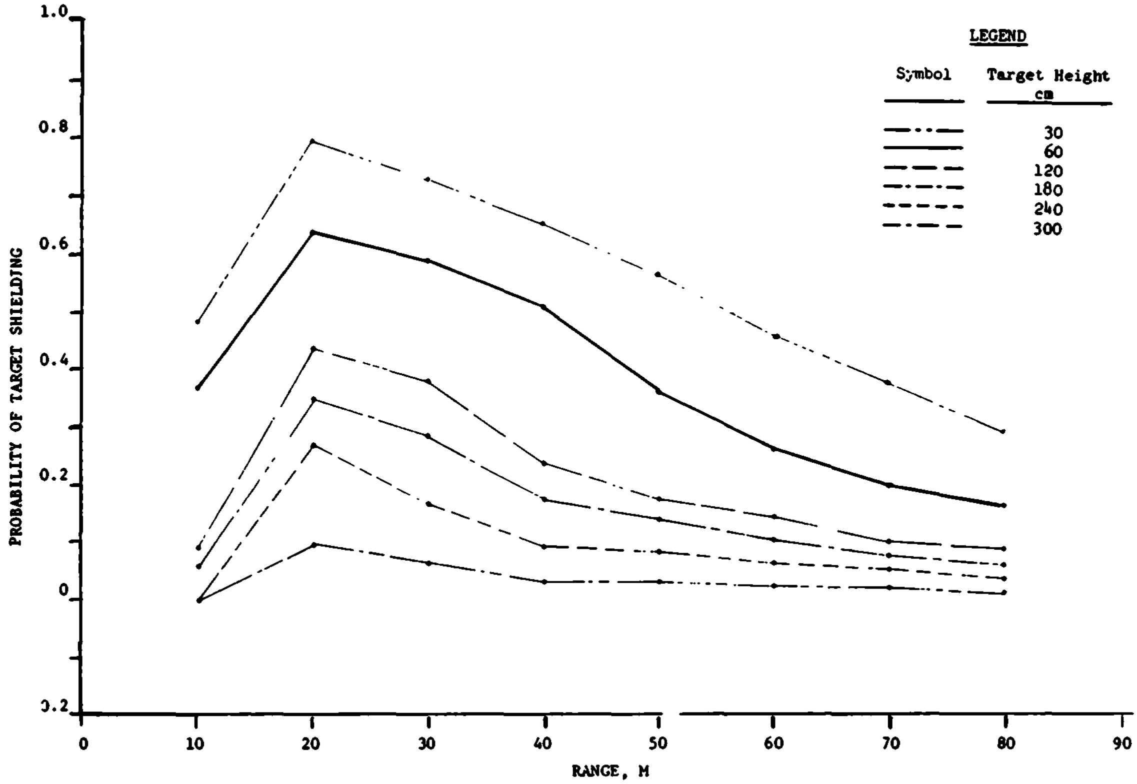


a. HOB = 0 cm

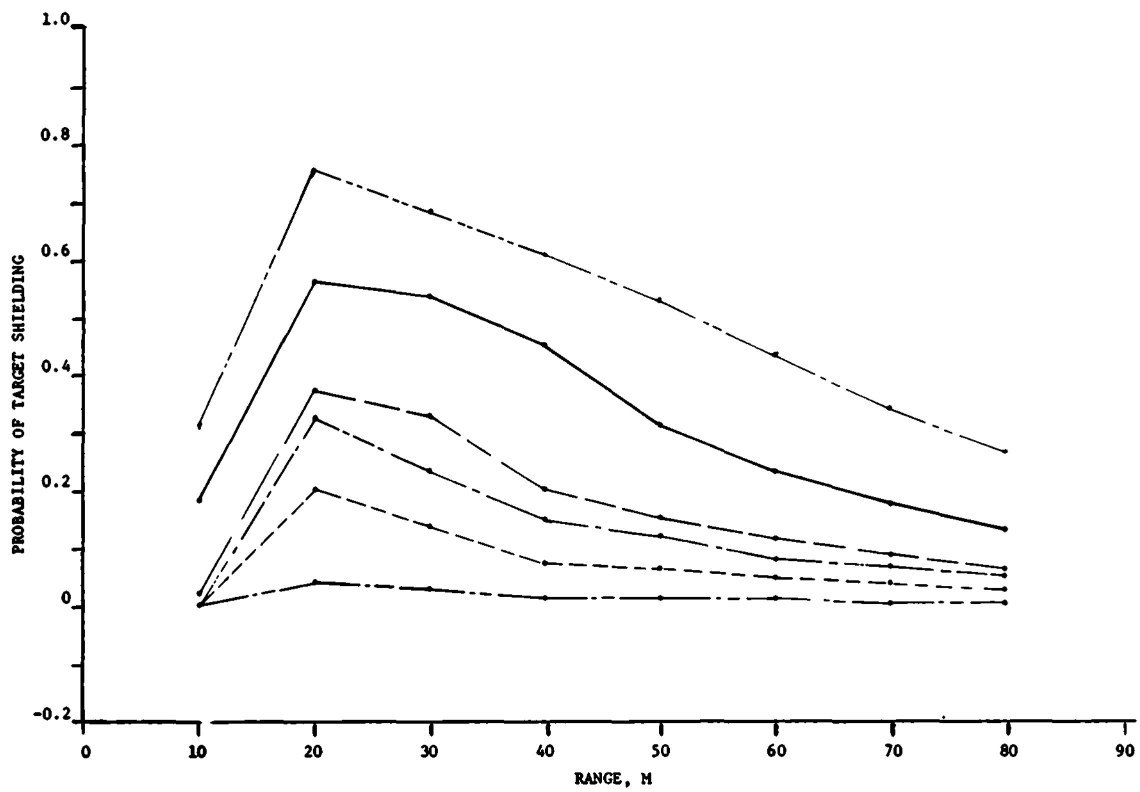


b. HOB = 10 cm

Fig. 35. Probability of shielding for different target heights, site 5 (sheet 1 of 5)

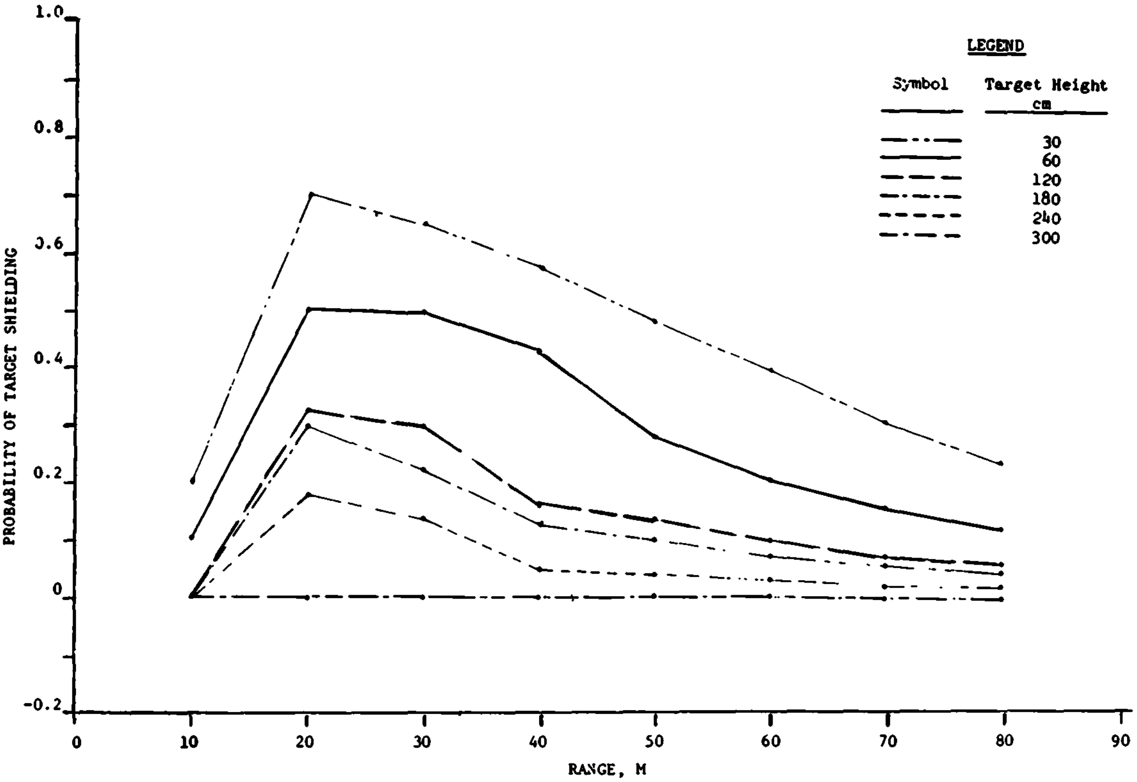


c. HOB = 25 cm

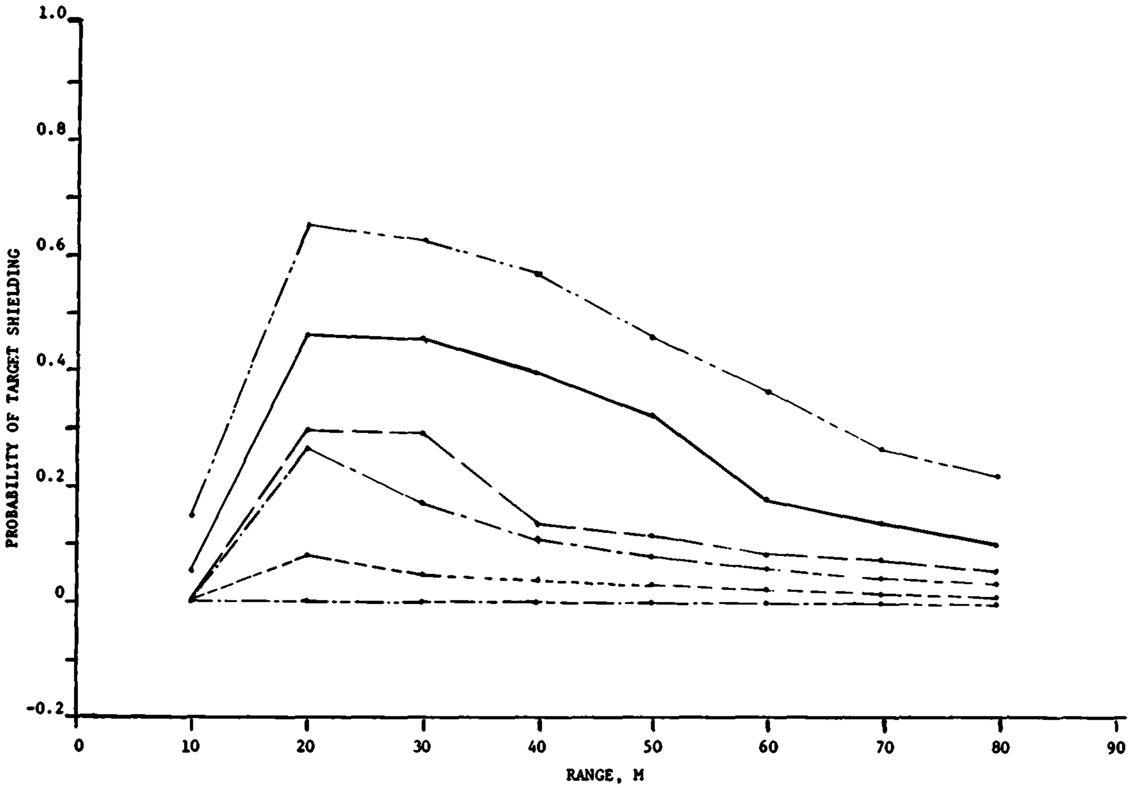


d. HOB = 50 cm

Fig. 35 (sheet 2 of 5)

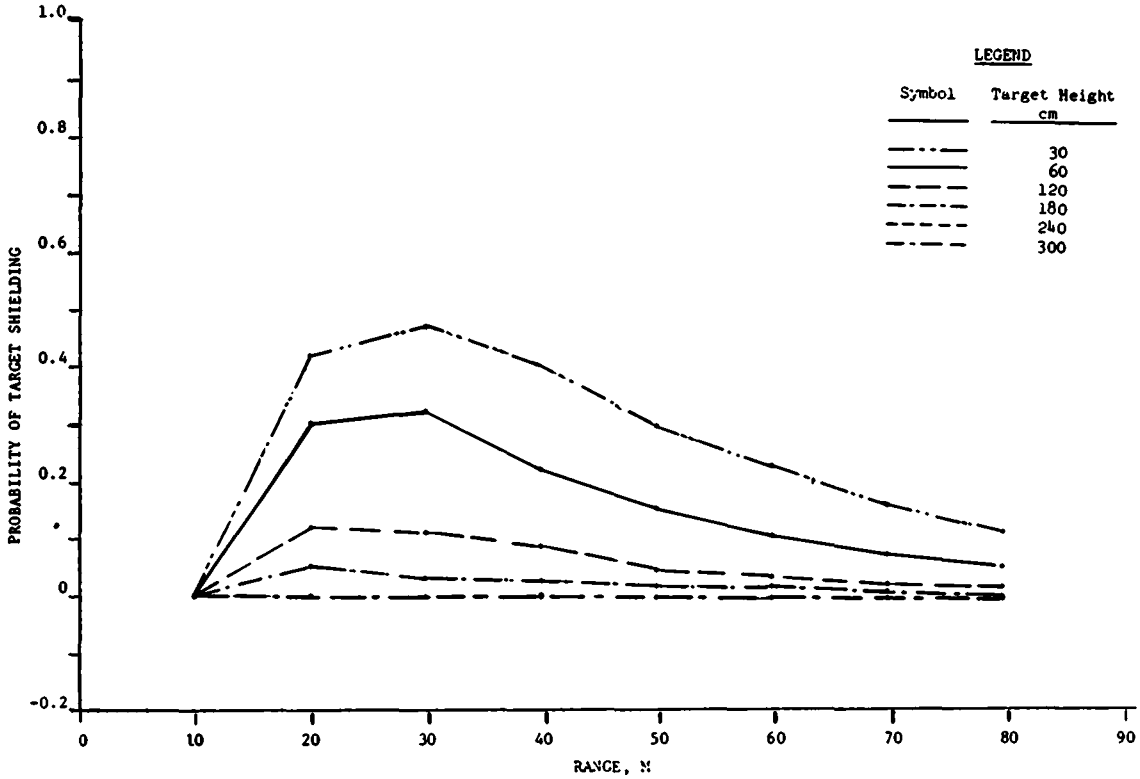


e. HOB = 75 cm

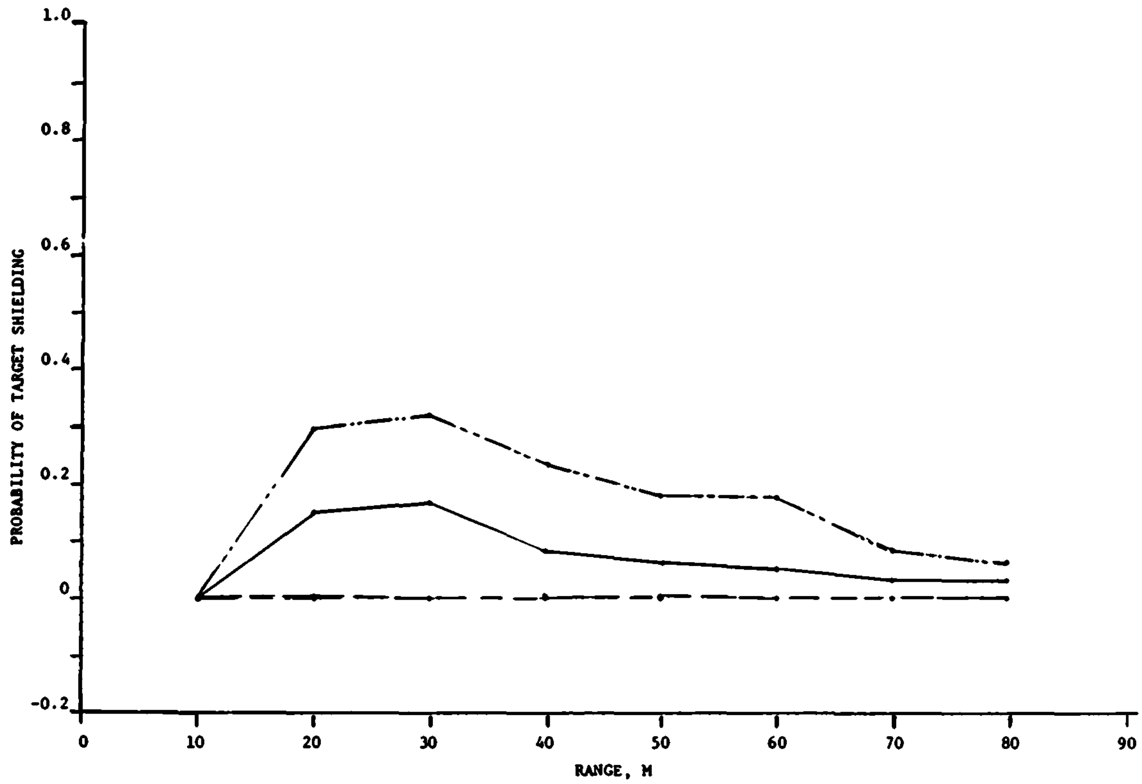


f. HOB = 100 cm

Fig. 35 (sheet 3 of 5)

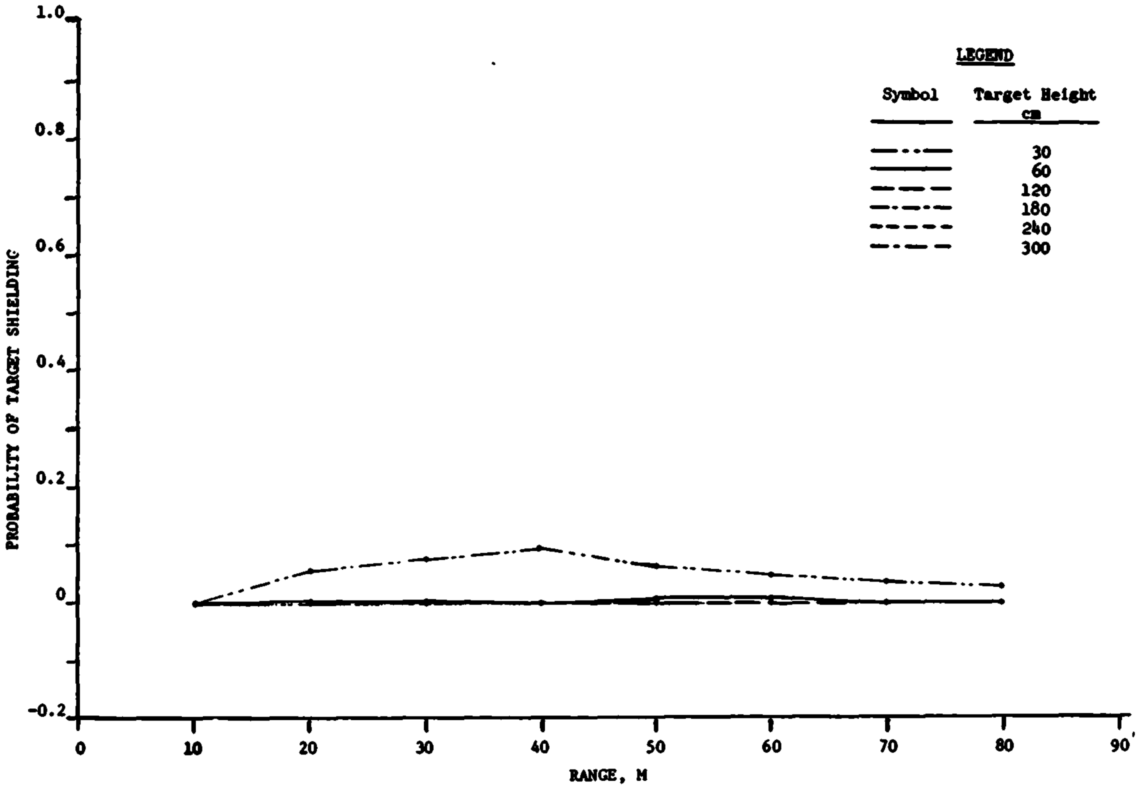


g. HOB = 200 cm

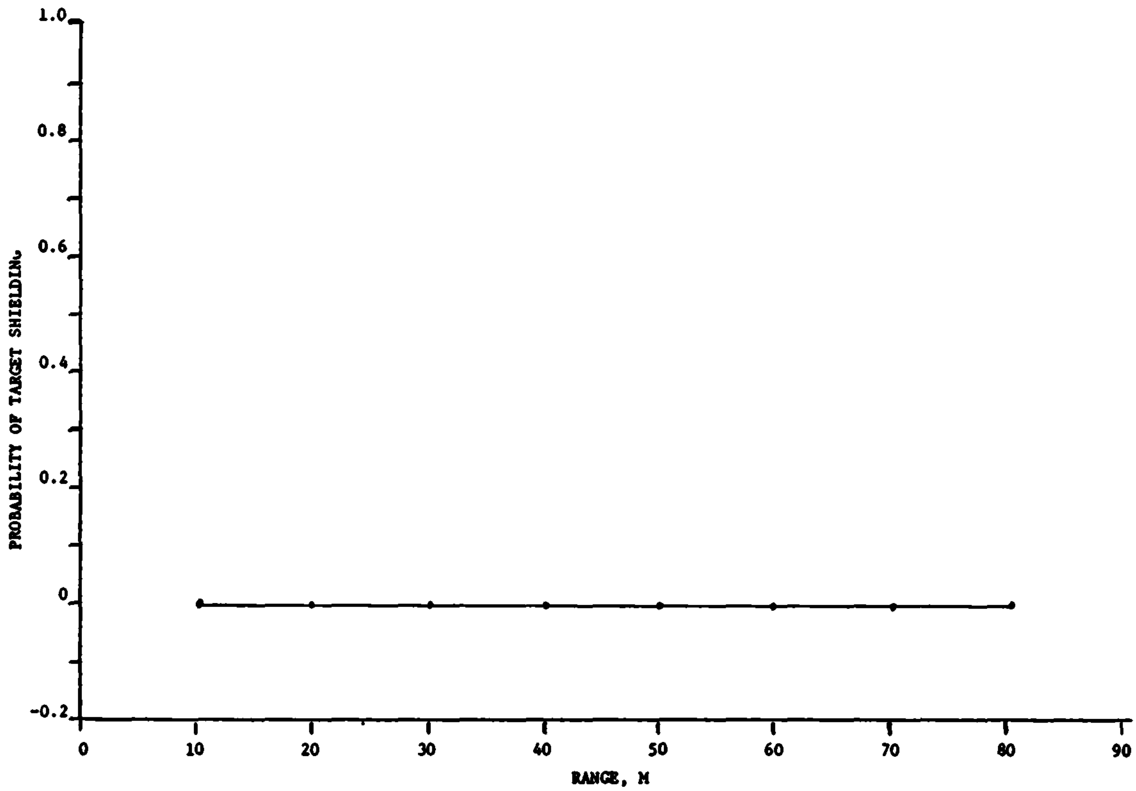


h. HOB = 300 cm

Fig. 35 (sheet 4 of 5)

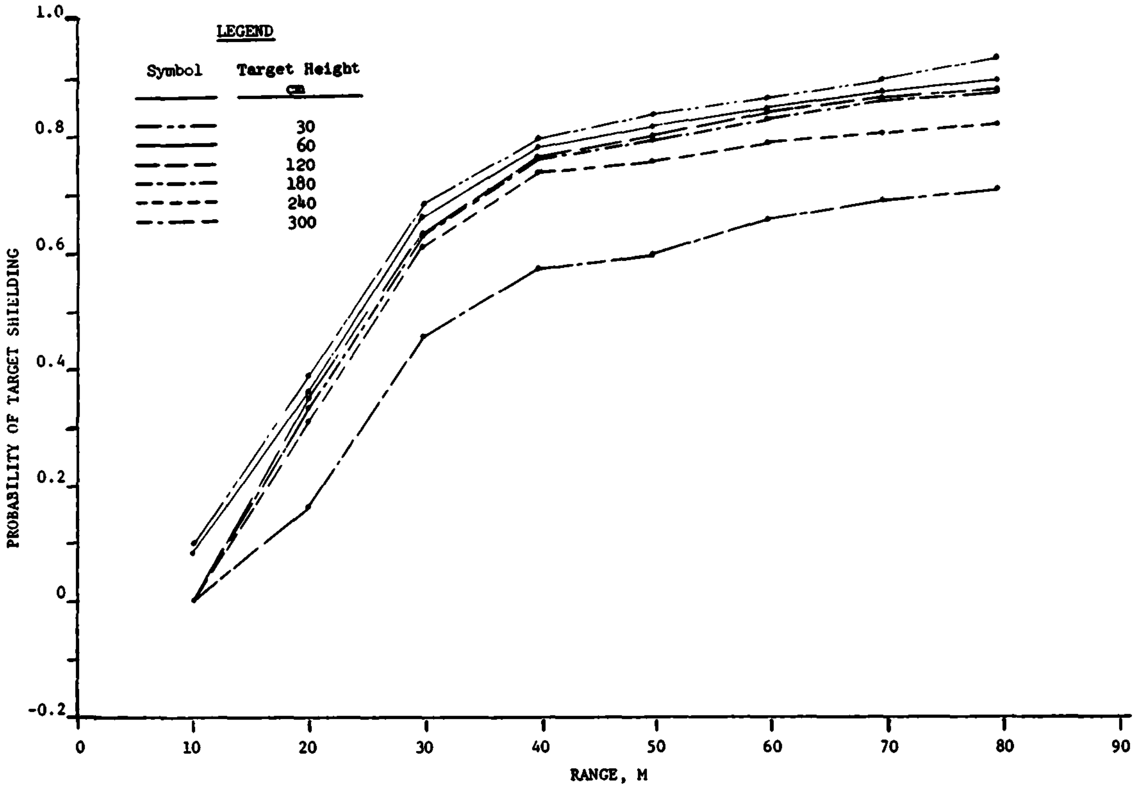


i. HOB = 400 cm

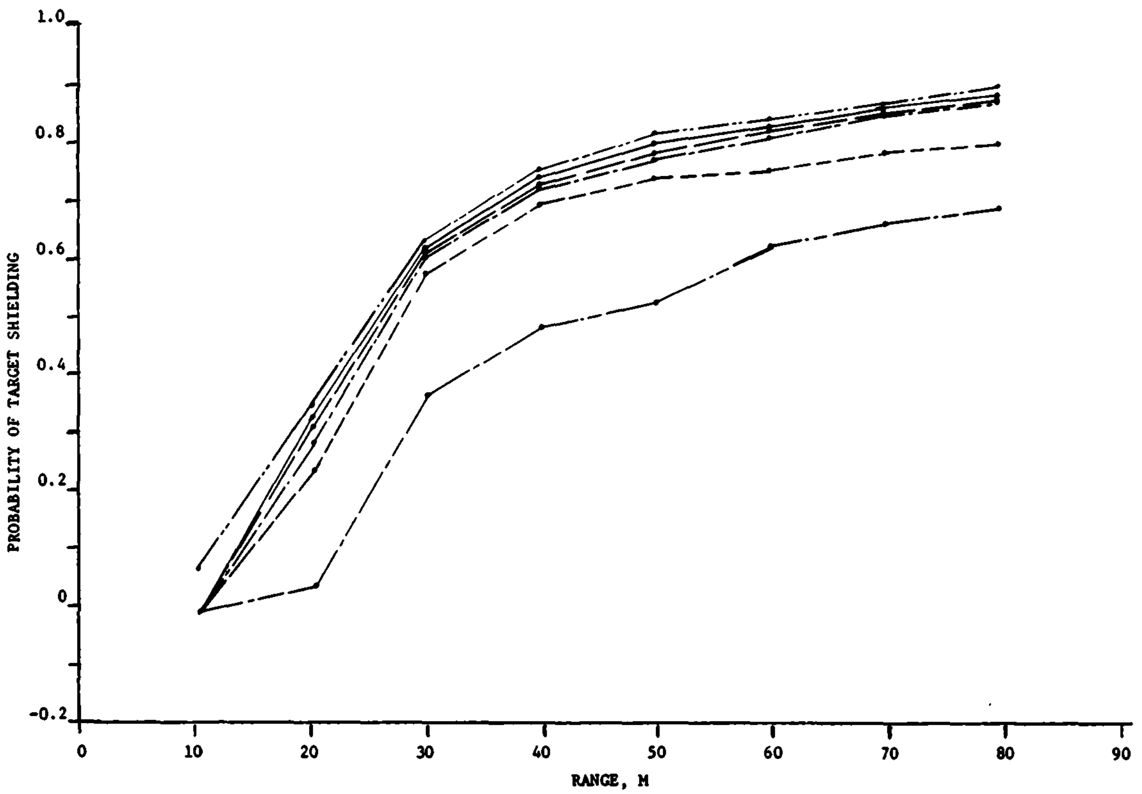


j. HOB = 500 cm

Fig. 35 (sheet 5 of 5)

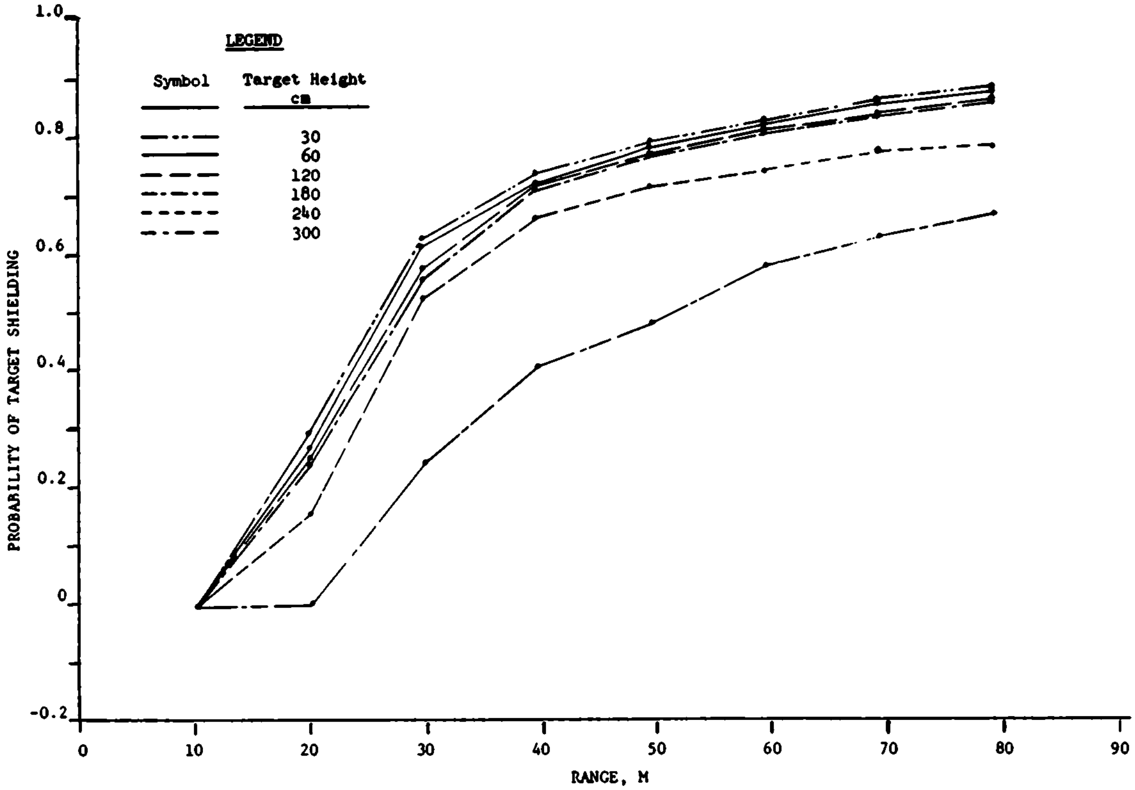


a. HOB = 0 cm

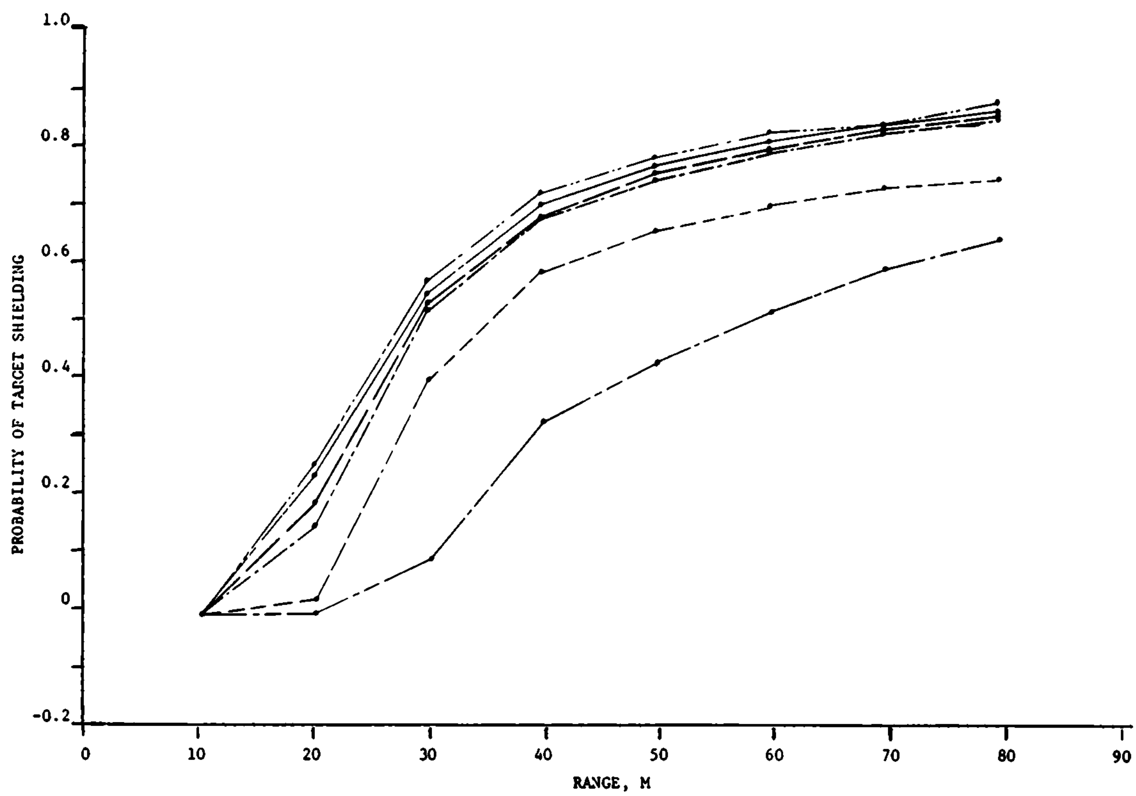


b. HOB = 10 cm

Fig. 36. Probability of shielding for different target heights, site 6 (sheet 1 of 5)

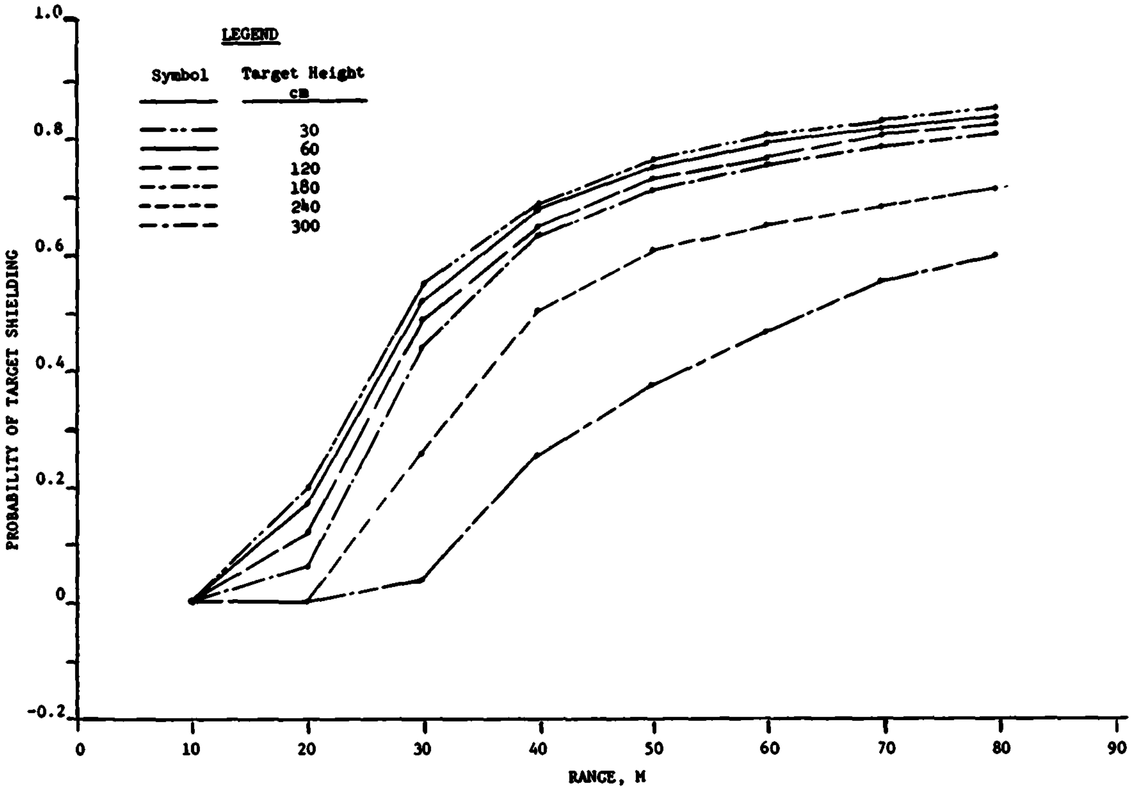


c. HOB = 25 cm

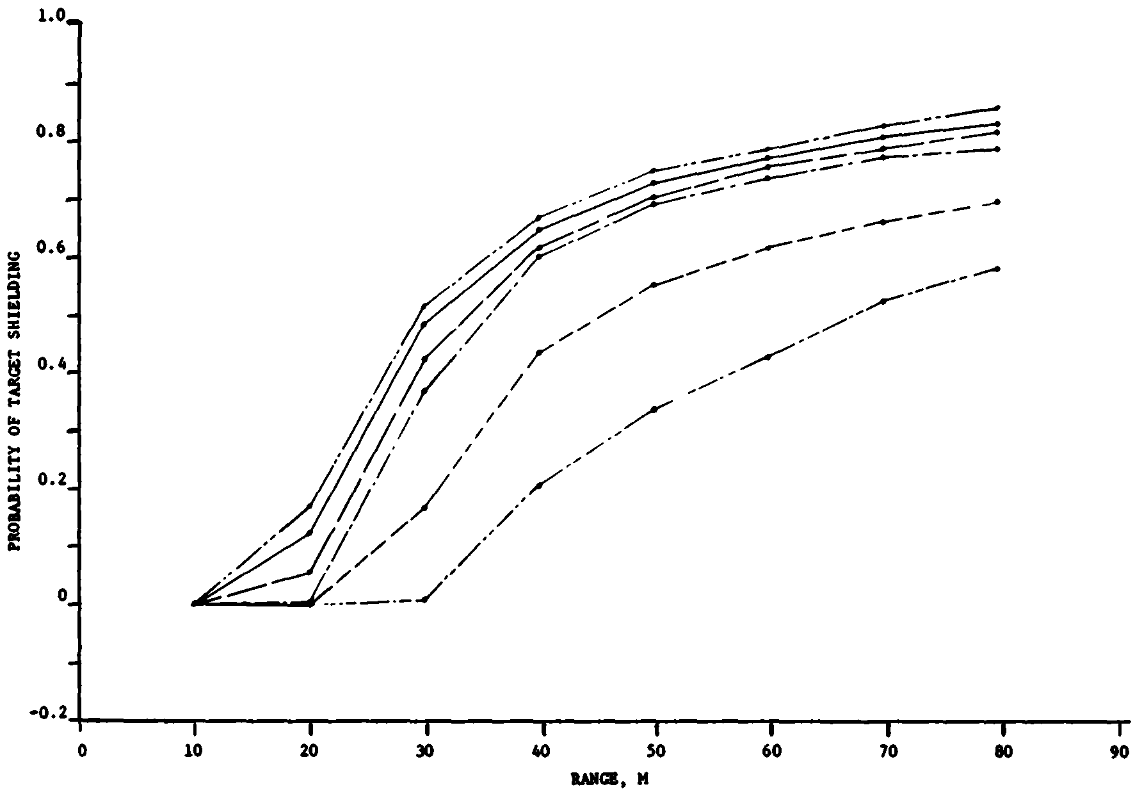


d. HOB = 50 cm

Fig. 36 (sheet 2 of 5)

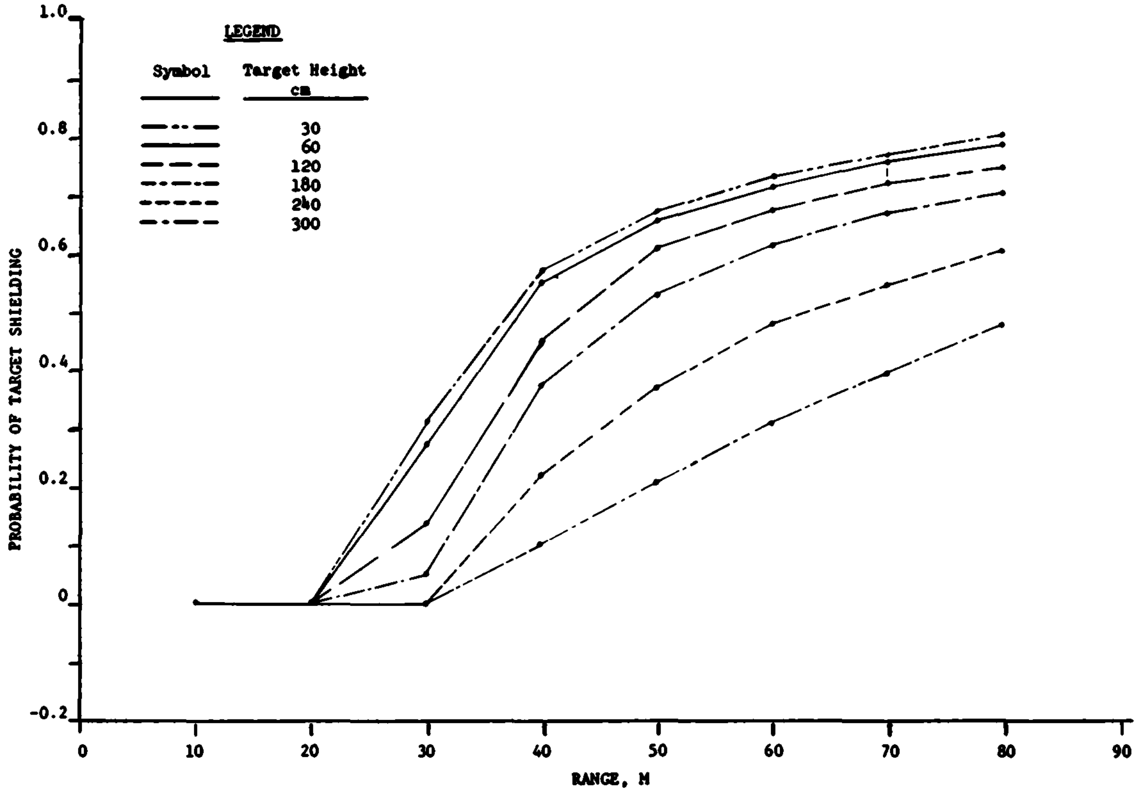


e. HOB = 75 cm

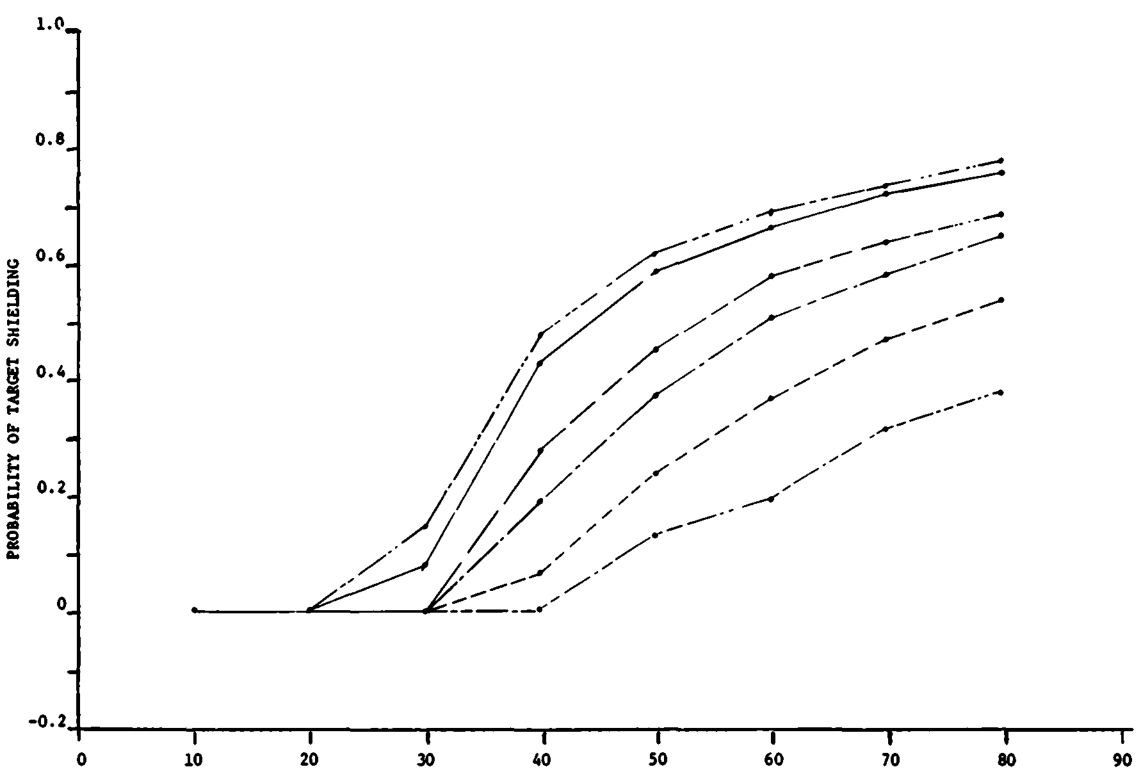


f. HOB = 100 cm

Fig. 36 (sheet 3 of 5)

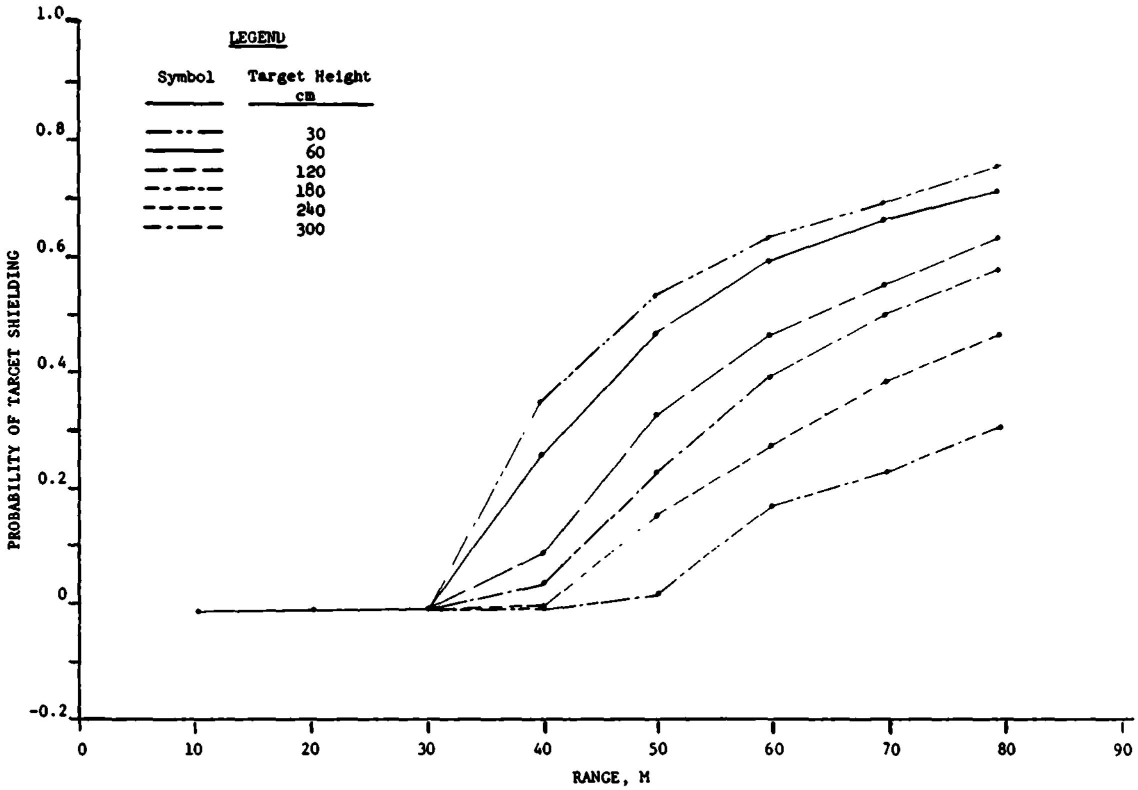


g. HOB = 200 cm

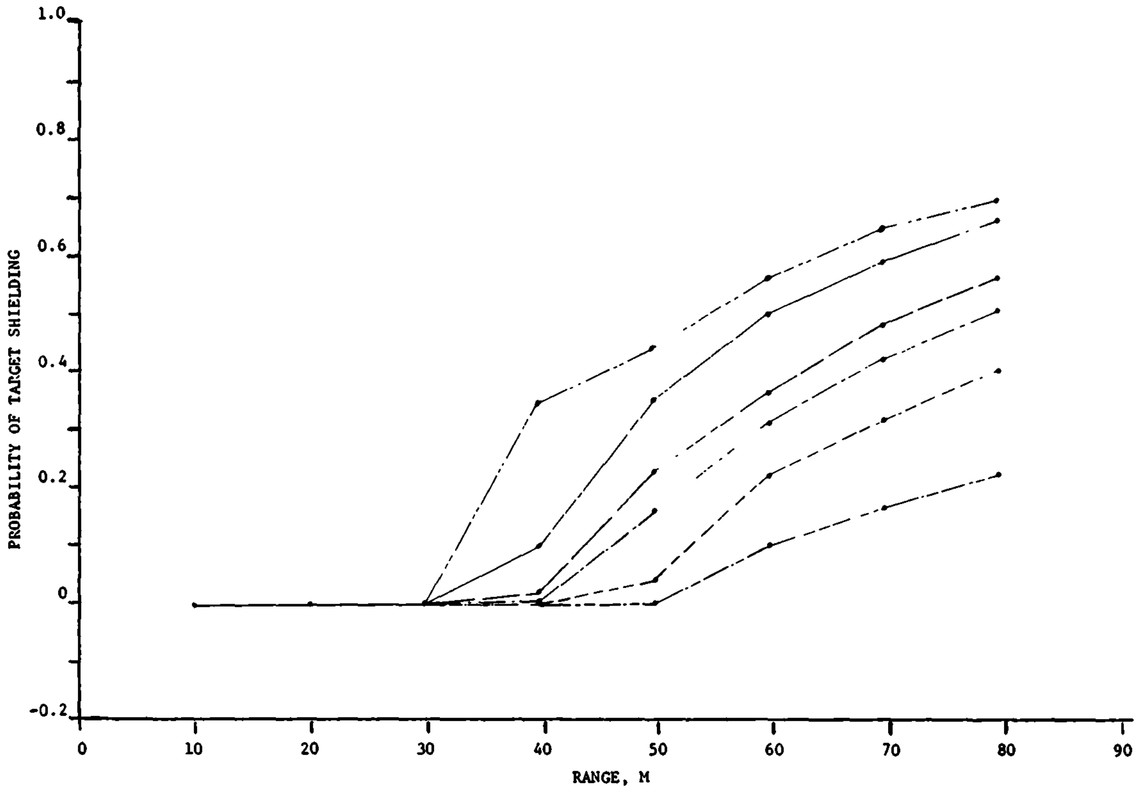


h. HOB = 300 cm

Fig. 36 (sheet 4 of 5)



i. HOB = 400 cm



j. HOB = 500 cm

Fig. 36 (sheet 5 of 5)

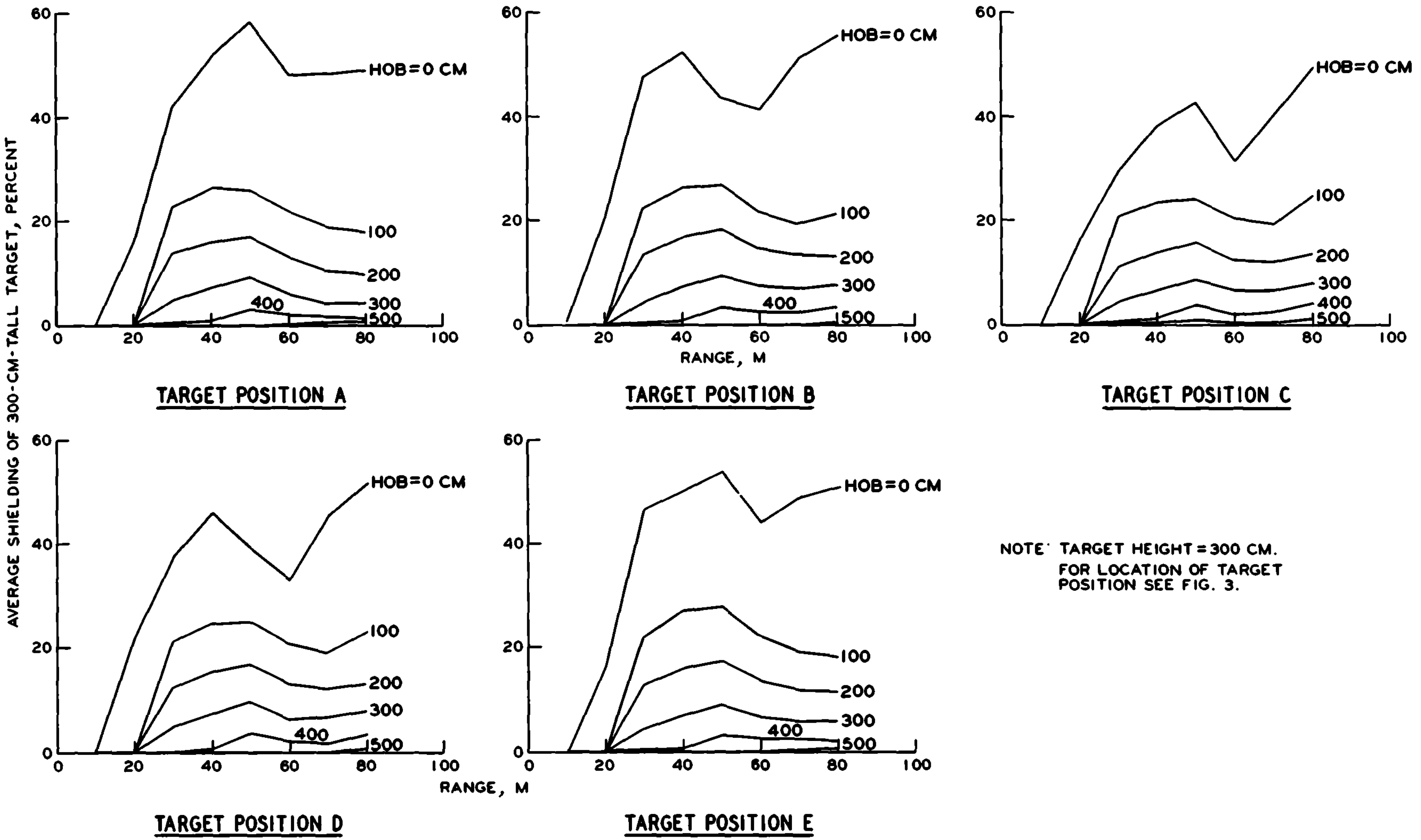


Fig. 37. Shielding of 300-cm-tall target by ground surface for five positions along center line of road, site 1

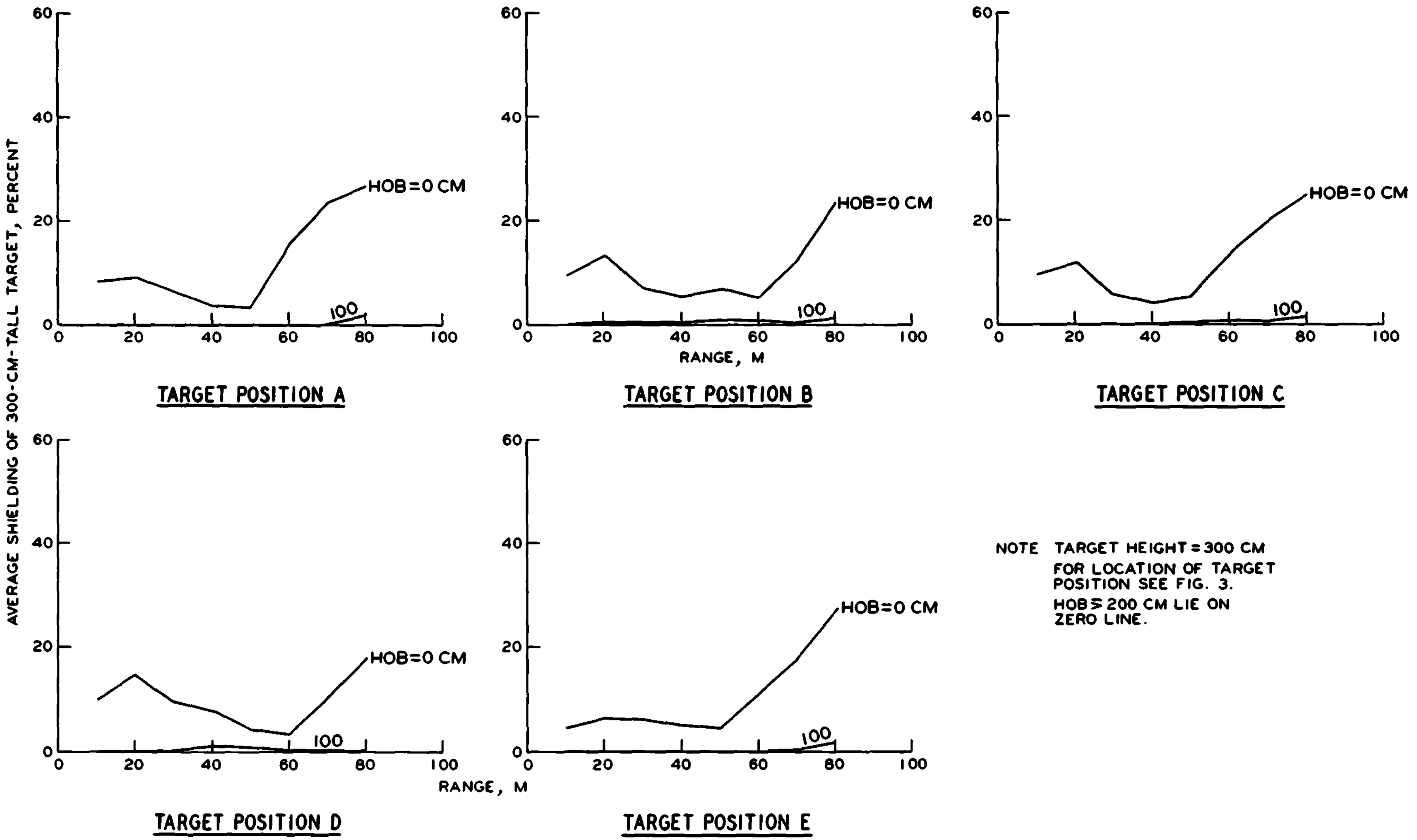


Fig. 38. Shielding of 300-cm-tall target by ground surface for five positions along center line of road, site 2

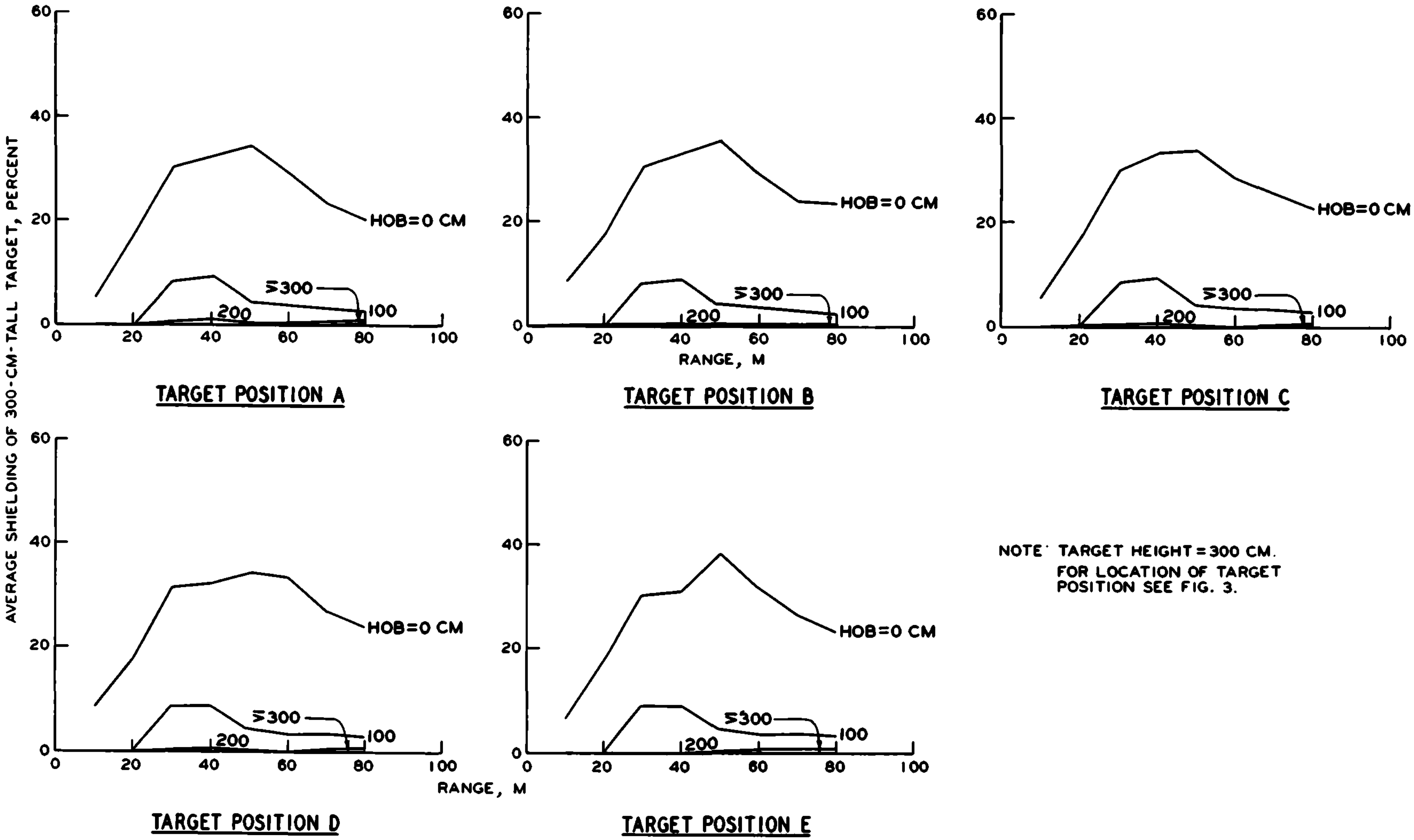


Fig. 39. Shielding of 300-cm-tall target by ground surface for five positions along center line of road, site 3

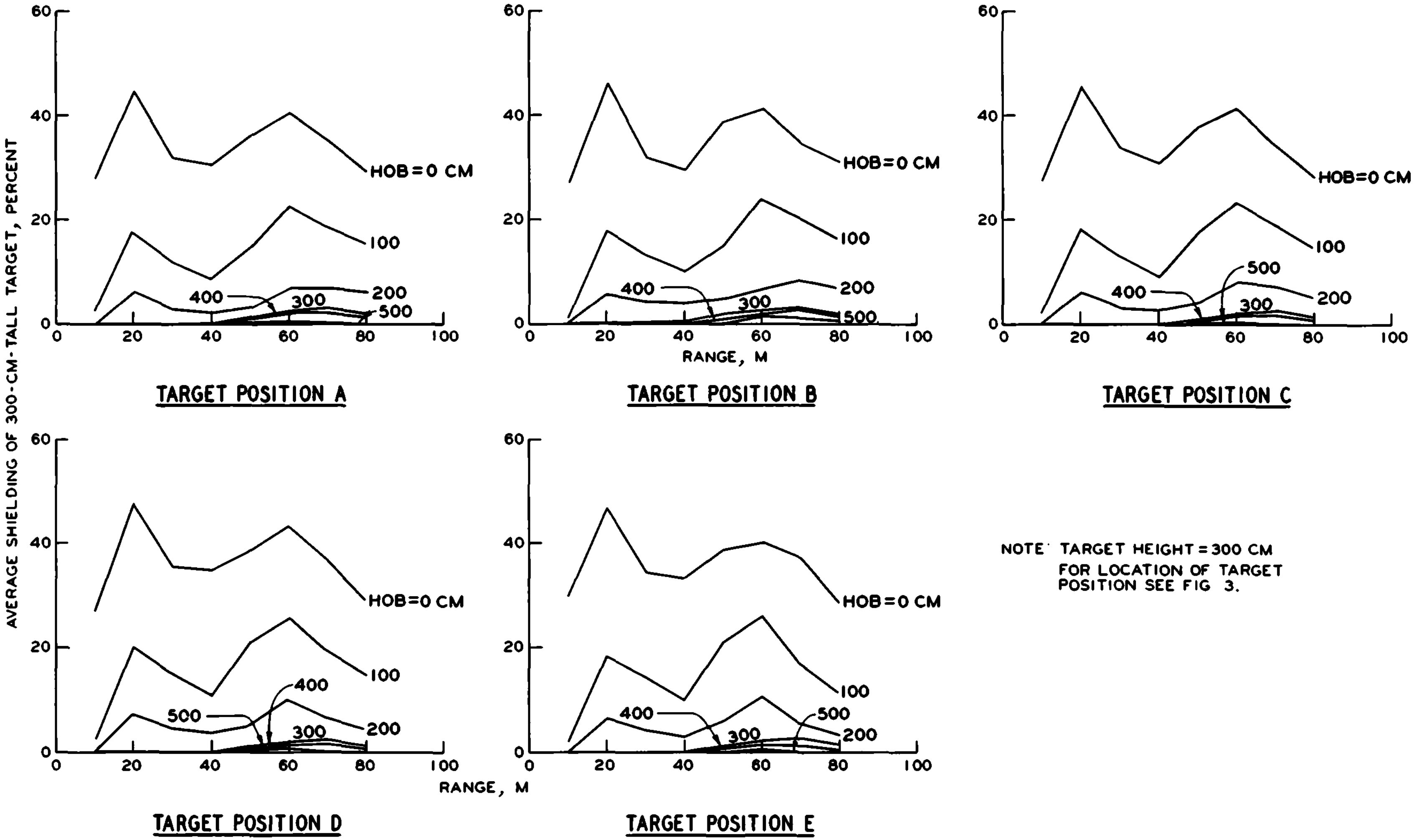


Fig. 40. Shielding of 300-cm-tall target by ground surface for five positions along center line of road, site 4

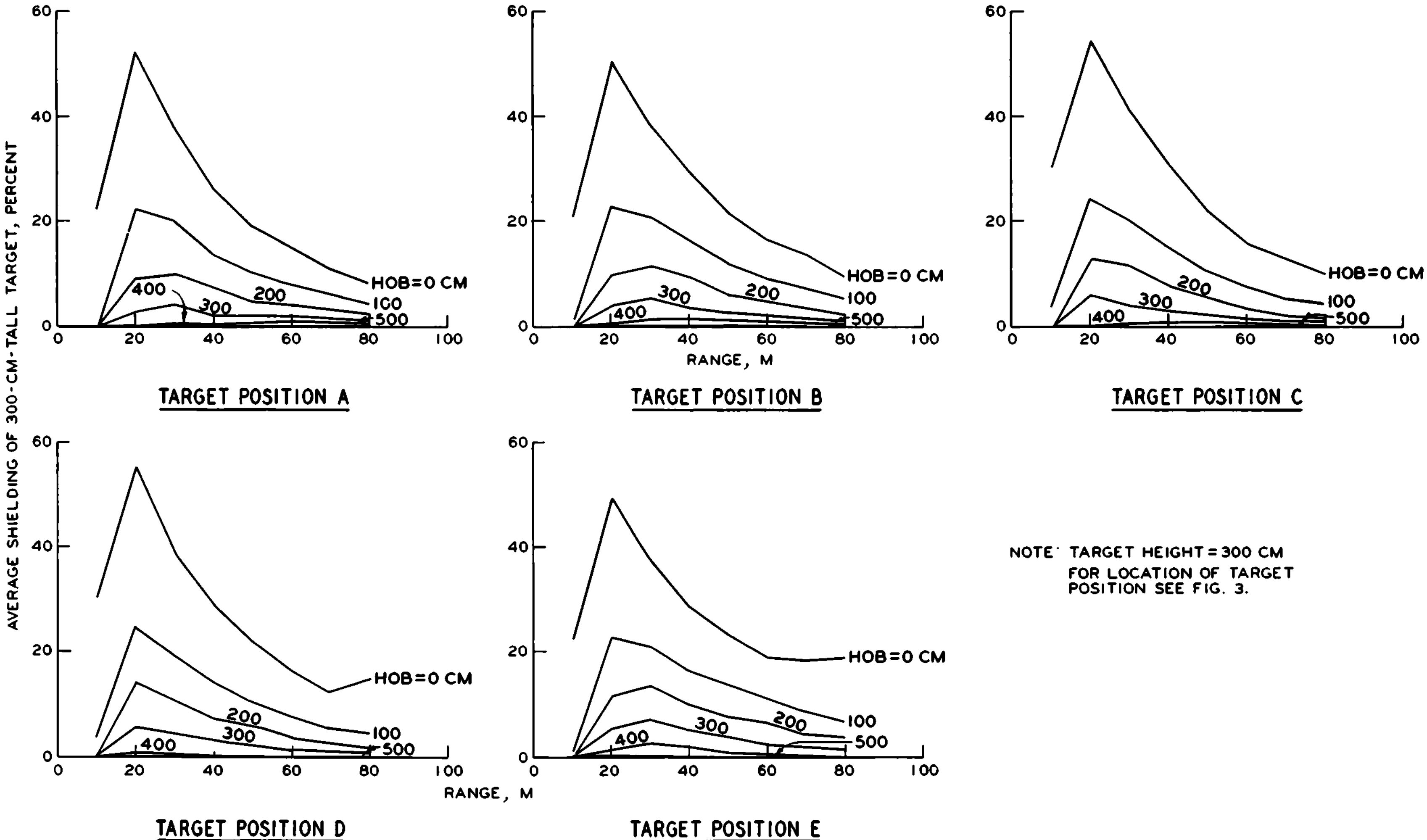


Fig. 41. Shielding of 300-cm-tall target by ground surface for five positions along center line of road, site 5

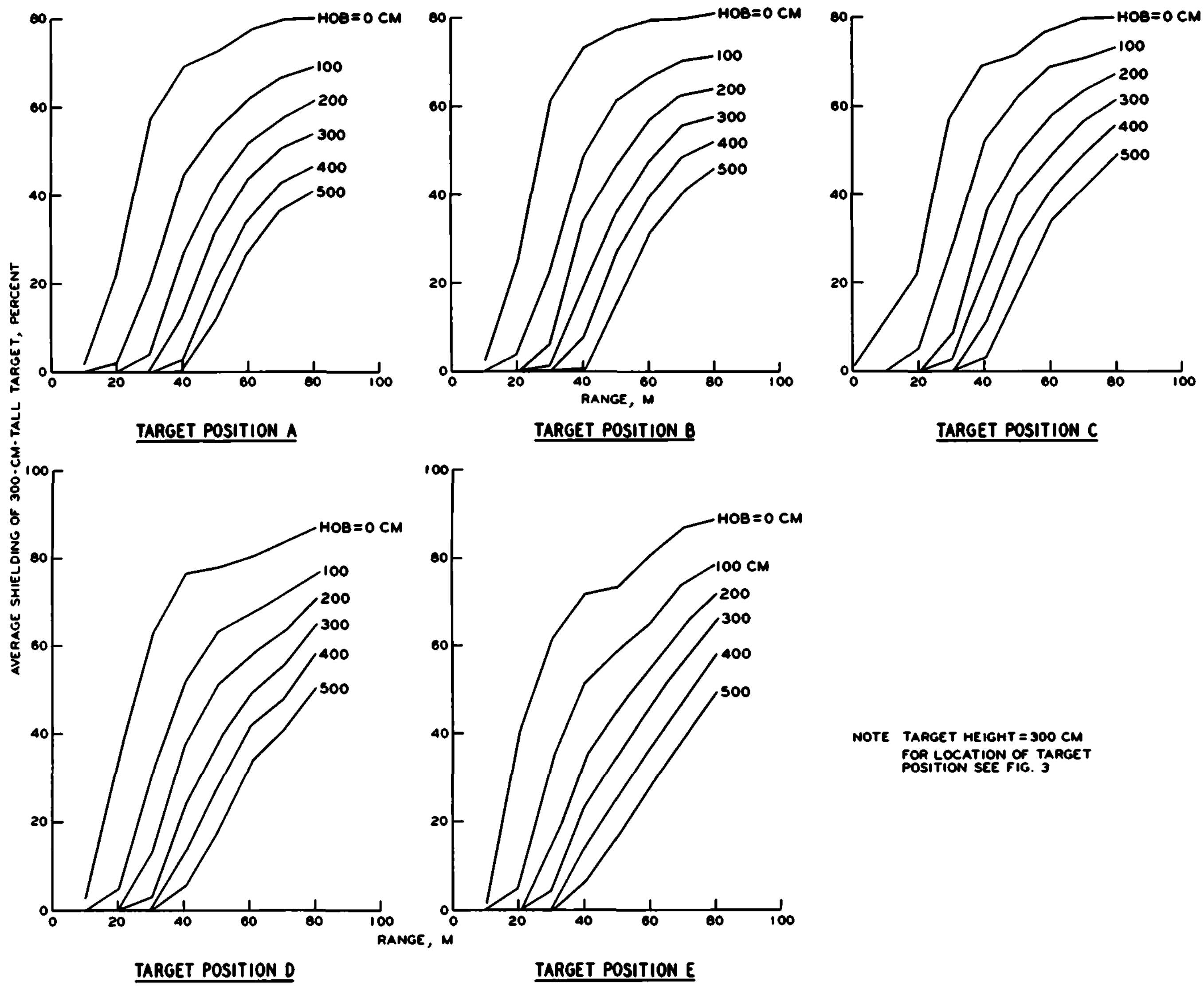


Fig. 42. Shielding of 300-cm-tall target by ground surface for five positions along center line of road, site 6

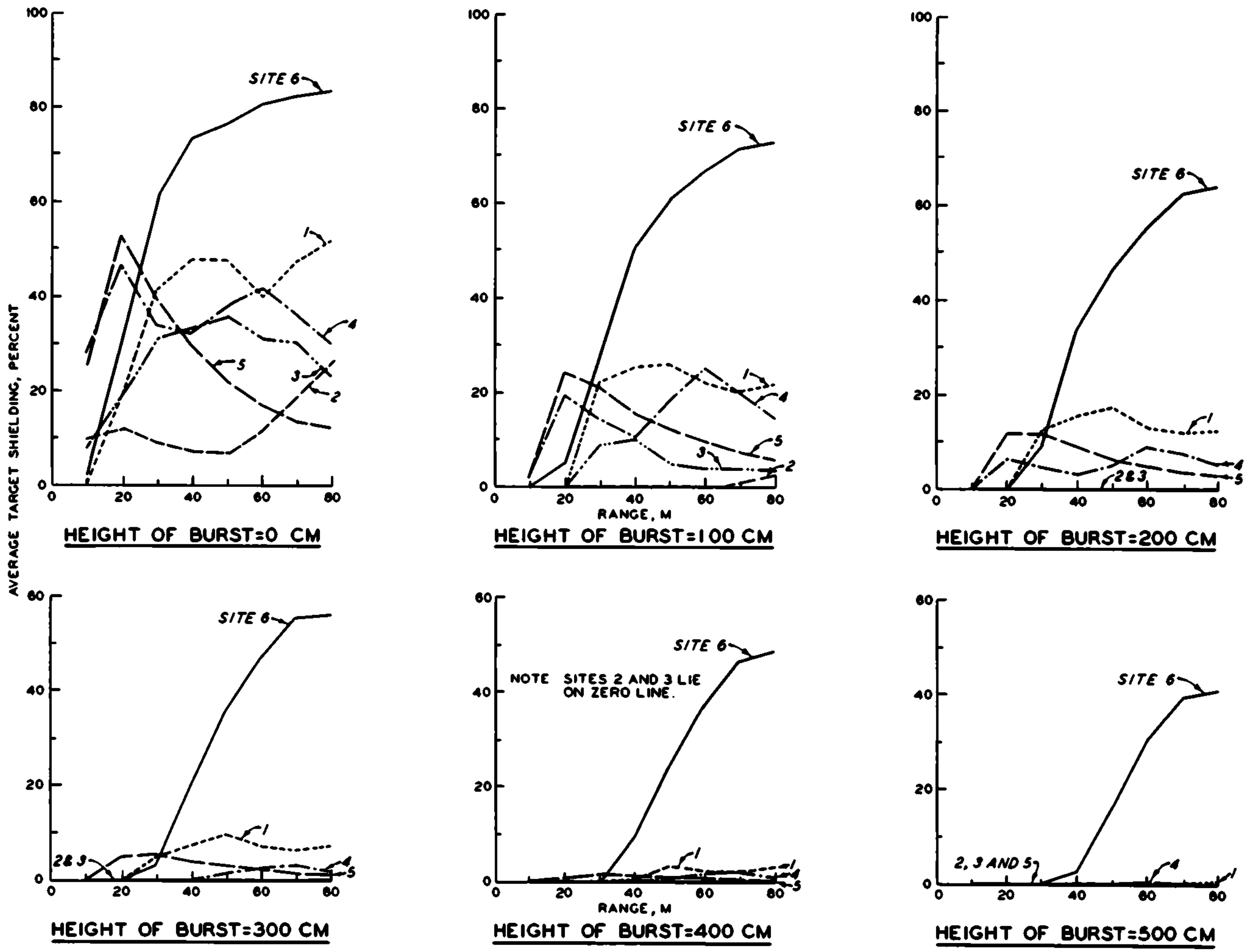


Fig. 43. Comparison of average shielding of 300-cm-tall target at the six road sites

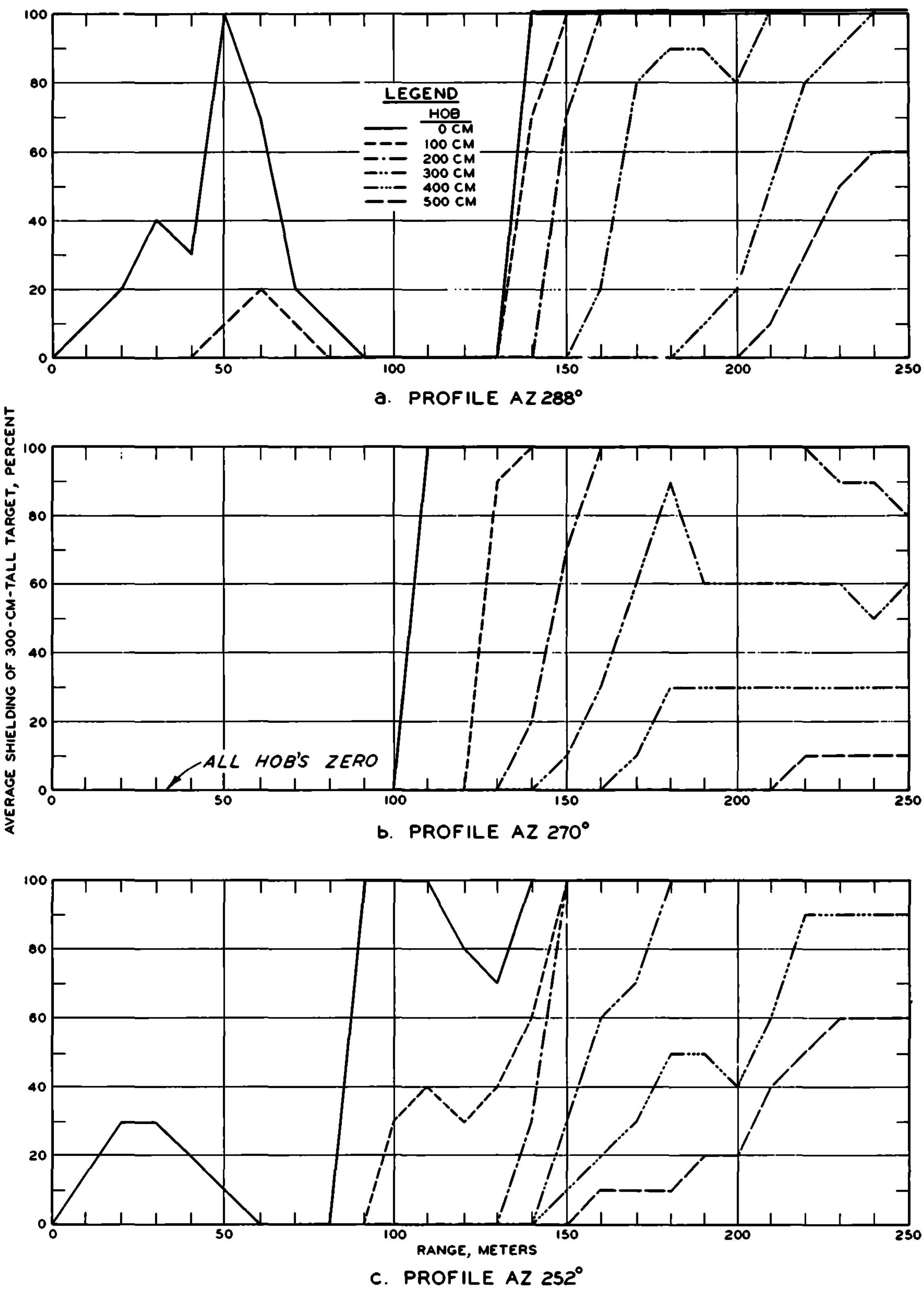


Fig. 44. Shielding of 300-cm-tall target by ground surface on 250-m profiles, site 2

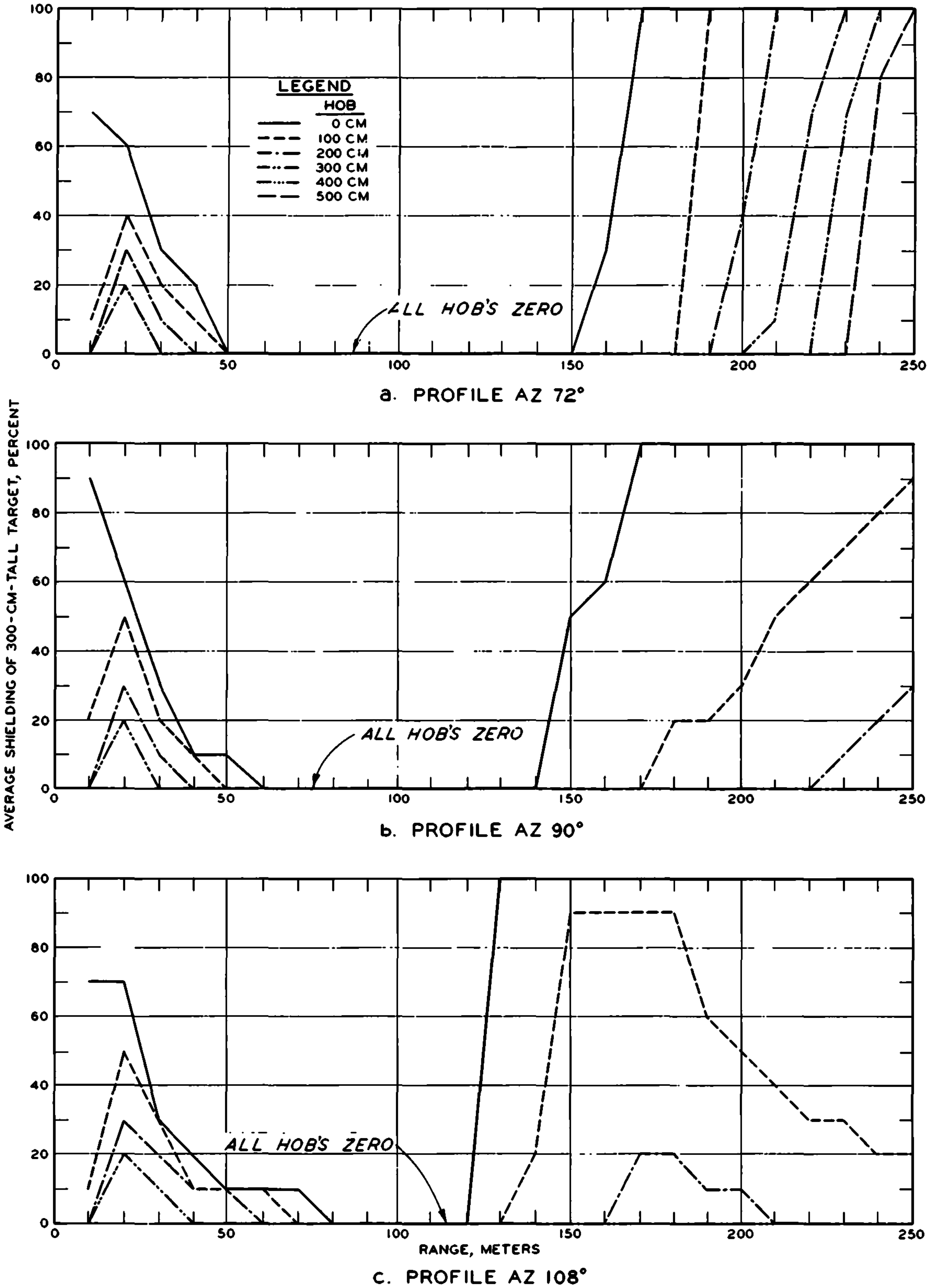


Fig. 45. Shielding of 300-cm-tall target by ground surface on 250-m profiles, site 5

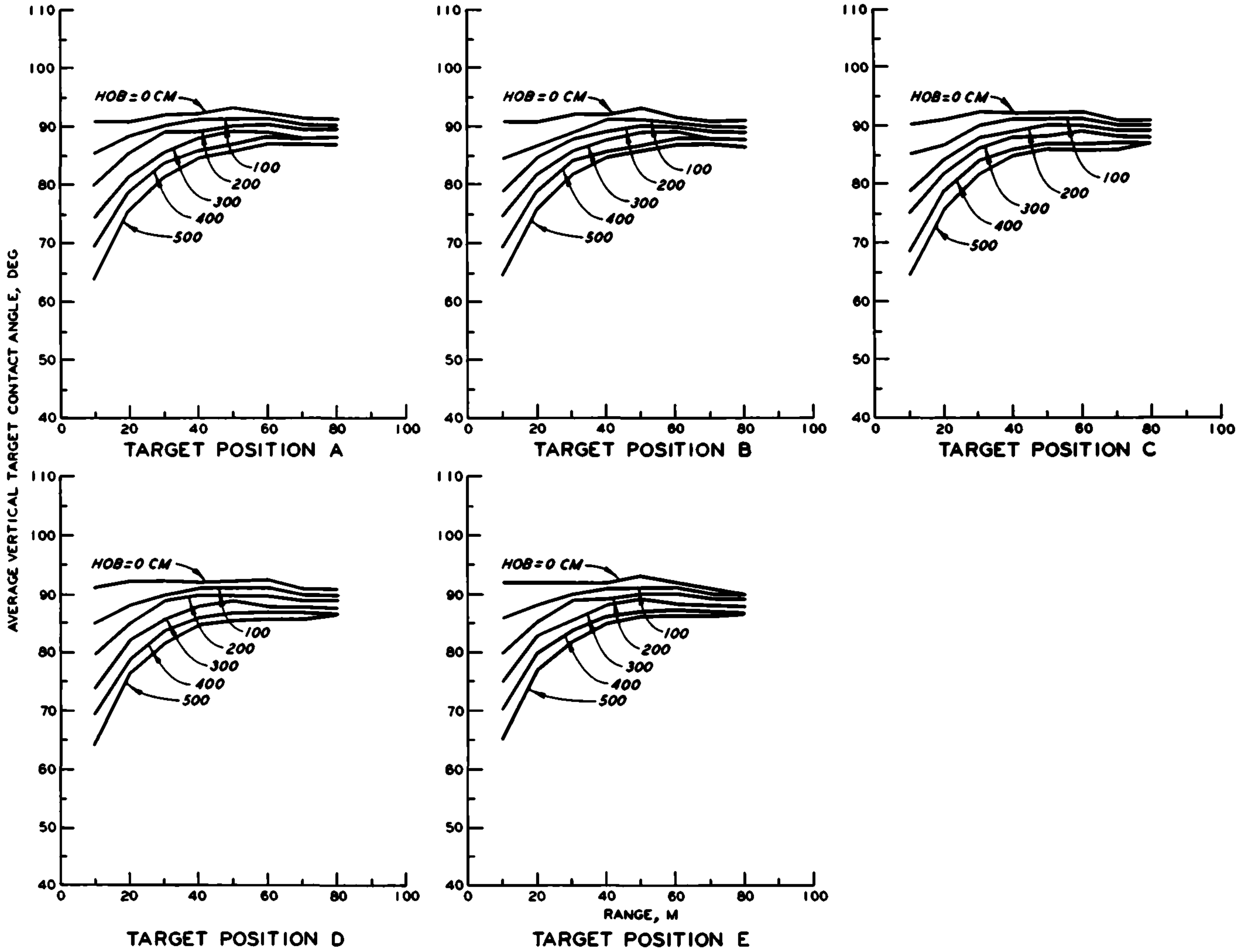


Fig. 46. Vertical target contact angles for five positions along the center line of road, site 1

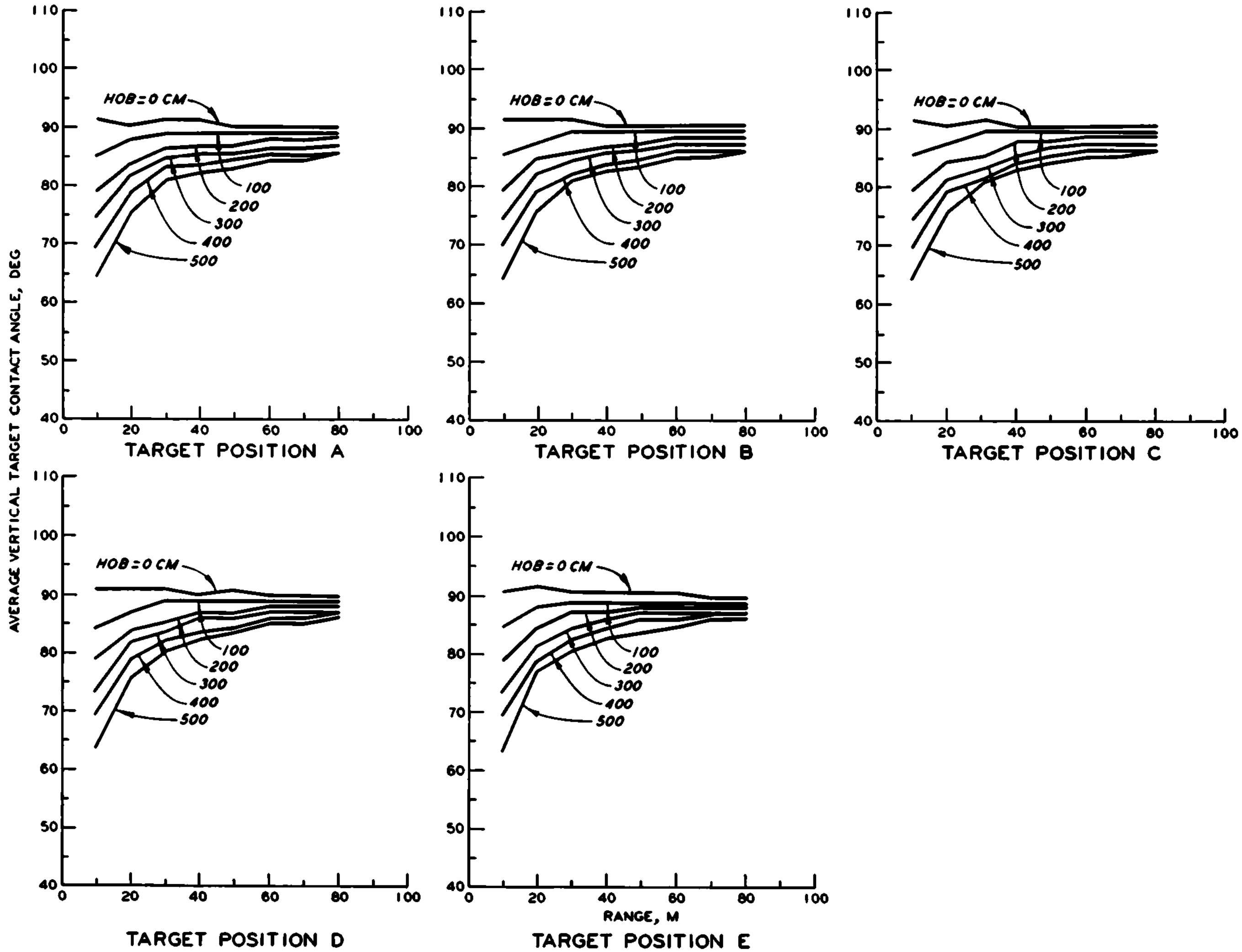


Fig. 47. Vertical target contact angles for five positions along the center line of road, site 2

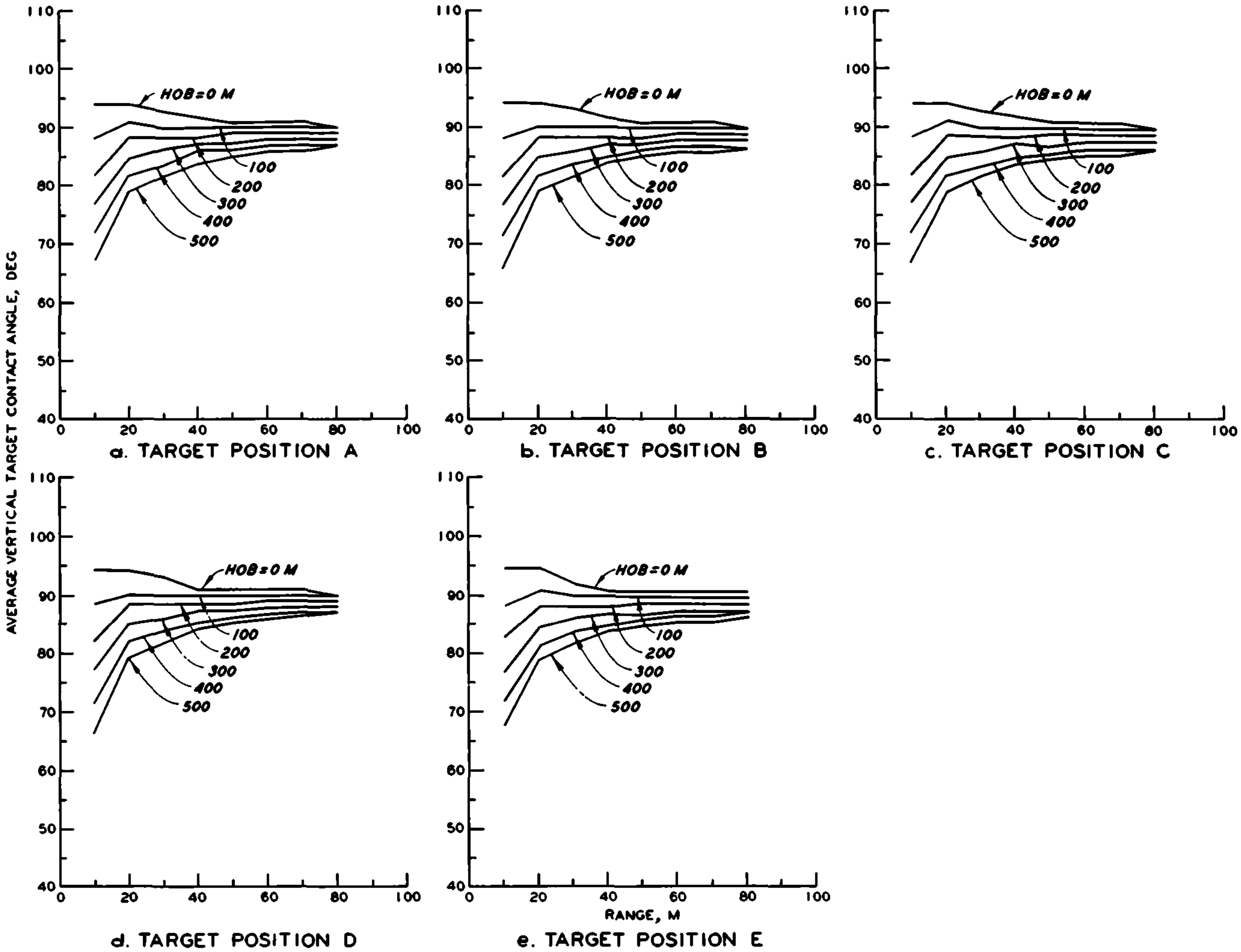


Fig. 48. Vertical target contact angles for five positions along the center line of road, site 3

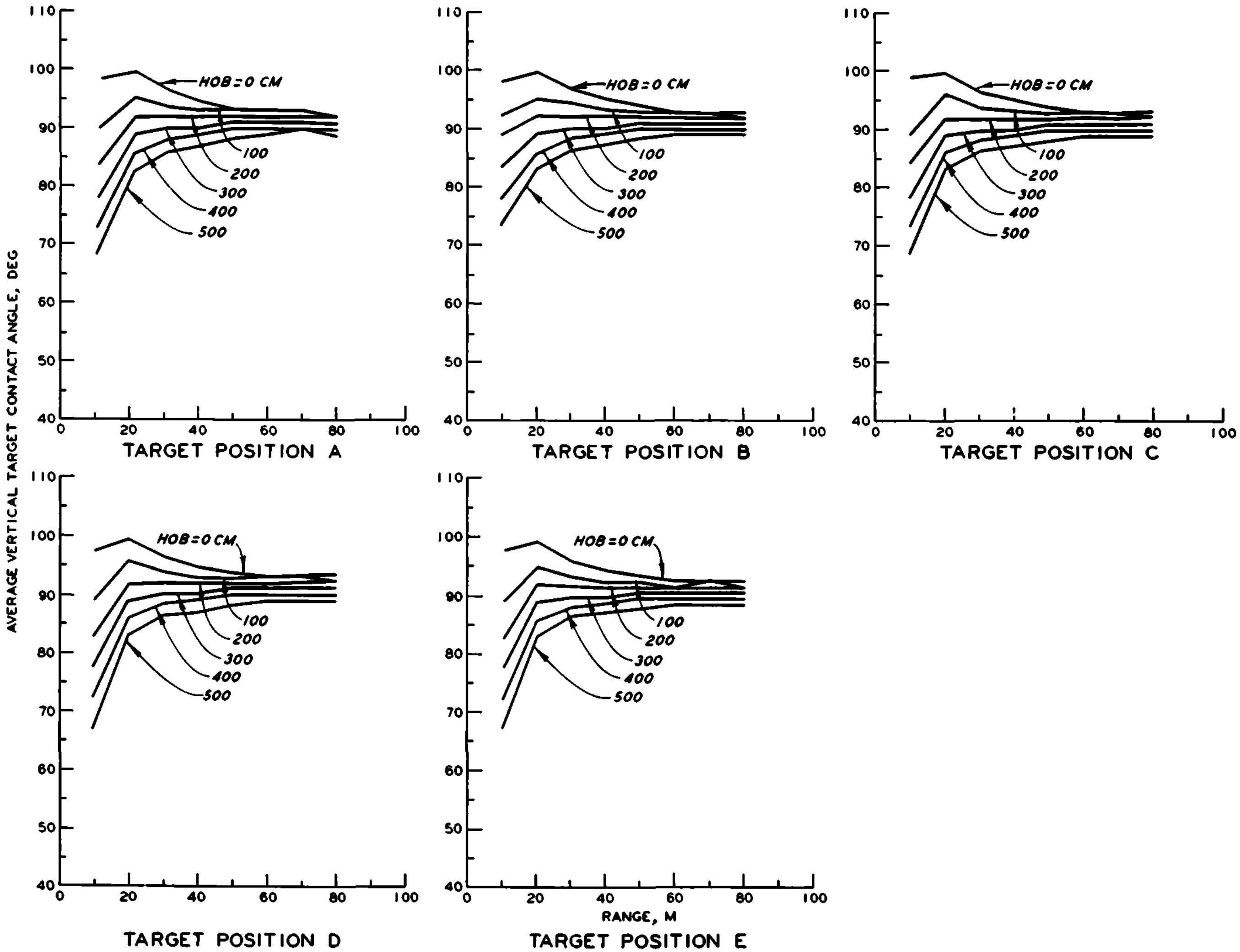


Fig. 49. Vertical target contact angles for five positions along the center line of road, site 4

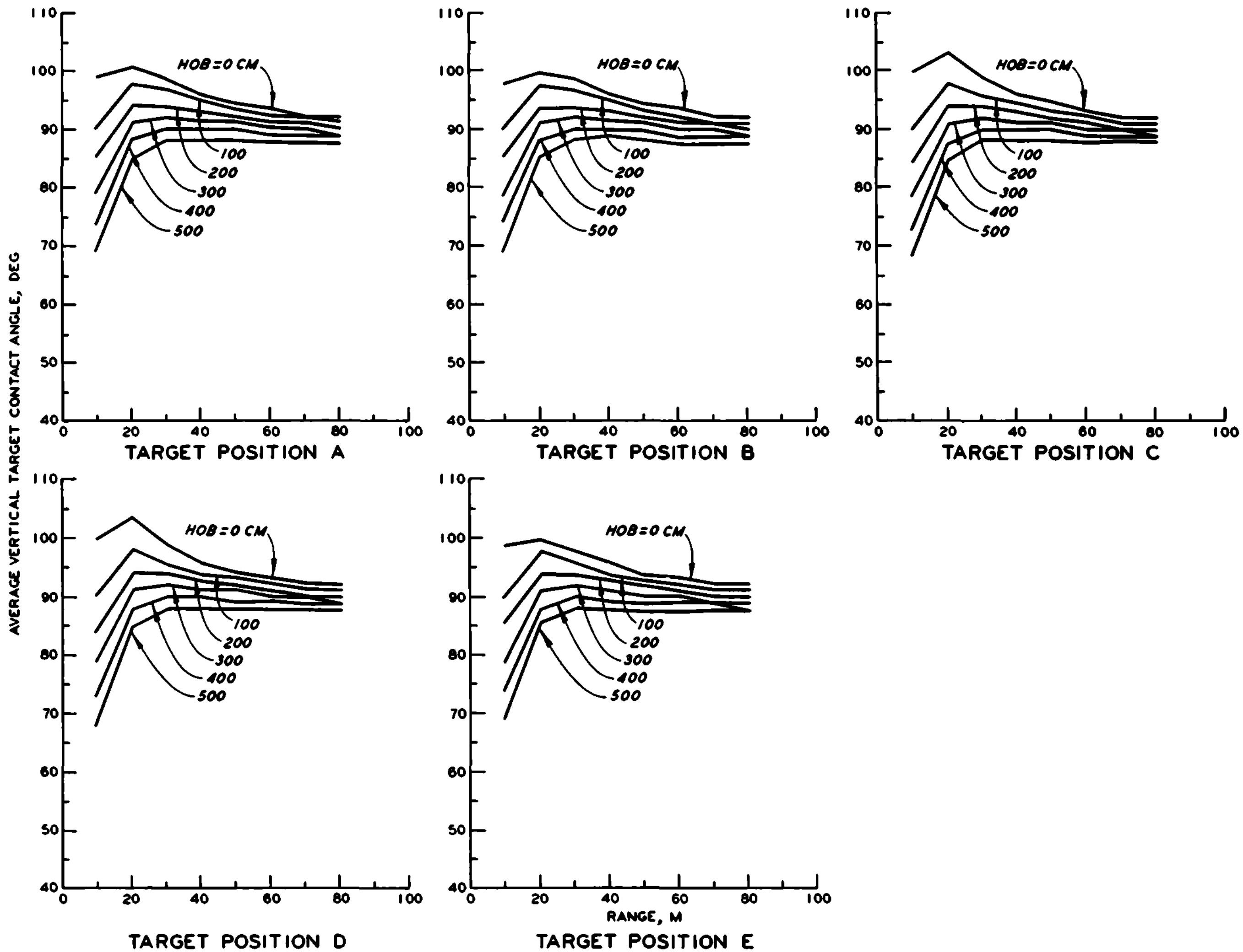


Fig. 50. Vertical target contact angles for five positions along the center line of road, site 5

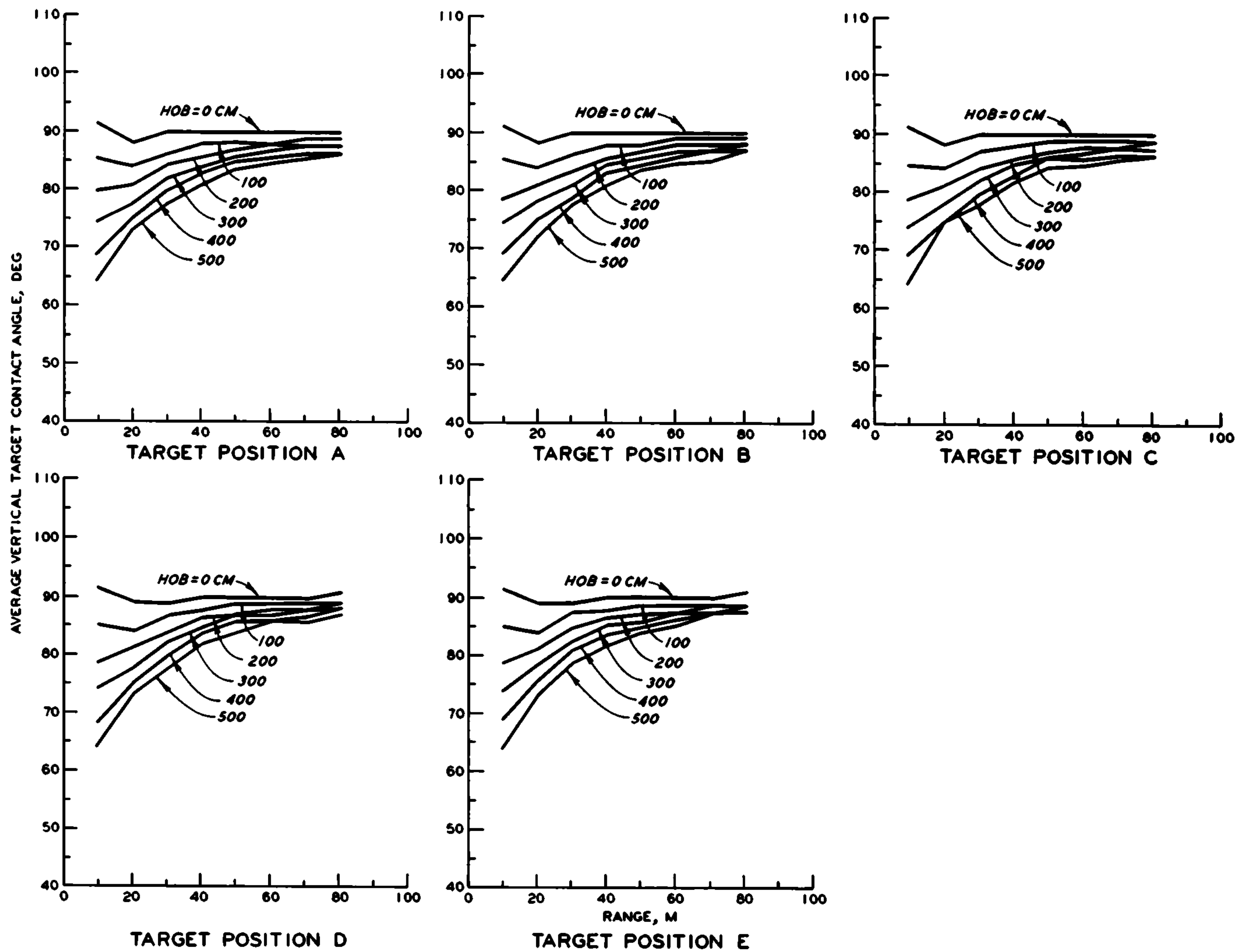


Fig. 51. Vertical target contact angles for five positions along the center line of road, site 6

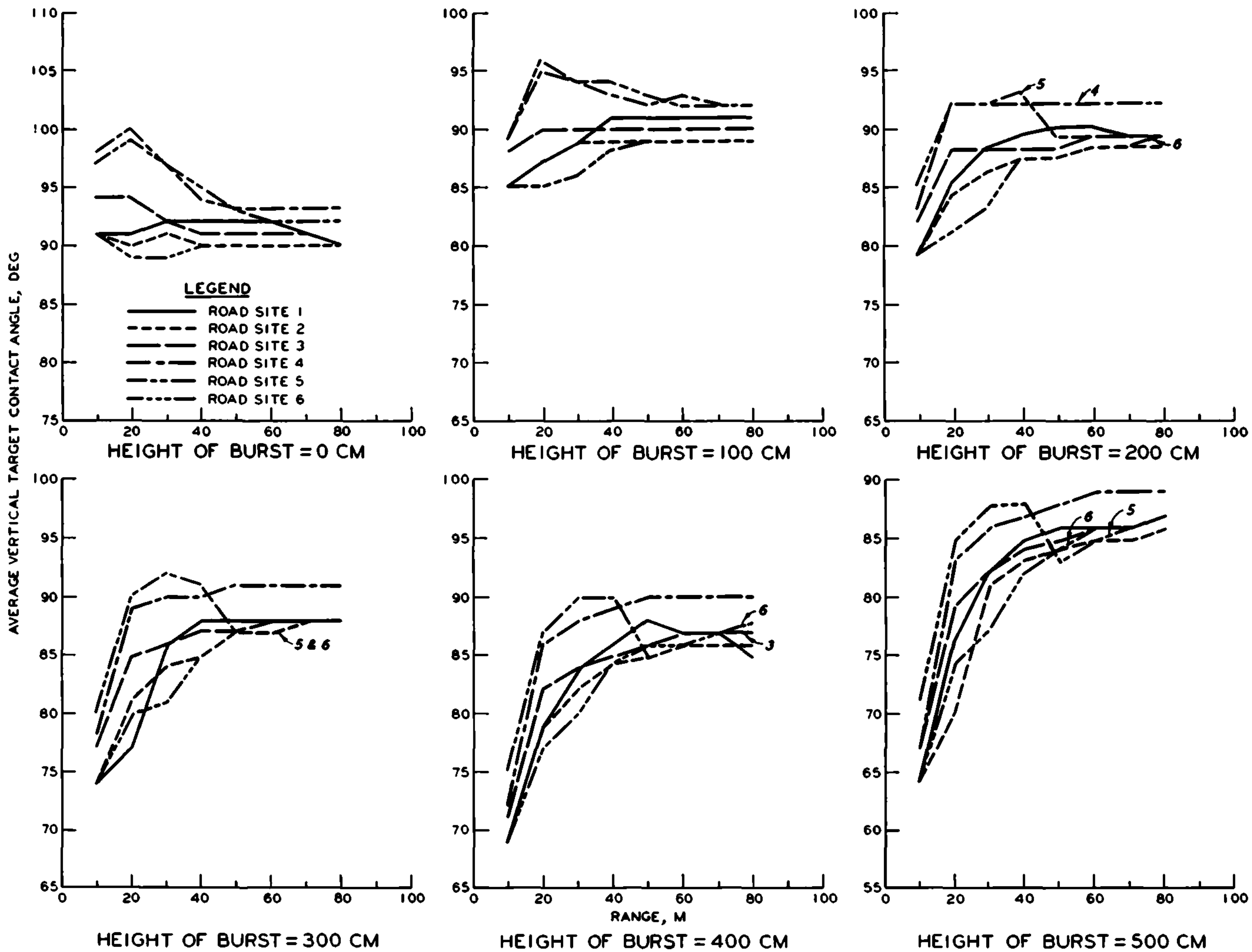
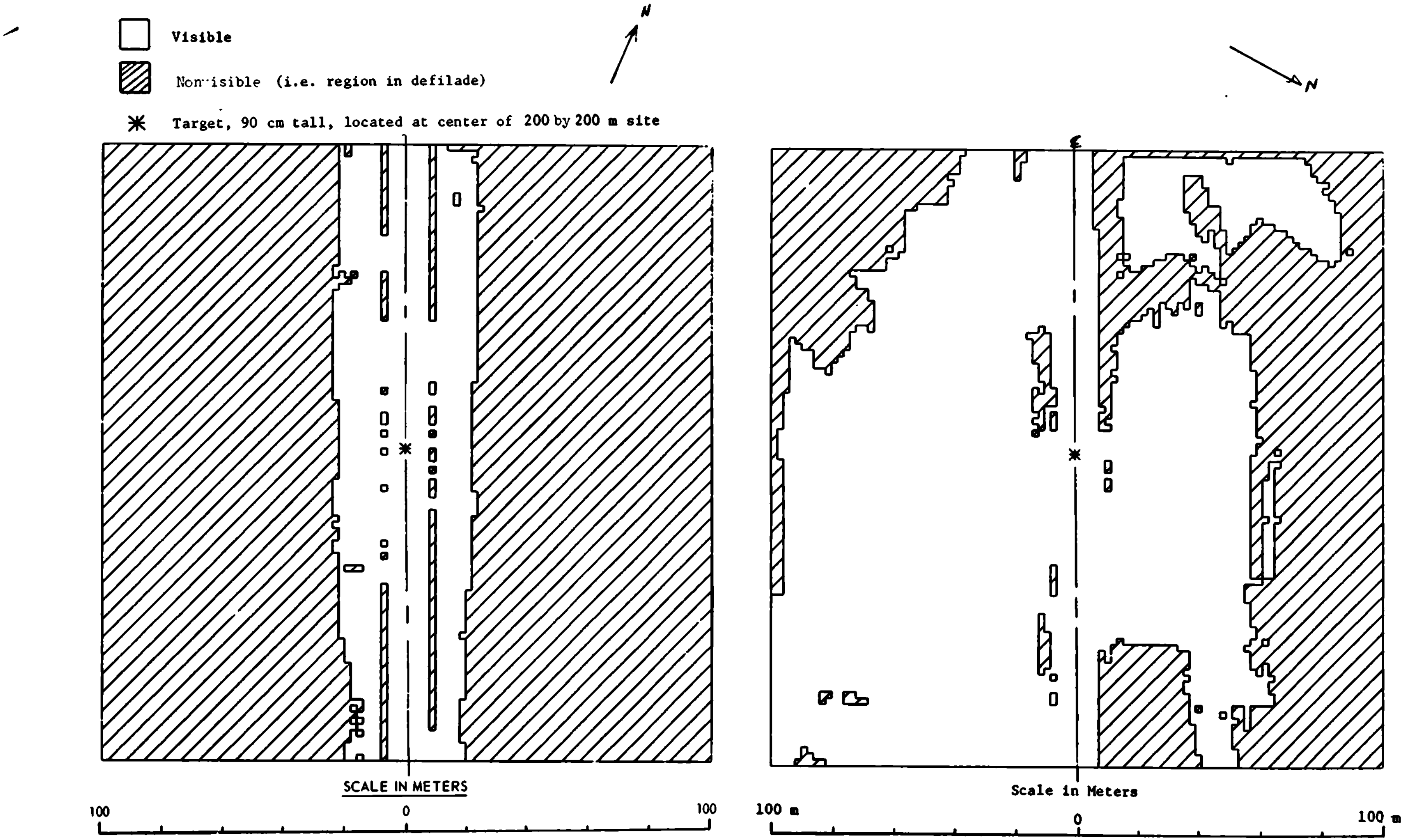


Fig. 52. Comparison of average vertical target contact angles for the six road sites



a. Road site 1

b. Road site 2

Fig. 53. Computer plots of visible and nonvisible regions as observed from a height of 90 cm, sites 1-6 (sheet 1 of 3)

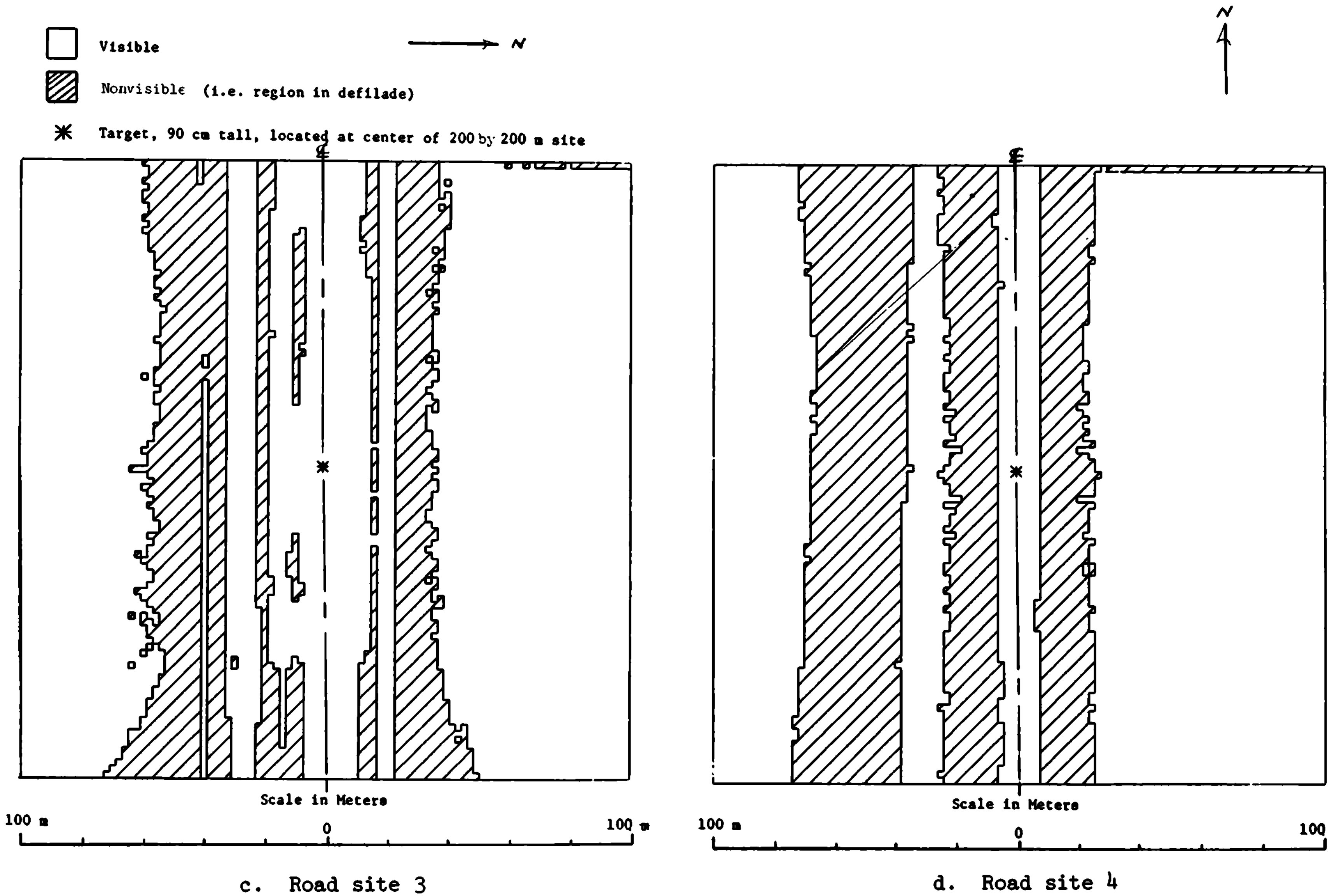
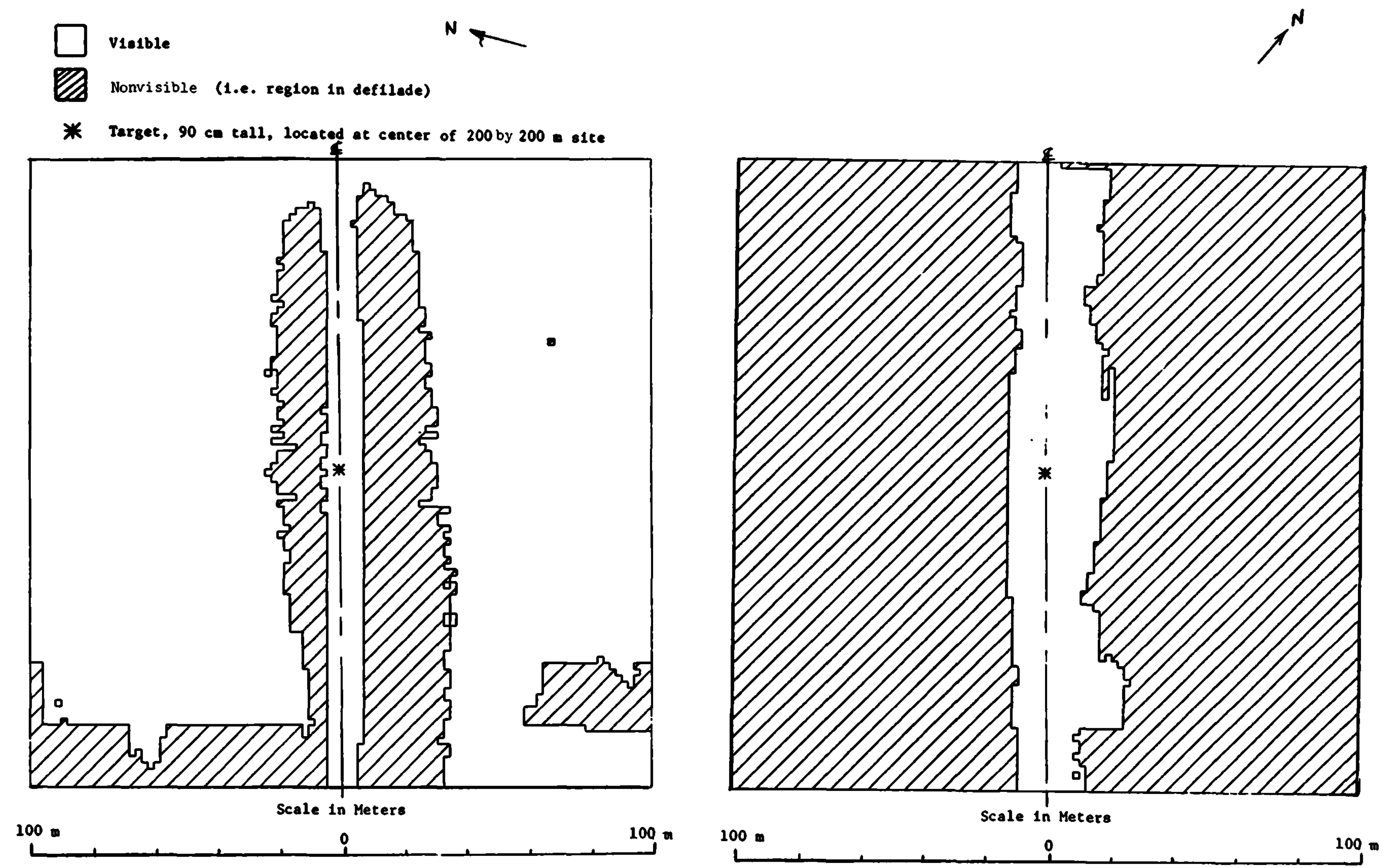


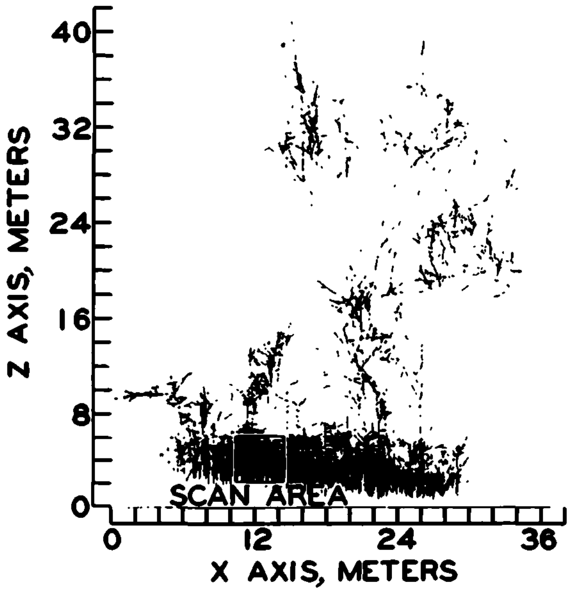
Fig. 53 (sheet 2 of 3)



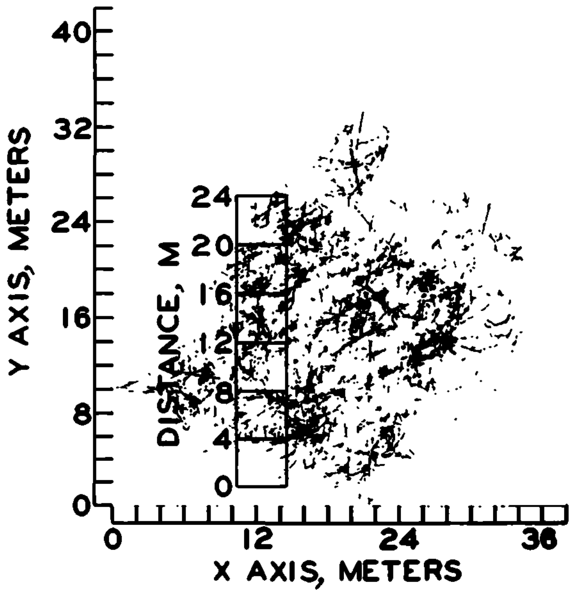
e. Road site 5

f. Road site 6

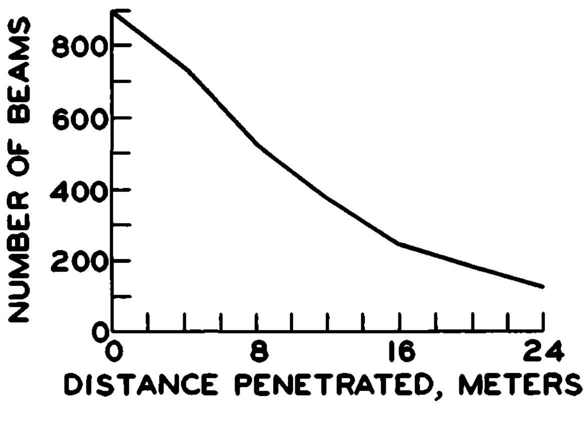
Fig. 53 (sheet 3 of 3)



a. Profile XZ view of a tropical forest site showing XZ location of scan area



b. Top view of tropical forest site showing XY location of scan area



c. Degradation of horizontal beams projected into a three-dimensional forest stand

Fig. 54. Effects of vegetation on horizontal, parallel beams; tropical forest site P3-10, Panama Canal Zone

APPENDIX A: GENERAL PROCEDURES FOR THE ACQUISITION AND RECORDING OF ON-SITE THREE-DIMENSIONAL TOPOGRAPHIC DATA

1. This appendix briefly describes the general procedures used for measuring and recording three-dimensional topographic (i.e. azimuth and distance) data. Before topographic data can be obtained, a three-dimensional coordinate system must be established, as discussed below.

2. The origin of the three-dimensional coordinate system (fig. A1) is usually an arbitrarily selected point near the area for which topographic data are to be measured, although it may be any convenient benchmark near or within the area to be surveyed. The origin of the three-dimensional coordinate system is designated as topographic (or control) point 1 (TP1). No data are required for the location of TP1, since the computer program that reduces the orthogonal coordinates to rectangular coordinates assumes the x,y,z coordinates of TP1 to be 0,0,0. To establish the position of the positive x-axis to which all data are referenced, the following procedure is used.

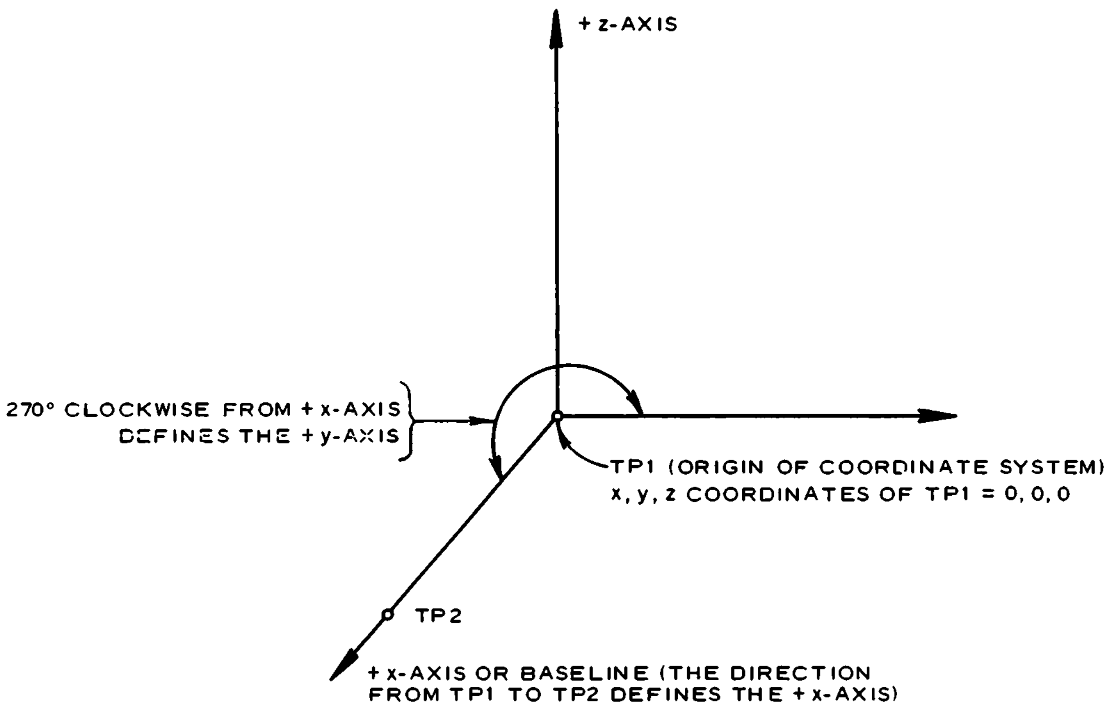


Fig. A1. Coordinate system

a. Set up and level a transit or theodolite over TP1 (origin of coordinate system).

b. Adjust the instrument's horizontal circle (i.e. azimuth circle) to read 360 deg 00 sec (or 0 deg 00 min 00 sec for some instruments) when sighted in the direction of magnetic north of any other selected reference. For this study the horizontal angle reference was along the baseline.

c. Along the reference line, establish topographic point 2 (TP2) at any selected distance. For this study, TP2 was located at 20 m along the baseline. Information pertaining to the location of TP2 must be entered on the first line of the topographic data form (fig. A2) according to the instructions in paragraph 3. This line of data establishes the positive x-axis for the survey. From the positive x-axis, the positive y-axis is then always assumed to lie 270 deg clockwise, and the positive z-axis is assumed to lie in the vertical or zenith direction and perpendicular to the x-y plane. These axes (i.e. y and z) do not require location in the field. These coordinate axes are illustrated on the following page.

3. Once the coordinate system has been established, other topographic points are selected and located, as required in the topographic survey. To provide the three-dimensional location of each topographic point (except TP1, which is assumed to be 0,0,0), the following data are required, and are recorded on the topographic data form (fig. A2) as follows. (The numbers in parentheses indicate the corresponding column numbers on the topographic data form and also correspond to those on an automatic data processing (ADP) card.)

a. Columns 1-17. The information in these columns is used for computer storage and retrieval systems at WES, and is not required in conducting the topographic survey.

b. Height of instrument (18-20). To locate a new topographic point, a transit or theodolite is set up and leveled over an already existing point, such as TP1. The height of instrument is the vertical distance, in centimeters, from the horizontal axis of the instrument (or scope) to the topographic point beneath the instrument.

c. Instrument TP (21-24). The number assigned the topographic point beneath the instrument.

d. Backsight TP (25-28). The number assigned the already established topographic point being used to reference the horizontal angle of 360 deg 00 min 00 sec. The first number recorded on the data form is always 02.

TOPOGRAPHIC DATA

MAP REF ____________ MILITARY GRID ____________

PAGE ________ OF ________ DATE ____________

CREW

____

____

____

COUNTRY	SITE NUMBER	SAMPLE NUMBER	FACTOR FAMILY	DATA FORM REFERENCE	DATA GROUP REFERENCE	LINE NUMBER	INSTRUMENT A: H I (CM)	INSTRUMENT A: AT T P	INSTRUMENT A: B S T P	INSTRUMENT A: F.S T P	ROD READING (CM)	HORIZ DISTANCE (CM)	HORIZ ANGLE: DEG	HORIZ ANGLE: MIN	HORIZ ANGLE: SEC	VERT ANGLE: DEG	VERT ANGLE: MIN	VERT ANGLE: SEC	REMARKS	COM'T	REP'T
1 2 3	4 5 6 7	8 9	10	11 12	13 14	15 16 17	18 19 20	21 22 23 24	25 26 27 28	29 30 31 32	33 34 35 36	37 38 39 40 41	42 43 44	45 46	47 48	49 50 51	52 53	54 55	56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78	79	80
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																
				1 1	0 2																

WES FORM NO 1937
REV AUG 1971

Fig. A2. Topographic data form

e. Foresight TP (29-32). The number assigned the new topographic point being located. The first number recorded in this field is always 02, which establishes the positive x axis. All other foresight TP's should follow 02 in an increasing numerical sequence (i.e. 03, 04, 05, through 9999) on the data form.

f. Rod reading (33-36). A metric stadia rod is used to locate the elevation of topographic points. The rod reading is recorded in centimeters.

g. Horizontal distance (37-41). The distance, in centimeters, measured horizontally between the instrument and the new topographic point being established.

h. Horizontal angle (deg (42-44), min (45-46), sec (47-48)). The clockwise angle between the reference line (i.e. 360 deg 00 min 00 sec) or backsight TP and the new topographic point being established.

i. Vertical angle (deg (49-51), min (52-53), sec (54-55)). The clockwise angle between zenith (vertically upward) and the line-of-sight to the topographic point being established. For running a line of levels, the vertical is assumed to read 90 deg 00 min 00 sec and is the number that is recorded for the vertical angle.

j. Remarks (56-80). This field is used to record any narrative information pertinent to the topographic point being located.

4. After all the topographic points have been surveyed and the data recorded on the form (fig. A2), the data sheets are given to a keypunch operator for punching the field data into standard ADP cards. (It should be noted that one ADP card represents one line of data on the field form, fig. A2.) Once the topographic data are on ADP cards, they are then ready to be used as input to a computer program (Fortran IV, G-635 program) that computes the x,y,z coordinates for all points in the survey. Coordinates can be computed in metric or English units by inputting a specific data card in the program.

5. The surveyed three-dimensional x,y,z, coordinates for each of the six road sites are given in tables A1-A6. Coordinate data on the 250-m survey line for sites 2 and 5 are given in tables A7 and A8, respectively.

Table A1

Topographic Data (cm)

Road Site 1

T.P.	X	Y	Z
1	0.	0.	0.
2	2000.0	0.	-43.0
3	4000.0	-0.0	-35.0
4	6000.0	-0.0	-76.0
5	8000.0	-0.0	-73.0
6	10000.0	-0.0	-88.0
7	12000.0	-0.0	-99.0
8	14000.0	-0.0	-105.0
9	16000.0	-0.0	-144.0
10	18000.0	-0.1	-187.0
11	20000.0	-0.1	-218.0
12	0.0	455.0	-77.0
13	0.0	1500.0	-181.0
14	0.0	2200.0	-250.1
15	0.0	2642.0	-262.7
16	0.0	3515.0	-425.4
17	0.0	4710.0	-460.6
18	0.0	5600.0	-459.0
19	0.0	6160.0	-458.5
20	0.0	6400.0	-602.4
21	0.0	7020.0	-561.2
22	0.0	7480.0	-719.0
23	0.0	7830.0	-725.4
24	0.0	7950.0	-502.5
25	0.0	8000.0	-473.7
26	-0.0	-500.0	-104.0
27	-0.0	-1150.0	-237.0
28	-0.0	-1390.0	-182.0
29	-0.0	-1610.0	-176.0
30	-0.0	-2000.0	-166.0
31	-0.0	-2350.0	-172.0
32	-0.0	-2680.0	-188.0
33	-0.0	-2940.0	-238.0
34	-0.0	-3370.0	-158.0
35	-0.0	-3720.0	-88.0
36	-0.0	-4430.0	-147.0
37	-0.0	-4800.0	-193.0
38	-0.0	-5000.0	-176.0
39	-0.0	-5710.0	-272.0

Table A1 (Continued)

T.P.	X	Y	Z
40	-0.0	-6670.0	-315.0
41	-0.0	-7500.0	-371.0
42	-0.0	-8050.0	-405.0
43	-0.0	-8870.0	-458.8
44	-0.0	-9800.0	-525.0
45	-0.0	-10800.0	-579.4
46	-0.0	-11000.0	-579.2
47	-0.0	-11350.0	-643.7
48	-0.0	-12000.0	-663.6
49	2000.0	440.0	-131.0
50	2000.0	1300.0	-211.0
51	2000.0	2000.0	-236.0
52	2000.0	3000.0	-397.0
53	2000.0	4000.0	-439.3
54	2000.0	5000.0	-466.2
55	2000.0	6000.0	-484.6
56	2000.0	7000.0	-505.4
57	2000.0	7900.0	-497.7
58	2000.0	8000.0	-625.5
59	2000.0	-300.0	-66.0
60	2000.0	-550.0	-123.0
61	2000.0	-1000.0	-255.0
62	2000.0	-1130.0	-262.0
63	2000.0	-1370.0	-211.0
64	2000.0	-1620.0	-205.0
65	2000.0	-2000.0	-196.0
66	2000.0	-2360.0	-202.0
67	2000.0	-2650.0	-218.0
68	2000.0	-2670.0	-266.0
69	2000.0	-2930.0	-272.0
70	2000.0	-3000.0	-261.0
71	2000.0	-3400.0	-168.0
72	2000.0	-3800.0	-88.0
73	2000.0	-4000.0	-105.0
74	2000.0	-4430.0	-175.0
75	2000.0	-5400.0	-219.0
76	2000.0	-5800.0	-241.0
77	2000.0	-6200.0	-302.0
78	2000.0	-7000.0	-353.0

Table A1 (Continued)

T.P.	X	Y	Z
79	2000.0	-8000.0	-427.6
80	2000.0	-9000.0	-486.5
81	2000.0	-10000.0	-553.5
82	2000.0	-10300.0	-570.2
83	2000.0	-11000.0	-645.6
84	2000.0	-12000.0	-675.4
85	4000.0	135.0	-8.0
86	4000.0	440.0	-32.0
87	4000.0	1000.0	-135.0
88	4000.0	1600.0	-175.0
89	4000.0	2500.0	-331.0
90	4000.0	3500.0	-381.0
91	4000.0	4000.0	-401.0
92	4000.0	5000.0	-427.0
93	4000.0	6000.0	-448.0
94	4000.0	7000.0	-481.0
95	4000.0	8000.0	-508.0
96	4000.0	-465.0	-125.0
97	4000.0	-870.0	-261.0
98	4000.0	-1140.0	-290.0
99	4000.0	-1350.0	-245.0
100	4000.0	-1610.0	-235.0
101	4000.0	-2000.0	-224.0
102	4000.0	-2350.0	-232.0
103	4000.0	-2620.0	-242.0
104	4000.0	-2890.0	-297.0
105	4000.0	-3040.0	-282.0
106	4000.0	-3440.0	-190.0
107	4000.0	-3870.0	-108.0
108	4000.0	-4360.0	-156.0
109	4000.0	-5360.0	-234.0
110	4000.0	-6000.0	-290.0
111	4000.0	-7000.0	-375.0
112	4000.0	-8000.0	-446.0
113	4000.0	-9000.0	-514.0
114	4000.0	-9830.0	-558.0
115	4000.0	-10100.0	-612.0
116	3999.9	-11100.0	-656.0
117	3999.9	-12000.0	-694.0

Table A1 (Continued)

T.P.	X	Y	Z
118	6000.0	153.0	-54.0
119	6000.0	440.0	-51.0
120	6000.0	800.0	-68.0
121	6000.0	1800.0	-223.0
122	6000.0	2800.0	-290.0
123	6000.0	3000.0	-300.0
124	6000.0	4000.0	-356.0
125	6000.0	5000.0	-400.0
126	6000.0	6000.0	-432.0
127	6000.0	7000.0	-452.0
128	6000.0	8000.0	-469.0
129	6341.6	1223.2	-136.0
130	6000.0	-525.0	-176.0
131	6000.0	-1090.0	-318.0
132	6000.0	-1340.0	-274.0
133	6000.0	-1615.0	-264.0
134	6000.0	-2000.0	-255.0
135	6000.0	-2360.0	-260.0
136	6000.0	-2630.0	-272.0
137	6000.0	-2880.0	-326.0
138	6000.0	-3000.0	-310.0
139	6000.0	-3460.0	-184.0
140	6000.0	-3720.0	-124.0
141	6000.0	-3960.0	-47.0
142	6000.0	-4160.0	-55.0
143	6000.0	-4380.0	-111.0
144	6000.0	-5300.0	-198.0
145	6000.0	-6000.0	-258.0
146	6000.0	-7000.0	-352.0
147	6000.0	-8000.0	-443.0
148	6000.0	-9000.0	-505.0
149	6000.0	-10000.0	-572.0
150	6000.0	-10170.0	-609.0
151	5999.9	-11000.0	-655.0
152	5999.9	-12000.0	-710.0
153	8000.0	260.0	-10.0
154	8000.0	450.0	7.0
155	8000.0	1350.0	-84.0
156	8000.0	2000.0	-122.0

Table A1 (Continued)

T.P.	X	Y	Z
157	8000.0	2870.0	-186.0
158	8000.0	3500.0	-273.0
159	8000.0	4500.0	-327.0
160	8000.0	5000.0	-354.0
161	8000.0	6000.0	-393.0
162	8000.0	7000.0	-431.0
163	8000.0	8000.0	-448.0
164	8000.0	-450.0	-176.0
165	8000.0	-915.0	-326.0
166	8000.0	-1040.0	-343.0
167	8000.0	-1080.0	-343.0
168	8000.0	-1160.0	-336.0
169	8000.0	-1375.0	-299.0
170	8000.0	-1620.0	-291.0
171	8000.0	-2000.0	-283.0
172	8000.0	-2365.0	-288.0
173	8000.0	-2650.0	-300.0
174	8000.0	-2900.0	-356.0
175	8000.0	-3100.0	-311.0
176	8000.0	-3720.0	-149.0
177	8000.0	-3980.0	-57.0
178	8000.0	-4150.0	-29.0
179	8000.0	-4360.0	-77.0
180	8000.0	-5000.0	-125.0
181	8000.0	-6000.0	-217.0
182	8000.0	-7000.0	-300.0
183	8000.0	-8000.0	-395.0
184	8000.0	-9000.0	-465.0
185	8000.0	-10000.0	-541.0
186	7999.9	-10440.0	-621.0
187	7999.9	-11000.0	-661.0
188	7999.9	-12000.0	-701.0
189	10000.0	253.0	-21.0
190	10000.0	438.0	-23.0
191	10000.0	1058.0	-47.0
192	10000.0	1225.0	-99.0
193	10000.0	1400.0	-102.0
194	10000.0	1485.0	-90.0
195	10000.0	2370.0	-131.0

Table A1 (Continued)

T.P.	X	Y	Z
196	10000.0	2460.0	-105.0
197	10000.0	3000.0	-124.0
198	10000.0	4000.0	-166.0
199	10000.0	5000.0	-244.0
200	10000.0	6000.0	-321.0
201	10000.0	6610.0	-383.0
202	10000.0	7500.0	-408.0
203	10000.0	8000.0	-418.0
204	10000.0	-375.0	-178.0
205	10000.0	-880.0	-334.0
206	10000.0	-1050.0	-376.0
207	10000.0	-1110.0	-378.0
208	10000.0	-1160.0	-368.0
209	10000.0	-1380.0	-325.0
210	10000.0	-1620.0	-322.0
211	10000.0	-2000.0	-314.0
212	10000.0	-2360.0	-320.0
213	10000.0	-2650.0	-335.0
214	10000.0	-2860.0	-388.0
215	10000.0	-3000.0	-374.0
216	10000.0	-3430.0	-237.0
217	10000.0	-3800.0	-159.0
218	10000.0	-4000.0	-91.0
219	10000.0	-4120.0	-80.0
220	10000.0	-4340.0	-123.0
221	10000.0	-5000.0	-144.0
222	10000.0	-6000.0	-163.0
223	10000.0	-7000.0	-233.0
224	10000.0	-8000.0	-316.0
225	10000.0	-9000.0	-414.0
226	10000.0	-10000.0	-528.0
227	9999.9	-10520.0	-592.0
228	9999.9	-11000.0	-673.0
229	9999.9	-12000.0	-722.0
230	12000.0	295.0	-9.0
231	12000.0	445.0	-22.0
232	12000.0	1000.0	-43.0
233	12000.0	2000.0	-83.0
234	12000.0	3000.0	-119.0

Table A1 (Continued)

T.P.	X	Y	Z
235	12000.0	4000.0	-154.0
236	12000.0	4160.0	-159.0
237	12000.0	4175.0	-222.0
238	12000.0	5000.0	-279.0
239	12000.0	6000.0	-299.0
240	12000.0	7000.0	-346.0
241	12000.0	8000.0	-387.0
242	11890.1	4193.5	-158.0
243	12000.0	-330.0	-184.0
244	12000.0	-615.0	-271.0
245	12000.0	-960.0	-394.0
246	12000.0	-1070.0	-404.0
247	12000.0	-1160.0	-395.0
248	12000.0	-1390.0	-355.0
249	12000.0	-1620.0	-349.0
250	12000.0	-2000.0	-344.0
251	12000.0	-2370.0	-349.0
252	12000.0	-2660.0	-365.0
253	12000.0	-2850.0	-411.0
254	12000.0	-2970.0	-412.0
255	12000.0	-3090.0	-392.0
256	12000.0	-3470.0	-265.0
257	12000.0	-3900.0	-171.0
258	12000.0	-4090.0	-137.0
259	12000.0	-4390.0	-169.0
260	12000.0	-5000.0	-187.0
261	12000.0	-6000.0	-208.0
262	12000.0	-7000.0	-214.0
263	12000.0	-7330.0	-230.0
264	12000.0	-8000.0	-303.0
265	12000.0	-9000.0	-424.0
266	12000.0	-10000.0	-530.0
267	11999.9	-11000.0	-613.0
268	11999.9	-12000.0	-718.0
269	14000.0	370.0	5.0
270	14000.0	410.0	-1.0
271	14000.0	457.0	-25.0
272	14000.0	1000.0	-38.0
273	14000.0	2000.0	-62.0

Table A1 (Continued)

T.P.	X	Y	Z
274	14000.0	3000.0	-91.0
275	14000.0	4000.0	-115.0
276	14000.0	5000.0	-124.0
277	14000.0	5480.0	-139.0
278	14000.0	5750.0	-172.0
279	14000.0	5940.0	-215.0
280	14000.0	6500.0	-226.0
281	14000.0	7000.0	-247.0
282	14000.0	8000.0	-279.0
283	14000.0	-283.0	-166.0
284	14000.0	-590.0	-284.0
285	14000.0	-940.0	-418.0
286	14000.0	-1070.0	-428.0
287	14000.0	-1170.0	-415.0
288	14000.0	-1405.0	-375.0
289	14000.0	-1630.0	-371.0
290	14000.0	-2000.0	-365.0
291	14000.0	-2340.0	-368.0
292	14000.0	-2680.0	-381.0
293	14000.0	-2890.0	-433.0
294	14000.0	-2970.0	-434.0
295	14000.0	-3090.0	-405.0
296	14000.0	-3530.0	-272.0
297	14000.0	-3940.0	-170.0
298	14000.0	-4170.0	-152.0
299	14000.0	-4260.0	-139.0
300	14000.0	-4360.0	-150.0
301	14000.0	-4420.0	-187.0
302	14000.0	-5000.0	-208.0
303	14000.0	-5620.0	-222.0
304	14000.0	-6000.0	-234.0
305	14000.0	-7000.0	-319.0
306	14000.0	-6000.0	-368.0
307	14000.0	-9000.0	-413.0
308	14000.0	-10000.0	-465.0
309	13999.9	-11000.0	-550.0
310	13999.9	-12000.0	-645.0
311	16000.0	250.0	-66.0
312	16000.0	445.0	-62.0

Table A1 (Continued)

T.P.	X	Y	Z
313	16000.0	1000.0	-78.0
314	16000.0	2000.0	-83.0
315	16000.0	3000.0	-88.0
316	16000.0	4000.0	-91.0
317	16000.0	5000.0	-86.0
318	16000.0	6000.0	-110.0
319	16000.0	6620.0	-166.0
320	16000.0	7000.0	-172.0
321	16000.0	8000.0	-187.0
322	15478.1	1512.4	-51.0
323	16000.0	-400.0	-251.0
324	16000.0	-935.0	-451.0
325	16000.0	-1070.0	-468.0
326	16000.0	-1360.0	-419.0
327	16000.0	-1610.0	-412.0
328	16000.0	-2000.0	-404.0
329	16000.0	-2360.0	-409.0
330	16000.0	-2670.0	-423.0
331	16000.0	-2900.0	-475.0
332	16000.0	-3100.0	-452.0
333	16000.0	-3570.0	-282.0
334	16000.0	-3990.0	-167.0
335	16000.0	-4240.0	-94.0
336	16000.0	-4410.0	-111.0
337	16000.0	-5000.0	-130.0
338	16000.0	-6000.0	-189.0
339	16000.0	-7000.0	-248.0
340	16000.0	-7400.0	-264.0
341	16000.0	-8000.0	-283.0
342	16000.0	-8810.0	-325.0
343	16000.0	-9500.0	-525.0
344	16000.0	-10000.0	-680.0
345	15999.9	-10600.0	-710.0
346	15999.9	-11000.0	-721.0
347	15999.9	-12000.0	-730.0
348	18000.0	361.9	-87.0
349	18000.0	434.9	-117.0
350	18000.0	999.9	-147.0
351	18000.0	1999.9	-186.0

Table A1 (Continued)

I.P.	X	Y	Z
352	18000.0	2439.9	-198.0
353	18000.0	2579.9	-177.0
354	18000.0	3499.9	-167.0
355	18000.0	4499.9	-153.0
356	18000.0	4999.9	-147.0
357	18000.0	5999.9	-134.0
358	18000.0	6749.9	-100.0
359	18000.0	7199.9	-174.0
360	18000.0	7999.9	-193.0
361	18518.7	4575.6	-158.0
362	18000.0	-380.1	-282.0
363	18000.0	-860.1	-442.0
364	18000.0	-1100.1	-494.0
365	18000.0	-1390.1	-447.0
366	18000.0	-1620.1	-440.0
367	18000.0	-2000.1	-433.0
368	18000.0	-2360.1	-438.0
369	18000.0	-2650.1	-454.0
370	18000.0	-2880.1	-497.0
371	18000.0	-3060.1	-473.0
372	18000.0	-3560.1	-295.0
373	18000.0	-3850.1	-241.0
374	18000.0	-4290.1	-110.0
375	18000.0	-4380.1	-101.0
376	18000.0	-4440.1	-151.0
377	18000.0	-5000.1	-172.0
378	18000.0	-6000.1	-219.0
379	18000.0	-6650.1	-275.0
380	18000.0	-7000.1	-287.0
381	18000.0	-7700.1	-437.0
382	18000.0	-8000.1	-517.0
383	18000.0	-9000.1	-697.0
384	18000.0	-10000.1	-832.0
385	18000.0	-1100.1	-857.0
386	17999.9	-12000.1	-847.0
387	20000.0	319.9	-126.0
388	20000.0	439.9	-163.0
389	20000.0	999.9	-200.0
390	20000.0	1999.9	-243.0

Table A1 (Concluded)

T.P.	X	Y	Z
391	20000.0	2999.9	-296.0
392	20000.0	3999.9	-291.0
393	20000.0	4999.9	-237.0
394	20000.0	5999.9	-198.0
395	20000.0	6999.9	-182.0
396	20000.0	7999.9	-205.0
397	20000.0	-360.1	-307.0
398	20000.0	-700.1	-412.0
399	20000.0	-1020.1	-515.0
400	20000.0	-1120.1	-529.0
401	20000.0	-1360.1	-481.0
402	20000.0	-1630.1	-471.0
403	20000.0	-2000.1	-463.0
404	20000.0	-2370.1	-468.0
405	20000.0	-2620.1	-476.0
406	20000.0	-2840.1	-524.0
407	20000.0	-3055.1	-493.0
408	20000.0	-3620.1	-306.0
409	20000.0	-4230.1	-161.0
410	20000.0	-4370.1	-211.0
411	20000.0	-5000.1	-292.0
412	20000.0	-5320.1	-347.0
413	20000.0	-6000.1	-452.0
414	20000.0	-7000.1	-567.0
415	20000.0	-8000.1	-692.0
416	20000.0	-9000.1	-787.0
417	20000.0	-10000.1	-862.0
418	19999.9	-11000.1	-868.0
419	19999.9	-12000.1	-873.0

Table A2

Topographic Data

Road Site 2

T.P.	X	Y	Z
1	0.	0.	0.
2	2000.0	0.	-41.0
3	4000.0	-0.0	-74.0
4	6000.0	-0.0	-116.0
5	8000.0	-0.0	-154.0
6	10000.0	-0.0	-191.0
7	12000.0	-0.0	-235.0
8	14000.0	-0.0	-278.0
9	16000.0	-0.0	-324.0
10	18000.0	-0.1	-376.0
11	20000.0	-0.1	-427.0
12	0.0	152.0	4.0
13	0.0	467.0	2.0
14	0.0	787.0	-4.0
15	0.0	1055.0	-31.0
16	0.0	1290.0	-75.0
17	0.0	1620.0	-56.0
18	0.0	2352.0	-43.0
19	0.0	3000.0	-34.0
20	0.0	4000.0	-23.0
21	0.0	5000.0	-40.0
22	0.0	6000.0	-55.0
23	0.0	7000.0	-79.0
24	0.0	8000.0	-119.0
25	0.0	9000.0	-168.0
26	0.0	9580.0	-194.0
27	0.0	10500.0	-110.0
28	-0.0	-500.0	-88.0
29	-0.0	-880.0	-146.0
30	-0.0	-1200.0	-141.0
31	-0.0	-2200.0	-89.0
32	-0.0	-3000.0	10.0
33	-0.0	-4000.0	128.0
34	-0.0	-4600.0	190.0
35	-0.0	-5600.0	229.0
36	-0.0	-6000.0	250.0
37	-0.0	-7000.0	315.0
38	-0.0	-8000.0	317.0
39	-0.0	-9000.0	278.0

Table A2 (Continued)

T.P.	X	Y	Z
40	-0.0	-9500.0	240.0
41	2000.0	120.0	-37.0
42	2000.0	430.0	-38.0
43	2000.0	755.0	-47.0
44	2000.0	1095.0	-95.0
45	2000.0	1695.0	-214.0
46	2000.0	2275.0	-214.0
47	2000.0	3000.0	-207.0
48	2000.0	4000.0	-204.0
49	2000.0	5000.0	-209.0
50	2000.0	6000.0	-223.0
51	2000.0	7000.0	-243.0
52	2000.0	8000.0	-247.0
53	2000.0	9000.0	-211.0
54	2000.0	10000.0	-123.0
55	2000.0	10500.0	-72.0
56	2000.0	-390.0	-95.0
57	2000.0	-720.0	-143.0
58	2000.0	-1700.0	-72.0
59	2000.0	-2700.0	23.0
60	2000.0	-3000.0	53.0
61	2000.0	-4000.0	147.0
62	2000.0	-5000.0	220.0
63	2000.0	-5600.0	255.0
64	2000.0	-6000.0	265.0
65	2000.0	-7000.0	263.0
66	2000.0	-8000.0	248.0
67	2000.0	-9000.0	213.0
68	2000.0	-9500.0	184.0
69	4000.0	100.0	-72.0
70	4000.0	410.0	-77.0
71	4000.0	740.0	-84.0
72	4000.0	956.0	-107.0
73	4000.0	1690.0	-256.0
74	4000.0	2225.0	-258.0
75	4000.0	3000.0	-278.0
76	4000.0	4000.0	-293.0
77	4000.0	5000.0	-297.0
78	4000.0	6000.0	-287.0

Table A2 (Continued)

T.P.	X	Y	Z
79	4000.0	7000.0	-252.0
80	4000.0	8000.0	-170.0
81	4000.0	9000.0	-76.0
82	4000.0	10000.0	7.0
83	4000.0	10500.0	61.0
84	4000.0	-190.0	-95.0
85	4000.0	-375.0	-117.0
86	4000.0	-1000.0	-84.0
87	4000.0	-1100.0	-51.0
88	4000.0	-2000.0	8.0
89	4000.0	-3000.0	72.0
90	4000.0	-4000.0	140.0
91	4000.0	-5000.0	184.0
92	4000.0	-6000.0	200.0
93	4000.0	-7000.0	191.0
94	4000.0	-8000.0	177.0
95	4000.0	-9000.0	115.0
96	4000.0	-9500.0	87.0
97	6000.0	80.0	-112.0
98	6000.0	410.0	-117.0
99	6000.0	744.0	-123.0
100	6000.0	955.0	-151.0
101	6000.0	1380.0	-225.0
102	6000.0	2032.0	-304.0
103	6000.0	2300.0	-300.0
104	6000.0	3000.0	-319.0
105	6000.0	4000.0	-335.0
106	6000.0	4310.0	-351.0
107	6000.0	5000.0	-313.0
108	6000.0	6000.0	-289.0
109	6000.0	7000.0	-189.0
110	6000.0	8000.0	-97.0
111	6000.0	9000.0	-9.0
112	6000.0	10000.0	69.0
113	6000.0	10500.0	67.0
114	6000.0	-350.0	-149.0
115	6000.0	-785.0	-97.0
116	6000.0	-1000.0	-74.0
117	6000.0	-2000.0	-3.0

Table A2 (Continued)

T.P.	X	Y	Z
118	6000.0	-3000.0	52.0
119	6000.0	-4000.0	95.0
120	6000.0	-5000.0	122.0
121	6000.0	-6000.0	119.0
122	6000.0	-7000.0	123.0
123	6000.0	-8000.0	104.0
124	6000.0	-9000.0	45.0
125	6000.0	-9500.0	5.0
126	8000.0	90.0	-151.0
127	8000.0	410.0	-156.0
128	8000.0	755.0	-161.0
129	8000.0	1036.0	-190.0
130	8000.0	1715.0	-299.0
131	8000.0	2140.0	-339.0
132	8000.0	2345.0	-346.0
133	8000.0	3000.0	-379.0
134	8000.0	4000.0	-389.0
135	8000.0	5000.0	-353.0
136	8000.0	6000.0	-299.0
137	8000.0	7000.0	-222.0
138	8000.0	8000.0	-123.0
139	8000.0	9000.0	-56.0
140	8000.0	10000.0	3.0
141	8000.0	10500.0	3.0
142	8000.0	-300.0	-181.0
143	8000.0	-1000.0	-152.0
144	8000.0	-1255.0	-151.0
145	8000.0	-2000.0	-152.0
146	8000.0	-3000.0	-119.0
147	8000.0	-4000.0	-30.0
148	8000.0	-4665.0	-1.0
149	8000.0	-5000.0	6.0
150	8000.0	-5225.0	7.0
151	8000.0	-5370.0	-46.0
152	8000.0	-5610.0	-36.0
153	8000.0	-5770.0	38.0
154	8000.0	-6000.0	51.0
155	8000.0	-7000.0	36.0
156	8000.0	-8000.0	-3.0

Table A2 (Continued)

T.P.	X	Y	Z
157	8000.0	-9000.0	-50.0
158	8000.0	-9500.0	-54.0
159	10000.0	125.0	-188.0
160	10000.0	437.0	-194.0
161	10000.0	770.0	-201.0
162	10000.0	1028.0	-225.0
163	10000.0	1440.0	-318.0
164	10000.0	1910.0	-393.0
165	10000.0	2400.0	-414.0
166	10000.0	3000.0	-414.0
167	10000.0	4000.0	-409.0
168	10000.0	5000.0	-383.0
169	10000.0	6000.0	-307.0
170	10000.0	7000.0	-234.0
171	10000.0	8000.0	-145.0
172	10000.0	9000.0	-80.0
173	10000.0	10000.0	-64.0
174	10000.0	10500.0	-62.0
175	10000.0	-440.0	-261.0
176	10000.0	-945.0	-326.0
177	10000.0	-1165.0	-325.0
178	10000.0	-2000.0	-291.0
179	10000.0	-2470.0	-257.0
180	10000.0	-3000.0	-206.0
181	10000.0	-4000.0	-142.0
182	10000.0	-5000.0	-70.0
183	10000.0	-6000.0	-67.0
184	10000.0	-6220.0	-60.0
185	10000.0	-6610.0	-119.0
186	10000.0	-6915.0	-123.0
187	10000.0	-7060.0	-182.0
188	10000.0	-7515.0	-186.0
189	10000.0	-7890.0	-194.0
190	10000.0	-8200.0	-105.0
191	10000.0	-8430.0	-66.0
192	10000.0	-9000.0	-107.0
193	10000.0	-9500.0	-149.0
194	12000.0	155.0	-230.0
195	12000.0	500.0	-235.0

Table A2 (Continued)

T.P.	X	Y	Z
196	12000.0	830.0	-242.0
197	12000.0	1050.0	-268.0
198	12000.0	1510.0	-388.0
199	12000.0	2065.0	-512.0
200	12000.0	2310.0	-470.0
201	12000.0	2470.0	-447.0
202	12000.0	3000.0	-442.0
203	12000.0	4000.0	-409.0
204	12000.0	5000.0	-365.0
205	12000.0	6000.0	-266.0
206	12000.0	7000.0	-166.0
207	12000.0	8000.0	-141.0
208	12000.0	9000.0	-132.0
209	12000.0	10000.0	-122.0
210	12000.0	10500.0	-124.0
211	12000.0	-135.0	-251.0
212	12000.0	-470.0	-322.0
213	12000.0	-1000.0	-387.0
214	12000.0	-1715.0	-378.0
215	12000.0	-2000.0	-350.0
216	12000.0	-3000.0	-252.0
217	12000.0	-4000.0	-192.0
218	12000.0	-5000.0	-158.0
219	12000.0	-6000.0	-154.0
220	12000.0	-7000.0	-158.0
221	12000.0	-8000.0	-167.0
222	12000.0	-8640.0	-204.0
223	12000.0	-9000.0	-248.0
224	12000.0	-9500.0	-265.0
225	14000.0	225.0	-274.0
226	14000.0	555.0	-274.0
227	14000.0	890.0	-280.0
228	14000.0	1235.0	-327.0
229	14000.0	1630.0	-431.0
230	14000.0	2220.0	-581.0
231	14000.0	2360.0	-527.0
232	14000.0	2520.0	-502.0
233	14000.0	3000.0	-480.0
234	14000.0	4000.0	-404.0

Table A2 (Continued)

T.P.	X	Y	Z
235	14000.0	5000.0	-341.0
236	14000.0	6000.0	-270.0
237	14000.0	7000.0	-188.0
238	14000.0	8000.0	-182.0
239	14000.0	9000.0	-188.0
240	14000.0	10000.0	-181.0
241	14000.0	10500.0	-204.0
242	14000.0	-380.0	-354.0
243	14000.0	-700.0	-403.0
244	14000.0	-1000.0	-427.0
245	14000.0	-2000.0	-396.0
246	14000.0	-3000.0	-303.0
247	14000.0	-4000.0	-262.0
248	14000.0	-5000.0	-240.0
249	14000.0	-6000.0	-239.0
250	14000.0	-6670.0	-241.0
251	14000.0	-7000.0	-233.0
252	14000.0	-8000.0	-250.0
253	14000.0	-9000.0	-253.0
254	14000.0	-9500.0	-251.0
255	14541.1	-957.8	-467.0
256	14813.1	-2348.2	-394.0
257	15527.8	-3696.8	-357.0
258	15922.6	-3277.8	-508.0
259	15268.4	-2055.1	-534.0
260	14784.1	-895.2	-499.0
261	15771.9	-2168.1	-624.0
262	15519.7	-1604.6	-636.0
263	15373.3	-887.3	-631.0
264	15369.1	-884.6	-630.0
265	16000.0	310.0	-303.0
266	16000.0	620.0	-309.0
267	16000.0	955.0	-315.0
268	16000.0	1390.0	-374.0
269	16000.0	2100.0	-481.0
270	16000.0	2610.0	-495.0
271	16000.0	3000.0	-483.0
272	16000.0	4000.0	-391.0
273	16000.0	5000.0	-347.0

Table A2 (Continued)

T.P.	X	Y	Z
274	16000.0	6000.0	-279.0
275	16000.0	7000.0	-260.0
276	16000.0	8000.0	-249.0
277	16000.0	9000.0	-261.0
278	16000.0	10000.0	-305.0
279	16000.0	10500.0	-323.0
280	16000.0	-400.0	-411.0
281	16000.0	-830.0	-480.0
282	16000.0	-1760.0	-612.0
283	16000.0	-2270.0	-621.0
284	16000.0	-2700.0	-617.0
285	16000.0	-3000.0	-578.0
286	16000.0	-3570.0	-471.0
287	16000.0	-4100.0	-379.0
288	16000.0	-5000.0	-371.0
289	16000.0	-6000.0	-367.0
290	16000.0	-7000.0	-338.0
291	16000.0	-8000.0	-316.0
292	16000.0	-8450.0	-309.0
293	16000.0	-9000.0	-316.0
294	16000.0	-9500.0	-334.0
295	18000.0	139.9	-342.0
296	18000.0	409.9	-332.0
297	18000.0	729.9	-337.0
298	18000.0	1069.9	-342.0
299	18000.0	1529.9	-413.0
300	18000.0	2239.9	-496.0
301	18000.0	2669.9	-488.0
302	18000.0	2999.9	-481.0
303	18000.0	3999.9	-441.0
304	18000.0	4999.9	-401.0
305	18000.0	5999.9	-357.0
306	18000.0	6999.9	-352.0
307	18000.0	7999.9	-353.0
308	18000.0	8999.9	-355.0
309	18000.0	9999.9	-392.0
310	18000.0	10499.9	-410.0
311	18000.0	-500.1	-483.0
312	18000.0	-1115.1	-551.0

Table A2 (Continued)

T.P.	X	Y	Z
313	18000.0	-2000.1	-542.0
314	18000.0	-3000.1	-533.0
315	18000.0	-3630.1	-636.0
316	18000.0	-3900.1	-638.0
317	18000.0	-4135.1	-628.0
318	18000.0	-4480.1	-549.0
319	18000.0	-4900.1	-489.0
320	18000.0	-5000.1	-489.0
321	18000.0	-5500.1	-478.0
322	18000.0	-6000.1	-459.0
323	18000.0	-7000.1	-429.0
324	18000.0	-8000.1	-385.0
325	18000.0	-9000.1	-395.0
326	18000.0	-9500.1	-410.0
327	20000.0	269.9	-367.0
328	20000.0	529.9	-357.0
329	20000.0	839.9	-361.0
330	20000.0	1179.9	-367.0
331	20000.0	1649.9	-441.0
332	20000.0	2379.9	-540.0
333	20000.0	2749.9	-554.0
334	20000.0	2999.9	-553.0
335	20000.0	3999.9	-536.0
336	20000.0	4999.9	-517.0
337	20000.0	5999.9	-498.0
338	20000.0	6999.9	-480.0
339	20000.0	7999.9	-450.0
340	20000.0	8999.9	-458.0
341	20000.0	9999.9	-473.0
342	20000.0	10499.9	-490.0
343	20000.0	-320.1	-501.0
344	20000.0	-1015.1	-605.0
345	20000.0	-2000.1	-628.0
346	20000.0	-3000.1	-627.0
347	20000.0	-4000.1	-613.0
348	20000.0	-4340.1	-646.0
349	20000.0	-4510.1	-651.0
350	20000.0	-4635.1	-648.0
351	20000.0	-5000.1	-583.0

Table A2 (Concluded)

T.P.	X	Y	Z
352	20000.0	-6000.1	-554.0
353	20000.0	-7000.1	-537.0
354	20000.0	-8000.1	-537.0
355	20000.0	-9000.1	-539.0
356	20000.0	-9500.1	-545.0

Table A3

Topographic Data

Road Site 3

T.P.	X	Y	Z
1	0,	0,	0,
2	2000.0	0,	17.0
3	4000.0	-0.0	22.0
4	6000.0	-0.0	27.0
5	8000.0	-0.0	25.0
6	10000.0	-0.0	22.0
7	12000.0	-0.0	20.0
8	14000.0	-0.0	21.0
9	16000.0	-0.0	24.0
10	18000.0	-0.1	32.0
11	20000.0	-0.1	41.0
12	0.0	260.0	-15.0
13	0.0	400.0	-131.0
14	0.0	550.0	-181.0
15	0.0	700.0	-131.0
16	0.0	810.0	-74.0
17	0.0	940.0	-5.0
18	0.0	1140.0	-72.0
19	0.0	1270.0	-96.0
20	0.0	2000.0	-98.0
21	0.0	3000.0	-96.0
22	0.0	4000.0	-97.0
23	0.0	5000.0	-96.0
24	0.0	6000.0	-96.0
25	0.0	6950.0	-96.0
26	-0.0	-260.0	-11.0
27	-0.0	-350.0	-84.0
28	-0.0	-760.0	-97.0
29	-0.0	-930.0	-208.0
30	-0.0	-980.0	-223.0
31	-0.0	-1030.0	-208.0
32	-0.0	-1160.0	-144.0
33	-0.0	-1540.0	-90.0
34	-0.0	-1970.0	-75.0
35	-0.0	-2375.0	6.0
36	-0.0	-2650.0	33.0
37	-0.0	-3050.0	46.0
38	-0.0	-3420.0	34.0
39	-0.0	-3820.0	-9.0

Table A3 (Continued)

T.P.	X	Y	Z
40	-0.0	-4455.0	-92.0
41	-0.0	-4640.0	-123.0
42	-0.0	-4790.0	-96.0
43	-0.0	-5025.0	-53.0
44	-0.0	-5255.0	53.0
45	-0.0	-5510.0	-45.0
46	-0.0	-5660.0	-195.0
47	-0.0	-5770.0	-245.0
48	-0.0	-5920.0	-197.0
49	-0.0	-6070.0	-58.0
50	-0.0	-7000.0	-45.0
51	-0.0	-8000.0	-46.0
52	-0.0	-9000.0	-46.0
53	-0.0	-10000.0	-45.0
54	-0.0	-11000.0	-45.0
55	-0.0	-12000.0	-46.0
56	-0.0	-13000.0	-45.0
57	-0.0	-13050.0	-45.0
58	10000.0	295.0	29.0
59	10000.0	450.0	-114.0
60	10000.0	575.0	-169.0
61	10000.0	700.0	-114.0
62	10000.0	965.0	9.0
63	10000.0	1160.0	-57.0
64	10000.0	1260.0	-70.0
65	10000.0	2000.0	-68.0
66	10000.0	3000.0	-68.0
67	10000.0	4000.0	-70.0
68	10000.0	5000.0	-69.0
69	10000.0	6000.0	-68.0
70	10000.0	6950.0	-70.0
71	10000.0	-215.0	9.0
72	10000.0	-350.0	-88.0
73	10000.0	-665.0	-81.0
74	10000.0	-835.0	-205.0
75	10000.0	-910.0	-235.0
76	10000.0	-985.0	-205.0
77	10000.0	-1105.0	-145.0
78	10000.0	-1400.0	-98.0

Table A3 (Continued)

T.P.	X	Y	Z
79	10000.0	-1855,0	-92,0
80	10000.0	-2410,0	8,0
81	10000.0	-2650,0	38,0
82	10000.0	-3050,0	47,0
83	10000.0	-3400,0	37,0
84	10000.0	-4030,0	-42,0
85	10000.0	-4500,0	-99,0
86	10000.0	-4660,0	-135,0
87	10000.0	-4840,0	-85,0
88	10000.0	-5070,0	-32,0
89	10000.0	-5285,0	64,0
90	10000.0	-5550,0	-42,0
91	10000.0	-5630,0	-172,0
92	10000.0	-5730,0	-203,0
93	10000.0	-5830,0	-173,0
94	10000.0	-5920,0	-48,0
95	10000.0	-6500,0	-23,0
96	10000.0	-7000,0	-13,0
97	10000.0	-8000,0	-8,0
98	10000.0	-9000,0	-11,0
99	10000.0	-10000,0	-9,0
100	9999.9	-11000,0	-10,0
101	9999.9	-12000,0	-11,0
102	9999.9	-13050,0	-8,0
103	20000.0	324,9	30,0
104	20000.0	499,9	-103,0
105	20000.0	659,9	-168,0
106	20000.0	819,9	-103,0
107	20000.0	834,9	-61,0
108	20000.0	1049,9	26,0
109	20000.0	1329,9	-54,0
110	20000.0	1449,9	-74,0
111	20000.0	1999,9	-73,0
112	20000.0	2999,9	-74,0
113	20000.0	3999,9	-74,0
114	20000.0	4999,9	-73,0
115	20000.0	5999,9	-73,0
116	20000.0	6949,9	-73,0
117	20000.0	-220,1	35,0

Table A3 (Continued)

T.P.	X	Y	Z
118	20000.0	-390.1	11.0
119	20000.0	-770.1	-114.0
120	20000.0	-830.1	-189.0
121	20000.0	-905.1	-239.0
122	20000.0	-980.1	-189.0
123	20000.0	-1120.1	-120.0
124	20000.0	-1515.1	-61.0
125	20000.0	-2000.1	-55.0
126	20000.0	-2650.1	56.0
127	20000.0	-3050.1	67.0
128	20000.0	-3390.1	58.0
129	20000.0	-4080.1	-40.0
130	20000.0	-4260.1	-64.0
131	20000.0	-4660.1	-150.0
132	20000.0	-4835.1	-87.0
133	20000.0	-5230.1	72.0
134	20000.0	-5400.1	35.0
135	20000.0	-5525.1	-27.0
136	20000.0	-5645.1	-167.0
137	20000.0	-5710.1	-207.0
138	20000.0	-5920.1	-167.0
139	20000.0	-6010.1	-38.0
140	20000.0	-6500.1	-23.0
141	20000.0	-7000.1	-26.0
142	20000.0	-8000.1	-25.0
143	20000.0	-9000.1	-27.0
144	20000.0	-10000.1	-29.0
145	19999.9	-11000.1	-28.0
146	19999.9	-12000.1	-27.0
147	19999.9	-13000.1	-27.0
148	19999.9	-13050.1	-27.0
149	2000.0	260.0	7.0
150	2000.0	400.0	-109.0
151	2000.0	550.0	-159.0
152	2000.0	700.0	-109.0
153	2000.0	810.0	-52.0
154	2000.0	940.0	17.0
155	2000.0	1135.0	-50.0
156	2000.0	1275.0	-75.0

Table A3 (Continued)

T.P.	X	Y	Z
157	2000.0	2000.0	-77.0
158	2000.0	3000.0	-74.0
159	2000.0	4000.0	-73.0
160	2000.0	5000.0	-75.0
161	2000.0	6000.0	-75.0
162	2000.0	6950.0	-75.0
163	2000.0	-260.0	10.0
164	2000.0	-350.0	-62.0
165	2000.0	-760.0	-75.0
166	2000.0	-930.0	-186.0
167	2000.0	-980.0	-201.0
168	2000.0	-1030.0	-186.0
169	2000.0	-1160.0	-121.0
170	2000.0	-1540.0	-69.0
171	2000.0	-1970.0	-52.0
172	2000.0	-2375.0	28.0
173	2000.0	-2650.0	55.0
174	2000.0	-3050.0	68.0
175	2000.0	-3420.0	56.0
176	2000.0	-3825.0	13.0
177	2000.0	-4460.0	-71.0
178	2000.0	-4640.0	-101.0
179	2000.0	-4790.0	-74.0
180	2000.0	-5030.0	-31.0
181	2000.0	-5255.0	75.0
182	2000.0	-5510.0	-23.0
183	2000.0	-5660.0	-173.0
184	2000.0	-5775.0	-223.0
185	2000.0	-5920.0	-175.0
186	2000.0	-6070.0	-36.0
187	2000.0	-7000.0	-23.0
188	2000.0	-8000.0	-24.0
189	2000.0	-9000.0	-24.0
190	2000.0	-10000.0	-22.0
191	2000.0	-11000.0	-22.0
192	2000.0	-12000.0	-24.0
193	2000.0	-13000.0	-25.0
194	2000.0	-13050.0	-24.0
195	4000.0	265.0	27.0

Table A3 (Continued)

T.P.	X	Y	Z
196	4000,0	400,0	-89,0
197	4000,0	550,0	-139,0
198	4000,0	700,0	-89,0
199	4000,0	810,0	-32,0
200	4000,0	945,0	37,0
201	4000,0	1150,0	-30,0
202	4000,0	1270,0	-54,0
203	4000,0	2000,0	-56,0
204	4000,0	3000,0	-54,0
205	4000,0	4000,0	-55,0
206	4000,0	5000,0	-54,0
207	4000,0	6000,0	-54,0
208	4000,0	6950,0	-54,0
209	4000,0	-260,0	31,0
210	4000,0	-350,0	-42,0
211	4000,0	-760,0	-55,0
212	4000,0	-930,0	-166,0
213	4000,0	-980,0	-181.0
214	4000,0	-1030,0	-166,0
215	4000,0	-1160,0	-102,0
216	4000,0	-1540,0	-48,0
217	4000,0	-1970,0	-33,0
218	4000,0	-2375,0	48,0
219	4000,0	-2650,0	75,0
220	4000,0	-3050,0	88,0
221	4000,0	-3420,0	76,0
222	4000,0	-3820,0	33,0
223	4000,0	-4455,0	-50,0
224	4000,0	-4640,0	-81,0
225	4000,0	-4790,0	-54,0
226	4000,0	-5025,0	-11,0
227	4000,0	-5255,0	95,0
228	4000,0	-5510,0	-3,0
229	4000,0	-5660,0	-153,0
230	4000,0	-5770,0	-203,0
231	4000,0	-5920,0	-155,0
232	4000,0	-6070,0	-16,0
233	4000,0	-7000,0	-3,0
234	4000,0	-8000,0	-4,0

Table A3 (Continued)

T.P.	X	Y	Z
235	4000.0	-9000.0	-4.0
236	4000.0	-10000.0	-3.0
237	3999.9	-11000.0	-3.0
238	3999.9	-12000.0	-4.0
239	3999.9	-13000.0	-3.0
240	3999.9	-13050.0	-3.0
241	6000.0	280.0	12.0
242	6000.0	425.0	-104.0
243	6000.0	560.0	-154.0
244	6000.0	700.0	-104.0
245	6000.0	810.0	-47.0
246	6000.0	955.0	22.0
247	6000.0	1150.0	-45.0
248	6000.0	1265.0	-69.0
249	6000.0	2000.0	-71.0
250	6000.0	3000.0	-69.0
251	6000.0	4000.0	-70.0
252	6000.0	5000.0	-69.0
253	6000.0	6000.0	-69.0
254	6000.0	6950.0	-69.0
255	6000.0	-225.0	16.0
256	6000.0	-350.0	-81.0
257	6000.0	-685.0	-74.0
258	6000.0	-850.0	-198.0
259	6000.0	-900.0	-221.0
260	6000.0	-925.0	-228.0
261	6000.0	-1000.0	-198.0
262	6000.0	-1120.0	-138.0
263	6000.0	-1440.0	-91.0
264	6000.0	-1885.0	-85.0
265	6000.0	-2400.0	15.0
266	6000.0	-2650.0	45.0
267	6000.0	-3050.0	54.0
268	6000.0	-3408.0	44.0
269	6000.0	-3975.0	-35.0
270	6000.0	-4490.0	-38.0
271	6000.0	-4650.0	-128.0
272	6000.0	-4800.0	-78.0
273	6000.0	-5060.0	-25.0

Table A3 (Continued)

T.P.	X	Y	Z
274	6000.0	-5275.0	71.0
275	6000.0	-5540.0	-35.0
276	6000.0	-5640.0	-165.0
277	6000.0	-5740.0	-196.0
278	6000.0	-5840.0	-166.0
279	6000.0	-5935.0	-41.0
280	6000.0	-6500.0	-16.0
281	6000.0	-7000.0	-6.0
282	6000.0	-8000.0	-1.0
283	6000.0	-9000.0	-4.0
284	6000.0	-10000.0	-2.0
285	5999.9	-11000.0	-3.0
286	5999.9	-12000.0	-4.0
287	5999.9	-13000.0	-3.0
288	5999.9	-13050.0	-4.0
289	8000.0	290.0	34.0
290	8000.0	445.0	-109.0
291	8000.0	570.0	-164.0
292	8000.0	700.0	-109.0
293	8000.0	960.0	14.0
294	8000.0	1160.0	-52.0
295	8000.0	1260.0	-65.0
296	8000.0	2000.0	-63.0
297	8000.0	3000.0	-63.0
298	8000.0	4000.0	-65.0
299	8000.0	5000.0	-64.0
300	8000.0	6000.0	-63.0
301	8000.0	6950.0	-65.0
302	8000.0	-220.0	14.0
303	8000.0	-350.0	-83.0
304	8000.0	-680.0	-76.0
305	8000.0	-850.0	-200.0
306	8000.0	-920.0	-230.0
307	8000.0	-990.0	-200.0
308	8000.0	-1115.0	-140.0
309	8000.0	-1420.0	-93.0
310	8000.0	-1865.0	-87.0
311	8000.0	-2400.0	13.0
312	8000.0	-2650.0	43.0

Table A3 (Continued)

T.P.	X	Y	Z
313	8000.0	-3050.0	52.0
314	8000.0	-3400.0	42.0
315	8000.0	-4000.0	-37.0
316	8000.0	-4490.0	-94.0
317	8000.0	-4660.0	-130.0
318	8000.0	-4830.0	-80.0
319	8000.0	-5060.0	-27.0
320	8000.0	-5280.0	69.0
321	8000.0	-5540.0	-37.0
322	8000.0	-5640.0	-167.0
323	8000.0	-5740.0	-198.0
324	8000.0	-5840.0	-168.0
325	8000.0	-5930.0	-43.0
326	8000.0	-6500.0	-18.0
327	8000.0	-7000.0	-8.0
328	8000.0	-8000.0	-3.0
329	8000.0	-9000.0	-6.0
330	8000.0	-10000.0	-4.0
331	7999.9	-11000.0	-5.0
332	7999.9	-12000.0	-6.0
333	7999.9	-13000.0	-5.0
334	7999.9	-13050.0	-4.0
335	12000.0	295.0	29.0
336	12000.0	450.0	-114.0
337	12000.0	575.0	-169.0
338	12000.0	700.0	-114.0
339	12000.0	965.0	9.0
340	12000.0	1160.0	-57.0
341	12000.0	1260.0	-70.0
342	12000.0	2000.0	-68.0
343	12000.0	3000.0	-68.0
344	12000.0	4000.0	-70.0
345	12000.0	5000.0	-69.0
346	12000.0	6000.0	-68.0
347	12000.0	6950.0	-70.0
348	12000.0	-215.0	9.0
349	12000.0	-350.0	-88.0
350	12000.0	-665.0	-81.0
351	12000.0	-835.0	-205.0

Table A3 (Continued)

T.P.	X	Y	Z
352	12000.0	-910.0	-235.0
353	12000.0	-985.0	-205.0
354	12000.0	-1105.0	-145.0
355	12000.0	-1400.0	-98.0
356	12000.0	-1855.0	-92.0
357	12000.0	-2410.0	8.0
358	12000.0	-2650.0	38.0
359	12000.0	-3050.0	47.0
360	12000.0	-3400.0	37.0
361	12000.0	-4030.0	-42.0
362	12000.0	-4500.0	-99.0
363	12000.0	-4660.0	-135.0
364	12000.0	-4840.0	-85.0
365	12000.0	-5070.0	-32.0
366	12000.0	-5285.0	64.0
367	12000.0	-5550.0	-42.0
368	12000.0	-5630.0	-172.0
369	12000.0	-5730.0	-203.0
370	12000.0	-5830.0	-173.0
371	12000.0	-5920.0	-48.0
372	12000.0	-6500.0	-23.0
373	12000.0	-7000.0	-13.0
374	12000.0	-8000.0	-8.0
375	12000.0	-9000.0	-11.0
376	12000.0	-10000.0	-9.0
377	11999.9	-11000.0	-10.0
378	11999.9	-12000.0	-11.0
379	11999.9	-13000.0	-10.0
380	11999.9	-13050.0	-8.0
381	14000.0	310.0	30.0
382	14000.0	470.0	-113.0
383	14000.0	620.0	-168.0
384	14000.0	770.0	-113.0
385	14000.0	1000.0	10.0
386	14000.0	1260.0	-56.0
387	14000.0	1360.0	-69.0
388	14000.0	2000.0	-67.0
389	14000.0	3000.0	-67.0
390	14000.0	4000.0	-69.0

Table A3 (Continued)

T.P.	X	Y	Z
391	14000.0	5000.0	-68.0
392	14000.0	6000.0	-67.0
393	14000.0	6950.0	-69.0
394	14000.0	-215.0	10.0
395	14000.0	-350.0	-87.0
396	14000.0	-720.0	-80.0
397	14000.0	-830.0	-204.0
398	14000.0	-910.0	-234.0
399	14000.0	-985.0	-204.0
400	14000.0	-1105.0	-144.0
401	14000.0	-1450.0	-97.0
402	14000.0	-1925.0	-91.0
403	14000.0	-2410.0	9.0
404	14000.0	-2650.0	39.0
405	14000.0	-3050.0	48.0
406	14000.0	-3400.0	38.0
407	14000.0	-4030.0	-41.0
408	14000.0	-4500.0	-98.0
409	14000.0	-4660.0	-134.0
410	14000.0	-4840.0	-84.0
411	14000.0	-5070.0	-31.0
412	14000.0	-5285.0	65.0
413	14000.0	-5550.0	-41.0
414	14000.0	-5630.0	-171.0
415	14000.0	-5730.0	-202.0
416	14000.0	-5830.0	-172.0
417	14000.0	-5920.0	-47.0
418	14000.0	-6500.0	-22.0
419	14000.0	-7000.0	-12.0
420	14000.0	-8000.0	-7.0
421	14000.0	-10000.0	-10.0
422	13999.9	-11000.0	-8.0
423	13999.9	-12000.0	-9.0
424	13999.9	-13050.0	-7.0
425	16000.0	315.0	32.0
426	16000.0	475.0	-111.0
427	16000.0	625.0	-166.0
428	16000.0	790.0	-111.0
429	16000.0	1020.0	12.0

Table A3 (Continued)

T.P.	X	Y	Z
430	16000.0	1280.0	-54.0
431	16000.0	1380.0	-67.0
432	16000.0	2000.0	-65.0
433	16000.0	3000.0	-65.0
434	16000.0	4000.0	-67.0
435	16000.0	5000.0	-66.0
436	16000.0	6000.0	-65.0
437	16000.0	6950.0	-67.0
438	16000.0	-215.0	12.0
439	16000.0	-350.0	-85.0
440	16000.0	-720.0	-78.0
441	16000.0	-830.0	-202.0
442	16000.0	-910.0	-232.0
443	16000.0	-985.0	-202.0
444	16000.0	-1105.0	-142.0
445	16000.0	-1450.0	-95.0
446	16000.0	-1925.0	-89.0
447	16000.0	-2410.0	11.0
448	16000.0	-2650.0	41.0
449	16000.0	-3050.0	50.0
450	16000.0	-3400.0	40.0
451	16000.0	-4030.0	-39.0
452	16000.0	-4500.0	-96.0
453	16000.0	-4660.0	-132.0
454	16000.0	-4840.0	-82.0
455	16000.0	-5070.0	-29.0
456	16000.0	-5285.0	67.0
457	16000.0	-5550.0	-39.0
458	16000.0	-5630.0	-169.0
459	16000.0	-5730.0	-200.0
460	16000.0	-5830.0	-170.0
461	16000.0	-5920.0	-45.0
462	16000.0	-6500.0	-20.0
463	16000.0	-7000.0	-10.0
464	16000.0	-8000.0	-5.0
465	16000.0	-9000.0	-8.0
466	16000.0	-10000.0	-6.0
467	15999.9	-11000.0	-7.0
468	15999.9	-12000.0	-8.0

Table A3 (Continued)

T.P.	X	Y	Z
469	15999.9	-13050.0	-6.0
470	18000.0	319.9	21.0
471	18000.0	489.9	-112.0
472	18000.0	639.9	-177.0
473	18000.0	799.9	-112.0
474	18000.0	819.9	-70.0
475	18000.0	1029.9	17.0
476	18000.0	1299.9	-63.0
477	18000.0	1419.9	-83.0
478	18000.0	1999.9	-82.0
479	18000.0	2999.9	-83.0
480	18000.0	3999.9	-83.0
481	18000.0	4999.9	-82.0
482	18000.0	5999.9	-82.0
483	18000.0	6949.9	-82.0
484	18000.0	-220.1	26.0
485	18000.0	-380.1	2.0
486	18000.0	-770.1	-123.0
487	18000.0	-830.1	-198.0
488	18000.0	-905.1	-248.0
489	18000.0	-980.1	-198.0
490	18000.0	-1115.1	-129.0
491	18000.0	-1500.1	-70.0
492	18000.0	-2000.1	-64.0
493	18000.0	-2650.1	47.0
494	18000.0	-3050.1	58.0
495	18000.0	-3390.1	49.0
496	18000.0	-4080.1	-49.0
497	18000.0	-4260.1	-73.0
498	18000.0	-4660.1	-159.0
499	18000.0	-4835.1	-96.0
500	18000.0	-5230.1	63.0
501	18000.0	-5400.1	26.0
502	18000.0	-5525.1	-36.0
503	18000.0	-5625.1	-176.0
504	18000.0	-5710.1	-216.0
505	18000.0	-5920.1	-176.0
506	18000.0	-6010.1	-47.0
507	18000.0	-6500.1	-32.0

Table A3 (Concluded)

T.P.	X	Y	Z
508	18000.0	-7000.1	-35.0
509	18000.0	-8000.1	-34.0
510	18000.0	-9000.1	-36.0
511	18000.0	-10000.1	-38.0
512	17999.9	-11000.1	-37.0
513	17999.9	-12000.1	-36.0
514	17999.9	-13000.1	-36.0
515	17999.9	-13050.1	-36.0

(Sheet 14 of 14)

Table A4

Topographic Data

Road Site 4

T.P.	X	Y	Z
1	0.	0.	0.
2	2000.0	0.	1.0
3	4000.0	-0.0	4.0
4	6000.0	-0.0	7.0
5	8000.0	-0.0	10.0
6	10000.0	-0.0	9.0
7	12000.0	-0.0	13.0
8	14000.0	-0.0	12.0
9	16000.0	-0.0	15.0
10	18000.0	-0.1	16.0
11	20000.0	-0.1	17.0
12	-0.0	-115.0	2.0
13	-0.0	-500.0	13.0
14	-0.0	-880.0	0.0
15	-0.0	-1080.0	-4.0
16	-0.0	-1470.0	-165.0
17	-0.0	-2040.0	-371.0
18	-0.0	-2680.0	-364.0
19	-0.0	-3200.0	-340.0
20	-0.0	-3690.0	-309.0
21	-0.0	-4000.0	-287.0
22	-0.0	-5000.0	-274.0
23	-0.0	-6000.0	-269.0
24	-0.0	-7000.0	-264.0
25	-0.0	-8000.0	-264.0
26	-0.0	-9000.0	-264.0
27	-0.0	-10000.0	-264.0
28	-0.0	-10500.0	-264.0
29	0.0	100.0	1.0
30	0.0	500.0	-185.0
31	0.0	880.0	-325.0
32	0.0	1210.0	-391.0
33	0.0	1760.0	-413.0
34	0.0	2130.0	-396.0
35	0.0	2380.0	-400.0
36	0.0	2640.0	-308.0
37	0.0	2940.0	-319.0
38	0.0	3270.0	-338.0
39	0.0	3500.0	-409.0

Table A4 (Continued)

T.P.	X	Y	Z
40	0.0	4150.0	-608.0
41	0.0	4800.0	-727.0
42	0.0	5410.0	-849.0
43	0.0	5700.0	-909.0
44	0.0	5900.0	-1004.0
45	0.0	6270.0	-1019.0
46	0.0	6570.0	-1004.0
47	0.0	6830.0	-964.0
48	0.0	7130.0	-849.0
49	0.0	7700.0	-801.0
50	0.0	8360.0	-618.0
51	0.0	8770.0	-491.0
52	0.0	9100.0	-319.0
53	0.0	9500.0	-310.0
54	0.0	11000.0	-273.0
55	0.0	11600.0	-227.0
56	4000.0	-115.0	6.0
57	4000.0	-500.0	19.0
58	4000.0	-880.0	6.0
59	4000.0	-1090.0	-1.0
60	4000.0	-1540.0	-188.0
61	4000.0	-2050.0	-355.0
62	4000.0	-2570.0	-370.0
63	4000.0	-3200.0	-339.0
64	4000.0	-3700.0	-307.0
65	4000.0	-4600.0	-275.0
66	4000.0	-5700.0	-253.0
67	4000.0	-6000.0	-252.0
68	4000.0	-7000.0	-251.0
69	4000.0	-8000.0	-255.0
70	4000.0	-9000.0	-258.0
71	4000.0	-10000.0	-256.0
72	3999.9	-10500.0	-257.0
73	4000.0	100.0	9.0
74	4000.0	500.0	-170.0
75	4000.0	940.0	-361.0
76	4000.0	1580.0	-424.0
77	4000.0	2370.0	-419.0
78	4000.0	2600.0	-337.0

Table A4 (Continued)

T.P.	X	Y	Z
79	4000.0	3000.0	-376.0
80	4000.0	3450.0	-422.0
81	4000.0	3890.0	-557.0
82	4000.0	4200.0	-661.0
83	4000.0	4690.0	-796.0
84	4000.0	4875.0	-856.0
85	4000.0	5170.0	-926.0
86	4000.0	5842.0	-966.0
87	4000.0	6512.0	-946.0
88	4000.0	6810.0	-856.0
89	4000.0	6910.0	-776.0
90	4000.0	7020.0	-811.0
91	4000.0	7440.0	-672.0
92	4000.0	8045.0	-533.0
93	4000.0	8600.0	-331.0
94	4000.0	9500.0	-311.0
95	4000.0	10010.0	-326.0
96	4000.0	10500.0	-299.0
97	8000.0	-120.0	12.0
98	8000.0	-500.0	20.0
99	8000.0	-880.0	11.0
100	8000.0	-1200.0	2.0
101	8000.0	-1515.0	-156.0
102	8000.0	-2100.0	-323.0
103	8000.0	-2700.0	-344.0
104	8000.0	-3100.0	-343.0
105	8000.0	-3600.0	-281.0
106	8000.0	-3970.0	-268.0
107	8000.0	-4500.0	-260.0
108	8000.0	-5000.0	-261.0
109	8000.0	-6000.0	-257.0
110	8000.0	-7000.0	-259.0
111	8000.0	-8000.0	-255.0
112	8000.0	-9000.0	-256.0
113	8000.0	-10000.0	-255.0
114	7999.9	-10500.0	-257.0
115	8000.0	110.0	0.0
116	8000.0	480.0	-162.0
117	8000.0	1110.0	-380.0

Table A4 (Continued)

T.P.	X	Y	Z
118	8000,0	1720,0	-405,0
119	8000,0	2300,0	-413,0
120	8000,0	2580,0	-359,0
121	8000,0	3000,0	-382,0
122	8000,0	3450,0	-436,0
123	8000,0	3950,0	-655,0
124	8000,0	4665,0	-850,0
125	8000,0	4815,0	-895,0
126	8000,0	5050,0	-950,0
127	8000,0	5657,0	-985,0
128	8000,0	6000,0	-982,0
129	8000,0	6350,0	-975,0
130	8000,0	6650,0	-850,0
131	8000,0	6750,0	-800,0
132	8000,0	7200,0	-748,0
133	8000,0	7800,0	-558,0
134	8000,0	8300,0	-379,0
135	8000,0	9300,0	-340,0
136	8000,0	9500,0	-336,0
137	8000,0	10500,0	-293,0
138	8000,0	11100,0	-223,0
139	12000,0	-120,0	19,0
140	12000,0	-500,0	25,0
141	12000,0	-880,0	16,0
142	12000,0	-1100,0	11,0
143	12000,0	-1470,0	-150,0
144	12000,0	-1990,0	-352,0
145	12000,0	-2525,0	-384,0
146	12000,0	-2945,0	-388,0
147	12000,0	-3440,0	-303,0
148	12000,0	-4000,0	-277,0
149	12000,0	-5000,0	-251,0
150	12000,0	-6000,0	-249,0
151	12000,0	-7000,0	-250,0
152	12000,0	-8000,0	-248,0
153	12000,0	-9000,0	-239,0
154	12000,0	-10000,0	-243,0
155	11999,9	-10500,0	-245,0
156	12000,0	80,0	11,0

Table A4 (Continued)

T.P.	X	Y	Z
157	12000.0	460.0	-137.0
158	12000.0	1000.0	-331.0
159	12000.0	1700.0	-382.0
160	12000.0	2600.0	-378.0
161	12000.0	3000.0	-429.0
162	12000.0	3640.0	-549.0
163	12000.0	4050.0	-671.0
164	12000.0	4610.0	-850.0
165	12000.0	4800.0	-930.0
166	12000.0	5670.0	-973.0
167	12000.0	6430.0	-959.0
168	12000.0	6730.0	-850.0
169	12000.0	7000.0	-746.0
170	12000.0	7490.0	-651.0
171	12000.0	8000.0	-459.0
172	12000.0	9000.0	-344.0
173	12000.0	9500.0	-305.0
174	12000.0	10230.0	-224.0
175	12000.0	10980.0	-212.0
176	12000.0	11900.0	-209.0
177	16000.0	-110.0	18.0
178	16000.0	-500.0	28.0
179	16000.0	-880.0	18.0
180	16000.0	-1105.0	12.0
181	16000.0	-1545.0	-168.0
182	16000.0	-2150.0	-348.0
183	16000.0	-2600.0	-379.0
184	16000.0	-2970.0	-385.0
185	16000.0	-3400.0	-309.0
186	16000.0	-4000.0	-267.0
187	16000.0	-5000.0	-250.0
188	16000.0	-6000.0	-244.0
189	16000.0	-7000.0	-242.0
190	16000.0	-8000.0	-245.0
191	16000.0	-9000.0	-238.0
192	16000.0	-10000.0	-240.0
193	15999.9	-10500.0	-240.0
194	16000.0	110.0	12.0
195	16000.0	490.0	-161.0

Table A4 (Continued)

T.P.	X	Y	Z
196	16000.0	1060.0	-340.0
197	16000.0	1750.0	-377.0
198	16000.0	2580.0	-339.0
199	16000.0	3000.0	-367.0
200	16000.0	3460.0	-457.0
201	16000.0	3945.0	-601.0
202	16000.0	4650.0	-839.0
203	16000.0	4950.0	-929.0
204	16000.0	5800.0	-979.0
205	16000.0	6450.0	-919.0
206	16000.0	6750.0	-839.0
207	16000.0	7200.0	-692.0
208	16000.0	7700.0	-521.0
209	16000.0	8700.0	-452.0
210	16000.0	9500.0	-329.0
211	16000.0	10000.0	-249.0
212	16000.0	10620.0	-230.0
213	20000.0	-125.1	25.0
214	20000.0	-500.1	32.0
215	20000.0	-890.1	22.0
216	20000.0	-1110.1	19.0
217	20000.0	-1585.1	-166.0
218	20000.0	-2170.1	-360.0
219	20000.0	-2575.1	-380.0
220	20000.0	-2870.1	-381.0
221	20000.0	-3350.1	-283.0
222	20000.0	-4000.1	-264.0
223	20000.0	-5000.1	-246.0
224	20000.0	-6000.1	-239.0
225	20000.0	-7000.1	-233.0
226	20000.0	-8000.1	-233.0
227	20000.0	-9000.1	-234.0
228	20000.0	-10000.1	-238.0
229	19999.9	-10500.1	-238.0
230	20000.0	89.9	15.0
231	20000.0	479.9	-66.0
232	20000.0	869.9	-310.0
233	20000.0	1244.9	-374.0
234	20000.0	1734.9	-395.0

Table A4 (Continued)

T.P.	X	Y	Z
235	20000.0	2319.9	-404.0
236	20000.0	2559.9	-338.0
237	20000.0	2954.9	-359.0
238	20000.0	3329.9	-447.0
239	20000.0	4099.9	-631.0
240	20000.0	4829.9	-856.0
241	20000.0	5129.9	-956.0
242	20000.0	5864.9	-984.0
243	20000.0	6599.9	-926.0
244	20000.0	6899.9	-856.0
245	20000.0	7799.9	-653.0
246	20000.0	8529.9	-526.0
247	20000.0	8919.9	-377.0
248	20000.0	9299.9	-272.0
249	20000.0	9499.9	-273.0
250	20000.0	9799.9	-270.0
251	20000.0	10499.9	-261.0
252	2000.0	-115.0	3.0
253	2000.0	-500.0	14.0
254	2000.0	-880.0	1.0
255	2000.0	-1080.0	-3.0
256	2000.0	-1470.0	-164.0
257	2000.0	-2040.0	-370.0
258	2000.0	-2680.0	-363.0
259	2000.0	-3200.0	-339.0
260	2000.0	-3690.0	-308.0
261	2000.0	-4000.0	-286.0
262	2000.0	-5000.0	-273.0
263	2000.0	-6000.0	-268.0
264	2000.0	-7000.0	-263.0
265	2000.0	-8000.0	-263.0
266	2000.0	-9000.0	-263.0
267	2000.0	-10000.0	-263.0
268	2000.0	-10500.0	-263.0
269	2000.0	100.0	2.0
270	2000.0	500.0	-184.0
271	2000.0	880.0	-324.0
272	2000.0	1210.0	-390.0
273	2000.0	1760.0	-412.0

Table A4 (Continued)

T.P.	X	Y	Z
274	2000.0	2130.0	-395.0
275	2000.0	2380.0	-399.0
276	2000.0	2640.0	-307.0
277	2000.0	2940.0	-318.0
278	2000.0	3270.0	-337.0
279	2000.0	3500.0	-408.0
280	2000.0	4150.0	-607.0
281	2000.0	4800.0	-726.0
282	2000.0	5410.0	-848.0
283	2000.0	5700.0	-908.0
284	2000.0	5900.0	-1003.0
285	2000.0	6270.0	-1018.0
286	2000.0	6570.0	-1003.0
287	2000.0	6830.0	-963.0
288	2000.0	7130.0	-848.0
289	2000.0	7700.0	-800.0
290	2000.0	8360.0	-617.0
291	2000.0	8870.0	-490.0
292	2000.0	9100.0	-318.0
293	2000.0	9500.0	-309.0
294	2000.0	11000.0	-272.0
295	2000.0	11600.0	-226.0
296	6000.0	-120.0	9.0
297	6000.0	-500.0	17.0
298	6000.0	-880.0	8.0
299	6000.0	-1200.0	-1.0
300	6000.0	-1515.0	-159.0
301	6000.0	-2100.0	-326.0
302	6000.0	-2700.0	-347.0
303	6000.0	-3100.0	-346.0
304	6000.0	-3600.0	-284.0
305	6000.0	-3970.0	-271.0
306	6000.0	-4500.0	-263.0
307	6000.0	-5000.0	-264.0
308	6000.0	-6000.0	-260.0
309	6000.0	-7000.0	-262.0
310	6000.0	-8000.0	-258.0
311	6000.0	-9000.0	-259.0
312	6000.0	-10000.0	-258.0

Table A4 (Continued)

T.P.	X	Y	Z
313	5999.9	-10500.0	-260.0
314	6000.0	110.0	-3.0
315	6000.0	480.0	-165.0
316	6000.0	1110.0	-383.0
317	6000.0	1720.0	-408.0
318	6000.0	2300.0	-416.0
319	6000.0	2580.0	-362.0
320	6000.0	3000.0	-385.0
321	6000.0	3450.0	-439.0
322	6000.0	3950.0	-658.0
323	6000.0	4665.0	-853.0
324	6000.0	4815.0	-898.0
325	6000.0	5050.0	-953.0
326	6000.0	5657.0	-988.0
327	6000.0	6000.0	-985.0
328	6000.0	6350.0	-978.0
329	6000.0	6650.0	-853.0
330	6000.0	6750.0	-803.0
331	6000.0	7200.0	-751.0
332	6000.0	7800.0	-561.0
333	6000.0	8300.0	-382.0
334	6000.0	9300.0	-343.0
335	6000.0	9500.0	-339.0
336	6000.0	10500.0	-296.0
337	6000.0	11100.0	-226.0
338	10000.0	-120.0	15.0
339	10000.0	-500.0	21.0
340	10000.0	-880.0	12.0
341	10000.0	-1100.0	7.0
342	10000.0	-1470.0	-154.0
343	10000.0	-1990.0	-356.0
344	10000.0	-2525.0	-388.0
345	10000.0	-2945.0	-392.0
346	10000.0	-3440.0	-307.0
347	10000.0	-4000.0	-281.0
348	10000.0	-5000.0	-255.0
349	10000.0	-6000.0	-253.0
350	10000.0	-7000.0	-254.0
351	10000.0	-8000.0	-252.0

Table A4 (Continued)

T.P.	X	Y	Z
352	10000.0	-9000.0	-243.0
353	10000.0	-10000.0	-247.0
354	9999.9	-10500.0	-249.0
355	10000.0	80.0	7.0
356	10000.0	460.0	-141.0
357	10000.0	1000.0	-335.0
358	10000.0	1700.0	-386.0
359	10000.0	2600.0	-382.0
360	10000.0	3000.0	-433.0
361	10000.0	3640.0	-553.0
362	10000.0	4050.0	-675.0
363	10000.0	4610.0	-854.0
364	10000.0	4800.0	-934.0
365	10000.0	5670.0	-977.0
366	10000.0	6430.0	-963.0
367	10000.0	6730.0	-854.0
368	10000.0	7000.0	-750.0
369	10000.0	7490.0	-655.0
370	10000.0	8000.0	-463.0
371	10000.0	9000.0	-348.0
372	10000.0	9500.0	-309.0
373	10000.0	10230.0	-228.0
374	10000.0	10980.0	-216.0
375	10000.0	11900.0	-213.0
376	14000.0	-110.0	15.0
377	14000.0	-500.0	25.0
378	14000.0	-880.0	15.0
379	14000.0	-1105.0	9.0
380	14000.0	-1545.0	-171.0
381	14000.0	-2150.0	-351.0
382	14000.0	-2600.0	-382.0
383	14000.0	-2970.0	-388.0
384	14000.0	-3400.0	-312.0
385	14000.0	-4000.0	-270.0
386	14000.0	-5000.0	-253.0
387	14000.0	-6000.0	-247.0
388	14000.0	-7000.0	-245.0
389	14000.0	-8000.0	-248.0
390	14000.0	-9000.0	-241.0

Table A4 (Continued)

T.P.	X	Y	Z
391	14000.0	-10000.0	-243.0
392	13999.9	-10500.0	-243.0
393	14000.0	110.0	9.0
394	14000.0	490.0	-164.0
395	14000.0	1060.0	-343.0
396	14000.0	1750.0	-380.0
397	14000.0	2580.0	-342.0
398	14000.0	3000.0	-370.0
399	14000.0	3460.0	-460.0
400	14000.0	3945.0	-604.0
401	14000.0	4650.0	-842.0
402	14000.0	4950.0	-932.0
403	14000.0	5800.0	-982.0
404	14000.0	6450.0	-922.0
405	14000.0	6750.0	-842.0
406	14000.0	7200.0	-695.0
407	14000.0	7700.0	-524.0
408	14000.0	8700.0	-455.0
409	14000.0	9500.0	-332.0
410	14000.0	10000.0	-252.0
411	14000.0	10620.0	-233.0
412	18000.0	-125.1	30.0
413	18000.0	-500.1	37.0
414	18000.0	-890.1	27.0
415	18000.0	-1110.1	24.0
416	18000.0	-1585.1	-161.0
417	18000.0	-2170.1	-355.0
418	18000.0	-2575.1	-375.0
419	18000.0	-2870.1	-376.0
420	18000.0	-3350.1	-278.0
421	18000.0	-4000.1	-259.0
422	18000.0	-5000.1	-241.0
423	18000.0	-6000.1	-234.0
424	18000.0	-7000.1	-228.0
425	18000.0	-8000.1	-228.0
426	18000.0	-9000.1	-228.0
427	18000.0	-10000.1	-233.0
428	17999.9	-10500.1	-233.0
429	18000.0	89.9	20.0

Table A4 (Concluded)

T.P.	X	Y	Z
430	18000.0	479.9	-61.0
431	18000.0	869.9	-305.0
432	18000.0	1244.9	-369.0
433	18000.0	1734.9	-390.0
434	18000.0	2319.9	-399.0
435	18000.0	2559.9	-333.0
436	18000.0	2954.9	-354.0
437	18000.0	3329.9	-442.0
438	18000.0	4099.9	-626.0
439	18000.0	4829.9	-851.0
440	18000.0	5129.9	-951.0
441	18000.0	5864.9	-979.0
442	18000.0	6599.9	-921.0
443	18000.0	6899.9	-851.0
444	18000.0	7799.9	-648.0
445	18000.0	8529.9	-521.0
446	18000.0	8919.9	-372.0
447	18000.0	9299.9	-267.0
448	18000.0	9499.9	-268.0
449	18000.0	9799.9	-265.0
450	18000.0	10499.9	-256.0

Table A5

Topographic Data

Road Site 5

T.P.	X	Y	Z
1	0.	0.	0.
2	2000.0	0.	-4.0
3	4000.0	-0.0	-24.0
4	6000.0	-0.0	-37.0
5	8000.0	-0.0	-58.0
6	10000.0	-0.0	-77.0
7	12000.0	-0.0	-92.0
8	14000.0	-0.0	-119.0
9	16000.0	-0.0	-142.0
10	18000.0	-0.1	-167.0
11	20000.0	-0.1	-169.0
12	-0.0	-110.0	-27.0
13	-0.0	-440.0	-162.0
14	-0.0	-980.0	-387.0
15	-0.0	-1615.0	-474.0
16	-0.0	-1870.0	-539.0
17	-0.0	-2000.0	-547.0
18	-0.0	-2325.0	-497.0
19	-0.0	-3000.0	-441.0
20	-0.0	-4000.0	-419.0
21	-0.0	-5000.0	-375.0
22	-0.0	-6000.0	-322.0
23	-0.0	-7000.0	-279.0
24	-0.0	-8000.0	-251.0
25	-0.0	-9000.0	-212.0
26	-0.0	-9500.0	-207.0
27	0.0	165.0	12.0
28	0.0	485.0	7.0
29	0.0	815.0	1.0
30	0.0	1015.0	-23.0
31	0.0	1300.0	-135.0
32	0.0	1740.0	-279.0
33	0.0	2030.0	-313.0
34	0.0	2290.0	-297.0
35	0.0	3000.0	-260.0
36	0.0	4000.0	-181.0
37	0.0	5000.0	-113.0
38	0.0	6000.0	-35.0
39	0.0	7000.0	18.0

Table A5 (Continued)

T.P.	X	Y	Z
40	0.0	8000.0	73.0
41	0.0	9000.0	126.0
42	0.0	10000.0	143.0
43	0.0	10500.0	143.0
44	2000.0	-175.0	-35.0
45	2000.0	-420.0	-135.0
46	2000.0	-875.0	-363.0
47	2000.0	-1285.0	-460.0
48	2000.0	-1660.0	-520.0
49	2000.0	-2035.0	-574.0
50	2000.0	-2240.0	-574.0
51	2000.0	-2530.0	-516.0
52	2000.0	-3000.0	-484.0
53	2000.0	-4000.0	-448.0
54	2000.0	-5000.0	-433.0
55	2000.0	-6000.0	-430.0
56	2000.0	-7000.0	-405.0
57	2000.0	-8000.0	-365.0
58	2000.0	-9000.0	-329.0
59	2000.0	-9500.0	-319.0
60	2000.0	115.0	0.0
61	2000.0	445.0	-6.0
62	2000.0	800.0	-15.0
63	2000.0	1000.0	-40.0
64	2000.0	1255.0	-124.0
65	2000.0	1550.0	-195.0
66	2000.0	1840.0	-203.0
67	2000.0	2210.0	-177.0
68	2000.0	3000.0	-119.0
69	2000.0	4000.0	-50.0
70	2000.0	5000.0	-5.0
71	2000.0	6000.0	31.0
72	2000.0	6360.0	51.0
73	2000.0	7000.0	111.0
74	2000.0	7280.0	142.0
75	2000.0	8000.0	163.0
76	2000.0	9000.0	213.0
77	2000.0	9600.0	222.0
78	2000.0	10000.0	233.0

Table A5 (Continued)

T.P.	X	Y	Z
79	2000.0	10500.0	239.0
80	4000.0	-150.0	-35.0
81	4000.0	-520.0	-180.0
82	4000.0	-1175.0	-463.0
83	4000.0	-1670.0	-532.0
84	4000.0	-2000.0	-562.0
85	4000.0	-2290.0	-574.0
86	4000.0	-2625.0	-542.0
87	4000.0	-3000.0	-517.0
88	4000.0	-3790.0	-377.0
89	4000.0	-4000.0	-364.0
90	4000.0	-5000.0	-326.0
91	4000.0	-6000.0	-233.0
92	4000.0	-7000.0	-212.0
93	4000.0	-8000.0	-216.0
94	4000.0	-9000.0	-172.0
95	4000.0	-9500.0	-159.0
96	4000.0	80.0	-22.0
97	4000.0	410.0	-25.0
98	4000.0	745.0	-30.0
99	4000.0	950.0	-49.0
100	4000.0	1300.0	-181.0
101	4000.0	1735.0	-320.0
102	4000.0	2280.0	-312.0
103	4000.0	3000.0	-282.0
104	4000.0	4000.0	-245.0
105	4000.0	5000.0	-178.0
106	4000.0	6000.0	-70.0
107	4000.0	7000.0	5.0
108	4000.0	7450.0	61.0
109	4000.0	8000.0	98.0
110	4000.0	8300.0	128.0
111	4000.0	8800.0	177.0
112	4000.0	9000.0	185.0
113	4000.0	10000.0	220.0
114	4000.0	10500.0	225.0
115	6000.0	-170.0	-59.0
116	6000.0	-435.0	-161.0
117	6000.0	-820.0	-360.0

Table A5 (Continued)

T.P.	X	Y	Z
118	6000.0	-1225.0	-515.0
119	6000.0	-1500.0	-562.0
120	6000.0	-2025.0	-601.0
121	6000.0	-2400.0	-581.0
122	6000.0	-3000.0	-579.0
123	6000.0	-4000.0	-496.0
124	6000.0	-5000.0	-422.0
125	6000.0	-6000.0	-322.0
126	6000.0	-7000.0	-228.0
127	6000.0	-8000.0	-115.0
128	6000.0	-9000.0	-69.0
129	6000.0	-9500.0	-46.0
130	6000.0	55.0	-35.0
131	6000.0	405.0	-43.0
132	6000.0	750.0	-49.0
133	6000.0	930.0	-65.0
134	6000.0	1280.0	-197.0
135	6000.0	1570.0	-334.0
136	6000.0	2000.0	-469.0
137	6000.0	2500.0	-496.0
138	6000.0	3000.0	-474.0
139	6000.0	4000.0	-410.0
140	6000.0	5000.0	-328.0
141	6000.0	6000.0	-207.0
142	6000.0	7000.0	-108.0
143	6000.0	7360.0	-46.0
144	6000.0	8000.0	18.0
145	6000.0	8680.0	53.0
146	6000.0	9600.0	134.0
147	6000.0	10500.0	134.0
148	8000.0	-180.0	-81.0
149	8000.0	-500.0	-220.0
150	8000.0	-890.0	-423.0
151	8000.0	-1350.0	-581.0
152	8000.0	-1700.0	-621.0
153	8000.0	-2000.0	-609.0
154	8000.0	-3000.0	-592.0
155	8000.0	-4000.0	-558.0
156	8000.0	-5000.0	-520.0

Table A5 (Continued)

T.P.	X	Y	Z
157	8000.0	-6000.0	-462.0
158	8000.0	-7000.0	-367.0
159	8000.0	-8000.0	-281.0
160	8000.0	-9000.0	-207.0
161	8000.0	-9500.0	-176.0
162	8000.0	65.0	-57.0
163	8000.0	390.0	-64.0
164	8000.0	735.0	-70.0
165	8000.0	960.0	-95.0
166	8000.0	1285.0	-224.0
167	8000.0	1580.0	-367.0
168	8000.0	2100.0	-555.0
169	8000.0	2635.0	-608.0
170	8000.0	3000.0	-602.0
171	8000.0	4000.0	-523.0
172	8000.0	5000.0	-416.0
173	8000.0	6000.0	-317.0
174	8000.0	6600.0	-242.0
175	8000.0	7000.0	-204.0
176	8000.0	7400.0	-193.0
177	8000.0	8000.0	-132.0
178	8000.0	8300.0	-80.0
179	8000.0	9000.0	-69.0
180	8000.0	10000.0	-3.0
181	8000.0	10500.0	1.0
182	10000.0	-165.0	-88.0
183	10000.0	-470.0	-221.0
184	10000.0	-740.0	-347.0
185	10000.0	-1000.0	-464.0
186	10000.0	-1400.0	-547.0
187	10000.0	-1762.0	-531.0
188	10000.0	-2000.0	-513.0
189	10000.0	-3000.0	-437.0
190	10000.0	-4000.0	-371.0
191	10000.0	-5000.0	-353.0
192	10000.0	-6000.0	-333.0
193	10000.0	-7000.0	-304.0
194	10000.0	-8000.0	-282.0
195	10000.0	-9000.0	-232.0

Table A5 (Continued)

T.P.	X	Y	Z
196	10000.0	-9500.0	-192.0
197	10000.0	50.0	-75.0
198	10000.0	395.0	-81.0
199	10000.0	750.0	-89.0
200	10000.0	975.0	-118.0
201	10000.0	1410.0	-319.0
202	10000.0	1720.0	-463.0
203	10000.0	2200.0	-654.0
204	10000.0	2825.0	-696.0
205	10000.0	3500.0	-685.0
206	10000.0	4000.0	-666.0
207	10000.0	5000.0	-589.0
208	10000.0	6000.0	-492.0
209	10000.0	7000.0	-400.0
210	10000.0	7120.0	-397.0
211	10000.0	8000.0	-335.0
212	10000.0	9000.0	-237.0
213	10000.0	10000.0	-142.0
214	10000.0	10500.0	-122.0
215	12000.0	-142.0	-103.0
216	12000.0	-500.0	-239.0
217	12000.0	-840.0	-400.0
218	12000.0	-1380.0	-554.0
219	12000.0	-1540.0	-575.0
220	12000.0	-2000.0	-535.0
221	12000.0	-2565.0	-546.0
222	12000.0	-3000.0	-511.0
223	12000.0	-4000.0	-338.0
224	12000.0	-5000.0	-178.0
225	12000.0	-6000.0	-152.0
226	12000.0	-7000.0	-142.0
227	12000.0	-8000.0	-128.0
228	12000.0	-9000.0	-77.0
229	12000.0	-9500.0	-42.0
230	12000.0	90.0	-90.0
231	12000.0	420.0	-97.0
232	12000.0	770.0	-104.0
233	12000.0	1000.0	-138.0
234	12000.0	1340.0	-275.0

Table A5 (Continued)

T.P.	X	Y	Z
235	12000.0	1790.0	-476.0
236	12000.0	2150.0	-615.0
237	12000.0	2930.0	-711.0
238	12000.0	3500.0	-720.0
239	12000.0	4000.0	-730.0
240	12000.0	5000.0	-701.0
241	12000.0	6000.0	-660.0
242	12000.0	6800.0	-595.0
243	12000.0	7800.0	-583.0
244	12000.0	8000.0	-580.0
245	12000.0	9000.0	-508.0
246	12000.0	10000.0	-457.0
247	12000.0	10500.0	-436.0
248	14000.0	-50.0	-124.0
249	14000.0	-380.0	-234.0
250	14000.0	-665.0	-375.0
251	14000.0	-1000.0	-526.0
252	14000.0	-1360.0	-594.0
253	14000.0	-1660.0	-591.0
254	14000.0	-2000.0	-513.0
255	14000.0	-3000.0	-370.0
256	14000.0	-4000.0	-241.0
257	14000.0	-5000.0	-42.0
258	14000.0	-6000.0	-4.0
259	14000.0	-7000.0	-26.0
260	14000.0	-8000.0	-7.0
261	14000.0	-9000.0	66.0
262	14000.0	-9500.0	70.0
263	14000.0	120.0	-113.0
264	14000.0	470.0	-118.0
265	14000.0	820.0	-124.0
266	14000.0	1000.0	-142.0
267	14000.0	1290.0	-263.0
268	14000.0	1670.0	-449.0
269	14000.0	2100.0	-658.0
270	14000.0	2550.0	-705.0
271	14000.0	3000.0	-711.0
272	14000.0	4000.0	-801.0
273	14000.0	5000.0	-799.0

Table A5 (Continued)

T.P.	X	Y	Z
274	14000.0	6000.0	-794.0
275	14000.0	6300.0	-791.0
276	14000.0	7000.0	-784.0
277	14000.0	8000.0	-791.0
278	14000.0	9000.0	-786.0
279	14000.0	10000.0	-782.0
280	14000.0	10500.0	-781.0
281	16000.0	-255.0	-227.0
282	16000.0	-440.0	-315.0
283	16000.0	-870.0	-494.0
284	16000.0	-1165.0	-527.0
285	16000.0	-1425.0	-528.0
286	16000.0	-1680.0	-477.0
287	16000.0	-2200.0	-445.0
288	16000.0	-3000.0	-422.0
289	16000.0	-4000.0	-298.0
290	16000.0	-5000.0	-167.0
291	16000.0	-6000.0	-12.0
292	16000.0	-6440.0	82.0
293	16000.0	-7000.0	169.0
294	16000.0	-8000.0	248.0
295	16000.0	-9000.0	281.0
296	16000.0	-9500.0	317.0
297	16000.0	180.0	-127.0
298	16000.0	525.0	-132.0
299	16000.0	840.0	-139.0
300	16000.0	1000.0	-158.0
301	16000.0	1345.0	-304.0
302	16000.0	1820.0	-513.0
303	16000.0	2200.0	-601.0
304	16000.0	2800.0	-663.0
305	16000.0	3000.0	-668.0
306	16000.0	4000.0	-755.0
307	16000.0	5000.0	-823.0
308	16000.0	6000.0	-882.0
309	16000.0	7000.0	-879.0
310	16000.0	8000.0	-888.0
311	16000.0	9000.0	-898.0
312	16000.0	10000.0	-903.0

Table A5 (Continued)

T.P.	X	Y	Z
313	16000.0	10500.0	-904.0
314	18000.0	-300.1	-302.0
315	18000.0	-610.1	-408.0
316	18000.0	-1100.1	-447.0
317	18000.0	-1610.1	-444.0
318	18000.0	-2000.1	-433.0
319	18000.0	-3000.1	-408.0
320	18000.0	-4000.1	-257.0
321	18000.0	-5000.1	-21.0
322	18000.0	-6000.1	135.0
323	18000.0	-7000.1	296.0
324	18000.0	-8000.1	388.0
325	18000.0	-9000.1	424.0
326	18000.0	-9500.1	453.0
327	18000.0	99.9	-167.0
328	18000.0	239.9	-144.0
329	18000.0	569.9	-147.0
330	18000.0	899.9	-154.0
331	18000.0	1049.9	-178.0
332	18000.0	1499.9	-367.0
333	18000.0	1729.9	-443.0
334	18000.0	2159.9	-549.0
335	18000.0	2999.9	-625.0
336	18000.0	3999.9	-724.0
337	18000.0	4999.9	-770.0
338	18000.0	5329.9	-787.0
339	18000.0	5999.9	-818.0
340	18000.0	6999.9	-861.0
341	18000.0	7999.9	-883.0
342	18000.0	8999.9	-884.0
343	18000.0	9999.9	-912.0
344	18000.0	10499.9	-942.0
345	20000.0	-250.1	-197.0
346	20000.0	-600.1	-181.0
347	20000.0	-1000.1	-202.0
348	20000.0	-1800.1	-241.0
349	20000.0	-2000.1	-260.0
350	20000.0	-3000.1	-234.0
351	20000.0	-4000.1	-106.0

Table A5 (Concluded)

T.P.	X	Y	Z
352	20000.0	-5000.1	99.0
353	20000.0	-6000.1	240.0
354	20000.0	-7000.1	356.0
355	20000.0	-8000.1	425.0
356	20000.0	-9000.1	479.0
357	20000.0	-9500.1	518.0
358	20000.0	69.9	-164.0
359	20000.0	299.9	-162.0
360	20000.0	639.9	-167.0
361	20000.0	979.9	-177.0
362	20000.0	1149.9	-188.0
363	20000.0	1554.9	-245.0
364	20000.0	2149.9	-296.0
365	20000.0	2999.9	-438.0
366	20000.0	3999.9	-538.0
367	20000.0	4999.9	-644.0
368	20000.0	5999.9	-711.0
369	20000.0	6999.9	-802.0
370	20000.0	7999.9	-842.0
371	20000.0	8999.9	-902.0
372	20000.0	9999.9	-922.0
373	20000.0	10499.9	-927.0

Table A6

<u>Topographic Data (cm)</u>

<u>Road Site 6</u>

T.P.	X	Y	Z
1	0.	0.	0.
2	2000.0	0.	-70.0
3	4000.0	-0.0	-165.0
4	6000.0	-0.0	-241.0
5	8000.0	-0.0	-307.0
6	10000.0	-0.0	-382.0
7	12000.0	-0.0	-459.0
8	14000.0	-0.0	-559.0
9	16000.0	-0.0	-661.0
10	18000.0	-0.1	-693.0
11	20000.0	-0.1	-781.0
12	-0.0	-80.0	-7.0
13	-0.0	-200.0	-18.0
14	-0.0	-470.0	16.0
15	-0.0	-1100.0	11.0
16	-0.0	-1900.0	-52.0
17	-0.0	-2470.0	-157.0
18	-0.0	-2620.0	-357.0
19	-0.0	-3090.0	-478.0
20	-0.0	-3600.0	-713.0
21	-0.0	-4160.0	-893.0
22	-0.0	-4900.0	-1025.0
23	-0.0	-5800.0	-1305.0
24	-0.0	-6800.0	-1345.0
25	-0.0	-7400.0	-1015.0
26	-0.0	-7700.0	-1063.0
27	-0.0	-8270.0	-755.0
28	-0.0	-8700.0	-736.0
29	-0.0	-9300.0	-613.0
30	0.0	75.0	6.0
31	0.0	440.0	31.0
32	0.0	795.0	32.0
33	0.0	985.0	17.0
34	0.0	1115.0	-5.0
35	0.0	1270.0	44.0
36	0.0	1370.0	162.0
37	0.0	1600.0	242.0
38	0.0	1920.0	246.0
39	0.0	2500.0	191.0

Table A6 (Continued)

T.P.	X	Y	Z
40	0.0	3000.0	130.0
41	0.0	3720.0	51.0
42	0.0	4300.0	-71.0
43	0.0	4600.0	-58.0
44	0.0	5000.0	-241.0
45	0.0	6000.0	-341.0
46	0.0	6870.0	-433.0
47	0.0	7600.0	-565.0
48	0.0	8000.0	-545.0
49	0.0	9000.0	-565.0
50	0.0	9240.0	-565.0
51	0.0	9900.0	-415.0
52	0.0	10400.0	-415.0
53	0.0	10700.0	-325.0
54	2000.0	-160.0	-92.0
55	2000.0	-500.0	-21.0
56	2000.0	-955.0	-6.0
57	2000.0	-1500.0	-36.0
58	2000.0	-1700.0	-50.0
59	2000.0	-2000.0	-123.0
60	2000.0	-2945.0	-334.0
61	2000.0	-3410.0	-637.0
62	2000.0	-4320.0	-822.0
63	2000.0	-5200.0	-1029.0
64	2000.0	-5850.0	-1145.0
65	2000.0	-6500.0	-1357.0
66	2000.0	-7000.0	-1390.0
67	2000.0	-8000.0	-1332.0
68	2000.0	-8800.0	-1091.0
69	2000.0	-9300.0	-1023.0
70	2000.0	220.0	-60.0
71	2000.0	580.0	-46.0
72	2000.0	900.0	-47.0
73	2000.0	1075.0	-58.0
74	2000.0	1200.0	-89.0
75	2000.0	1370.0	-36.0
76	2000.0	1600.0	186.0
77	2000.0	2000.0	169.0
78	2000.0	2525.0	137.0

Table A6 (Continued)

T.P.	X	Y	Z
79	2000.0	3000.0	90.0
80	2000.0	3370.0	56.0
81	2000.0	3510.0	19.0
82	2000.0	4000.0	-1.0
83	2000.0	4560.0	-73.0
84	2000.0	4800.0	-150.0
85	2000.0	5260.0	-331.0
86	2000.0	6000.0	-388.0
87	2000.0	7000.0	-487.0
88	2000.0	7550.0	-555.0
89	2000.0	8000.0	-648.0
90	2000.0	9000.0	-705.0
91	2000.0	9650.0	-748.0
92	2000.0	10170.0	-705.0
93	2000.0	10400.0	-606.0
94	2000.0	10700.0	-557.0
95	4000.0	-343.0	-173.0
96	4000.0	-847.0	-149.0
97	4000.0	-1500.0	-154.0
98	4000.0	-2500.0	-168.0
99	4000.0	-3000.0	-186.0
100	4000.0	-4000.0	-309.0
101	4000.0	-4900.0	-433.0
102	4000.0	-5500.0	-698.0
103	4000.0	-6000.0	-880.0
104	4000.0	-6500.0	-1104.0
105	4000.0	-7000.0	-1384.0
106	4000.0	-7425.0	-1569.0
107	4000.0	-8000.0	-1593.0
108	4000.0	-8600.0	-1589.0
109	4000.0	-9000.0	-1544.0
110	4000.0	-9300.0	-1479.0
111	4000.0	290.0	-141.0
112	4000.0	660.0	-127.0
113	4000.0	980.0	-123.0
114	4000.0	1150.0	-137.0
115	4000.0	1270.0	-158.0
116	4000.0	1500.0	-98.0
117	4000.0	1720.0	104.0

Table A6 (Continued)

T.P.	X	Y	Z
118	4000.0	2120.0	109.0
119	4000.0	3000.0	55.0
120	4000.0	4000.0	-36.0
121	4000.0	4500.0	-56.0
122	4000.0	4790.0	-151.0
123	4000.0	5225.0	-168.0
124	4000.0	5860.0	-344.0
125	4000.0	6515.0	-420.0
126	4000.0	7000.0	-500.0
127	4000.0	7600.0	-544.0
128	4000.0	8000.0	-611.0
129	4000.0	9000.0	-730.0
130	4000.0	10000.0	-778.0
131	4000.0	10700.0	-770.0
132	6000.0	-320.0	-222.0
133	6000.0	-840.0	-207.0
134	6000.0	-950.0	-196.0
135	6000.0	-1030.0	-280.0
136	6000.0	-1500.0	-278.0
137	6000.0	-2000.0	-453.0
138	6000.0	-3000.0	-772.0
139	6000.0	-3570.0	-846.0
140	6000.0	-4220.0	-919.0
141	6000.0	-4550.0	-1019.0
142	6000.0	-5000.0	-1119.0
143	6000.0	-6000.0	-1212.0
144	6000.0	-7000.0	-1392.0
145	6000.0	-7520.0	-1492.0
146	6000.0	-8000.0	-1602.0
147	6000.0	-8600.0	-1671.0
148	6000.0	-9000.0	-1681.0
149	6000.0	-9300.0	-1701.0
150	6000.0	345.0	-221.0
151	6000.0	680.0	-211.0
152	6000.0	1010.0	-212.0
153	6000.0	1225.0	-221.0
154	6000.0	1340.0	-240.0
155	6000.0	1500.0	-176.0
156	6000.0	1740.0	69.0

Table A6 (Continued)

T.P.	X	Y	Z
157	6000.0	2240.0	74.0
158	6000.0	3000.0	29.0
159	6000.0	4000.0	-46.0
160	6000.0	4900.0	-106.0
161	6000.0	5160.0	-298.0
162	6000.0	5400.0	-399.0
163	6000.0	6000.0	-489.0
164	6000.0	7000.0	-543.0
165	6000.0	8000.0	-608.0
166	6000.0	8570.0	-626.0
167	6000.0	9000.0	-687.0
168	6000.0	10000.0	-800.0
169	6000.0	10700.0	-836.0
170	8000.0	-300.0	-265.0
171	8000.0	-700.0	-174.0
172	8000.0	-825.0	-165.0
173	8000.0	-1000.0	-150.0
174	8000.0	-1090.0	-206.0
175	8000.0	-1445.0	-208.0
176	8000.0	-2000.0	-309.0
177	8000.0	-2280.0	-382.0
178	8000.0	-3000.0	-601.0
179	8000.0	-3640.0	-496.0
180	8000.0	-4000.0	-599.0
181	8000.0	-5000.0	-884.0
182	8000.0	-5500.0	-852.0
183	8000.0	-6000.0	-952.0
184	8000.0	-6410.0	-1135.0
185	8000.0	-6700.0	-1178.0
186	8000.0	-7000.0	-1104.0
187	8000.0	-7335.0	-1060.0
188	8000.0	-7800.0	-1119.0
189	8000.0	-8000.0	-1159.0
190	8000.0	-8900.0	-1488.0
191	8000.0	-9300.0	-1658.0
192	8000.0	355.0	-299.0
193	8000.0	700.0	-291.0
194	8000.0	1040.0	-293.0
195	8000.0	1200.0	-304.0

Table A6 (Continued)

T.P.	X	Y	Z
196	8000.0	1340.0	-335.0
197	8000.0	1500.0	-271.0
198	8000.0	1800.0	-23.0
199	8000.0	2230.0	-14.0
200	8000.0	3000.0	-39.0
201	8000.0	4000.0	-96.0
202	8000.0	5000.0	-134.0
203	8000.0	6000.0	-211.0
204	8000.0	7000.0	-311.0
205	8000.0	8000.0	-414.0
206	8000.0	9000.0	-528.0
207	8000.0	9300.0	-632.0
208	8000.0	10000.0	-719.0
209	8000.0	10700.0	-794.0
210	10000.0	-360.0	-345.0
211	10000.0	-840.0	-210.0
212	10000.0	-1080.0	-130.0
213	10000.0	-1300.0	-133.0
214	10000.0	-1775.0	-120.0
215	10000.0	-2000.0	-154.0
216	10000.0	-3000.0	-343.0
217	10000.0	-4000.0	-500.0
218	10000.0	-4220.0	-527.0
219	10000.0	-4470.0	-584.0
220	10000.0	-5000.0	-739.0
221	10000.0	-5445.0	-936.0
222	10000.0	-5700.0	-948.0
223	10000.0	-6100.0	-987.0
224	10000.0	-6700.0	-946.0
225	10000.0	-7000.0	-1003.0
226	10000.0	-7715.0	-1139.0
227	10000.0	-8000.0	-1283.0
228	10000.0	-8775.0	-1519.0
229	10000.0	-9300.0	-1589.0
230	10000.0	150.0	-397.0
231	10000.0	335.0	-379.0
232	10000.0	700.0	-371.0
233	10000.0	1020.0	-375.0
234	10000.0	1170.0	-388.0

Table A6 (Continued)

T.P.	X	Y	Z
235	10000.0	1320.0	-433.0
236	10000.0	1500.0	-357.0
237	10000.0	1770.0	-111.0
238	10000.0	2180.0	-100.0
239	10000.0	3000.0	-158.0
240	10000.0	4000.0	-155.0
241	10000.0	5000.0	-152.0
242	10000.0	6000.0	-175.0
243	10000.0	7000.0	-259.0
244	10000.0	8000.0	-328.0
245	10000.0	9000.0	-405.0
246	10000.0	9700.0	-489.0
247	10000.0	10700.0	-646.0
248	12000.0	-415.0	-425.0
249	12000.0	-820.0	-269.0
250	12000.0	-1210.0	-158.0
251	12000.0	-2210.0	-169.0
252	12000.0	-3000.0	-344.0
253	12000.0	-4000.0	-548.0
254	12000.0	-5000.0	-806.0
255	12000.0	-6000.0	-1125.0
256	12000.0	-7000.0	-1259.0
257	12000.0	-8000.0	-1381.0
258	12000.0	-9000.0	-1419.0
259	12000.0	-9300.0	-1396.0
260	12000.0	210.0	-472.0
261	12000.0	350.0	-455.0
262	12000.0	700.0	-448.0
263	12000.0	1000.0	-457.0
264	12000.0	1200.0	-465.0
265	12000.0	1330.0	-509.0
266	12000.0	1500.0	-463.0
267	12000.0	1760.0	-228.0
268	12000.0	2225.0	-228.0
269	12000.0	3000.0	-247.0
270	12000.0	4000.0	-229.0
271	12000.0	5000.0	-195.0
272	12000.0	6000.0	-175.0
273	12000.0	7000.0	-183.0

Table A6 (Continued)

T.P.	X	Y	Z
274	12000.0	8000.0	-228.0
275	12000.0	9000.0	-311.0
276	12000.0	9800.0	-409.0
277	12000.0	10700.0	-540.0
278	14000.0	-400.0	-505.0
279	14000.0	-800.0	-401.0
280	14000.0	-1000.0	-350.0
281	14000.0	-2000.0	-381.0
282	14000.0	-3000.0	-408.0
283	14000.0	-3650.0	-353.0
284	14000.0	-4600.0	-383.0
285	14000.0	-5000.0	-503.0
286	14000.0	-5300.0	-471.0
287	14000.0	-5680.0	-519.0
288	14000.0	-6000.0	-654.0
289	14000.0	-6370.0	-679.0
290	14000.0	-6570.0	-773.0
291	14000.0	-7000.0	-760.0
292	14000.0	-7225.0	-696.0
293	14000.0	-7470.0	-685.0
294	14000.0	-8000.0	-796.0
295	14000.0	-8810.0	-858.0
296	14000.0	-9300.0	-874.0
297	14000.0	180.0	-559.0
298	14000.0	380.0	-533.0
299	14000.0	720.0	-526.0
300	14000.0	1070.0	-533.0
301	14000.0	1260.0	-540.0
302	14000.0	1390.0	-584.0
303	14000.0	1500.0	-519.0
304	14000.0	1730.0	-322.0
305	14000.0	2220.0	-347.0
306	14000.0	3000.0	-384.0
307	14000.0	4000.0	-349.0
308	14000.0	5000.0	-312.0
309	14000.0	6000.0	-223.0
310	14000.0	7000.0	-196.0
311	14000.0	8000.0	-200.0
312	14000.0	9000.0	-270.0

Table A6 (Continued)

T.P.	X	Y	Z
313	14000.0	10000.0	-372.0
314	14000.0	10290.0	-397.0
315	14000.0	10700.0	-479.0
316	16000.0	-150.0	-633.0
317	16000.0	-800.0	-579.0
318	16000.0	-1075.0	-561.0
319	16000.0	-1150.0	-601.0
320	16000.0	-1710.0	-583.0
321	16000.0	-2000.0	-675.0
322	16000.0	-3000.0	-821.0
323	16000.0	-4000.0	-856.0
324	16000.0	-4650.0	-769.0
325	16000.0	-5000.0	-629.0
326	16000.0	-5510.0	-503.0
327	16000.0	-6000.0	-353.0
328	16000.0	-6460.0	-292.0
329	16000.0	-6975.0	-343.0
330	16000.0	-7500.0	-381.0
331	16000.0	-8000.0	-411.0
332	16000.0	-9000.0	-405.0
333	16000.0	-9210.0	-398.0
334	16000.0	-9300.0	-432.0
335	16000.0	305.0	-607.0
336	16000.0	375.0	-604.0
337	16000.0	715.0	-602.0
338	16000.0	1090.0	-605.0
339	16000.0	1230.0	-627.0
340	16000.0	1415.0	-657.0
341	16000.0	1500.0	-627.0
342	16000.0	1690.0	-426.0
343	16000.0	2230.0	-458.0
344	16000.0	3000.0	-485.0
345	16000.0	4000.0	-442.0
346	16000.0	5000.0	-398.0
347	16000.0	6000.0	-313.0
348	16000.0	7000.0	-241.0
349	16000.0	8000.0	-219.0
350	16000.0	8650.0	-227.0
351	16000.0	9000.0	-231.0

Table A6 (Continued)

T.P.	X	Y	Z
352	16000.0	10000.0	-322.0
353	16000.0	10700.0	-422.0
354	18000.0	-740.1	-669.0
355	18000.0	-1020.1	-673.0
356	18000.0	-1440.1	-680.0
357	18000.0	-2000.1	-1038.0
358	18000.0	-2950.1	-1101.0
359	18000.0	-3600.1	-1351.0
360	18000.0	-4300.1	-1229.0
361	18000.0	-5000.1	-1143.0
362	18000.0	-5590.1	-1087.0
363	18000.0	-6000.1	-857.0
364	18000.0	-6760.1	-617.0
365	18000.0	-7000.1	-548.0
366	18000.0	-7520.1	-527.0
367	18000.0	-8000.1	-829.0
368	18000.0	-8300.1	-986.0
369	18000.0	-9000.1	-1099.0
370	18000.0	-9300.1	-1174.0
371	18000.0	274.9	-676.0
372	18000.0	399.9	-669.0
373	18000.0	734.9	-673.0
374	18000.0	1119.9	-683.0
375	18000.0	1249.9	-702.0
376	18000.0	1449.9	-728.0
377	18000.0	1584.9	-680.0
378	18000.0	1789.9	-522.0
379	18000.0	2259.9	-524.0
380	18000.0	2999.9	-540.0
381	18000.0	3999.9	-513.0
382	18000.0	4999.9	-464.0
383	18000.0	5609.9	-445.0
384	18000.0	5999.9	-387.0
385	18000.0	6999.9	-301.0
386	18000.0	7999.9	-256.0
387	18000.0	8999.9	-232.0
388	18000.0	9999.9	-283.0
389	18000.0	10699.9	-339.0
390	20000.0	-740.1	-755.0

Table A6 (Concluded)

T.P.	X	Y	Z
391	20000.0	-1050.1	-760.0
392	20000.0	-1450.1	-770.0
393	20000.0	-2000.1	-1125.0
394	20000.0	-2950.1	-1195.0
395	20000.0	-3600.1	-1439.0
396	20000.0	-4300.1	-1335.0
397	20000.0	-5000.1	-1235.0
398	20000.0	-5600.1	-1185.0
399	20000.0	-6000.1	-945.0
400	20000.0	-6750.1	-685.0
401	20000.0	-7000.1	-636.0
402	20000.0	-7500.1	-617.0
403	20000.0	-8000.1	-917.0
404	20000.0	-8300.1	-1077.0
405	20000.0	-9000.1	-1187.0
406	20000.0	-9300.1	-1267.0
407	20000.0	274.9	-765.0
408	20000.0	424.9	-760.0
409	20000.0	699.9	-763.0
410	20000.0	1064.9	-773.0
411	20000.0	1249.9	-795.0
412	20000.0	1449.9	-830.0
413	20000.0	1579.9	-773.0
414	20000.0	1799.9	-611.0
415	20000.0	2259.9	-613.0
416	20000.0	2999.9	-629.0
417	20000.0	3999.9	-598.0
418	20000.0	4999.9	-553.0
419	20000.0	5999.9	-533.0
420	20000.0	6499.9	-463.0
421	20000.0	6999.9	-393.0
422	20000.0	7999.9	-343.0
423	20000.0	8999.9	-318.0
424	20000.0	9999.9	-373.0
425	20000.0	10699.9	-428.0

Table A7

Topographic Data on 250-m Profiles
Road Site 2

	T.P.	X	Y	Z
	1*	6600.9	10898.6	38.0
	2	6291.9	11849.7	59.0
	3	5982.8	12800.7	83.0
	4	5876.2	13128.8	102.0
	5	5714.0	13628.1	69.0
	6	5673.6	13751.8	35.0
	7	5364.6	14702.8	-85.0
	8	5055.8	15653.9	-142.0
Az= 252°	9	4746.8	16605.0	-165.0
(See Fig 20	10	4437.6	17556.0	-183.0
	11	4128.8	18507.1	-180.0
	13	3619.8	19458.1	-158.0
	14	3510.7	20409.2	-232.0
	15	3201.7	21360.2	-260.0
	16	2892.7	22311.3	-294.0
	17	2583.7	23262.4	-314.0
		2274.7	24213.4	-318.0
	1*	10000.1	10550.0	-70.0
	2	10000.1	11437.0	-86.0
	3	10000.1	12437.0	-147.0
	4	10000.1	13207.0	-196.0
	5	10000.1	13437.0	-214.0
	6	10000.1	14437.0	-254.0
	7	10000.1	15437.0	-321.0
	8	10000.1	16437.0	-363.0
Az= 270°	9	10000.1	17437.0	-413.0
	10	10000.1	17787.0	-418.0
	11	10000.1	18437.0	-448.0
	12	10000.1	19437.0	-470.0
	13	10000.1	20437.0	-483.0
	14	10000.1	21437.0	-495.0
	15	10000.1	22437.0	-504.0
	16	10000.1	23437.0	-504.0
	17	10000.1	24437.0	-502.0
	18	10000.1	25437.0	-499.0
	1*	13399.2	10898.6	-188.0
	2	13708.3	11849.6	-244.0
	33	14017.3	12800.7	-298.0
	4	14193.4	13342.8	-323.0
	5	14326.3	13751.7	-355.0
	6	14635.3	14702.8	-418.0
	7	14944.4	15653.9	-466.0
	8	15253.4	16604.9	-507.0
Az= 288°	9	15562.4	17556.0	-538.0
	10	15871.4	18507.0	-556.0
	11	16056.8	19077.6	-602.0
	12	16069.2	19115.7	-712.0
	13	16103.2	19220.3	-708.0
	14	16273.1	19743.4	-583.0
	15	16489.5	20409.1	-528.0
	16	16798.5	21360.2	-539.0
	17	17107.5	22311.2	-532.0
	18	17416.5	23262.3	-515.0
	19	17725.6	24213.3	-508.0

* First survey point outside boundary of 200- by 200-m site for each profile azimuth.

Table A8

Topographic Data on 250-m Profiles
Road Site 5

	T.P.	X	Y	Z
Az= 70°	1*	13261.0	-9641.5	105.0
	2	13458.1	-10248.3	164.0
	3	13767.2	-11199.4	247.0
	4	14076.2	-12150.4	300.0
	5	14116.3	-12274.1	313.0
	6	14385.2	-13101.5	415.0
	7	14558.2	-13634.1	476.0
	8	14694.2	-14052.6	490.0
	9	15003.2	-15003.6	510.0
	10	15312.2	-15954.7	518.0
	11	15621.2	-16905.7	501.0
	12	15930.2	-17856.8	473.0
	13	16239.2	-18807.8	444.0
	14	16548.3	-19758.9	394.0
	15	16857.3	-20710.0	334.0
	16	17166.3	-21661.0	271.0
	17	17475.3	-22612.1	166.0
	18	17784.3	-23563.1	106.0
Az= 90°	1*	9999.9	-9605.0	-190.0
	2	9999.9	-10605.0	-117.0
	3	9999.9	-11605.0	13.0
	4	9999.9	-12605.0	157.0
	5	9999.9	-12985.0	174.0
	6	9999.9	-13605.0	204.0
	7	9999.9	-14605.0	258.0
	8	9999.9	-15605.0	274.0
	9	9999.9	-16605.0	265.0
	10	9999.9	-17605.0	229.0
	11	9999.9	-18605.0	236.0
	12	9999.9	-19605.0	229.0
	13	9999.9	-20605.0	222.0
	14	9999.9	-21605.0	222.0
	15	9999.9	-22605.0	213.0
	16	9999.9	-23605.0	207.0
	17	9999.8	-24605.0	201.0
Az= 108°	1*	6662.0	-9878.3	-46.0
	2	6600.8	-10066.6	-40.0
	3	6291.8	-11017.7	3.0
	4	5982.7	-11968.7	-11.0
	5	5673.7	-12919.8	-72.0
	6	5463.6	-13566.5	-105.0
	7	5364.7	-13870.9	-120.0
	8	5055.7	-14821.9	-146.0
	9	4746.7	-15773.0	-176.0
	10	4437.6	-16724.0	-166.0
	11	4128.6	-17675.1	-152.0
	12	3819.6	-18626.1	-135.0
	13	3510.6	-19577.2	-112.0
	14	3201.6	-20528.2	-109.0
	15	2892.5	-21479.3	-104.0
	16	2583.5	-22430.4	-99.0
	17	2274.5	-23381.4	-99.0

* First survey point outside boundary of 200- by 200-m site for each profile azimuth.

APPENDIX B: LINEAR INTERPOLATION PROCEDURE USED IN DETERMINING ELEVATION GRID ARRAYS

1. This appendix describes the linear interpolation procedure used in determining a fine grid of equally spaced discrete elevations (i.e. 2-m grid points) from a set of randomly located (i.e. field measured) elevation points. This gridded array of elevation points is often referred to as a digital terrain model (DTM), and is used as a basis for performing various functions, including the automated production of elevation contour maps.

2. The elevation interpolation procedure is composed of two parts: one for determining the elevation of a grid point with respect to its four nearest neighbors, one point being in each of the four quadrants; and the other, based on less than four data points such as when the grid point lies on the boundary of the site. Both procedures are discussed below.

Four-Variable Interpolation Procedure

3. The program divides the elevation domain into four quadrants centered on the selected grid point, and the four nearest data points (i.e. the nearest point in each of the four quadrants) are determined as illustrated below.

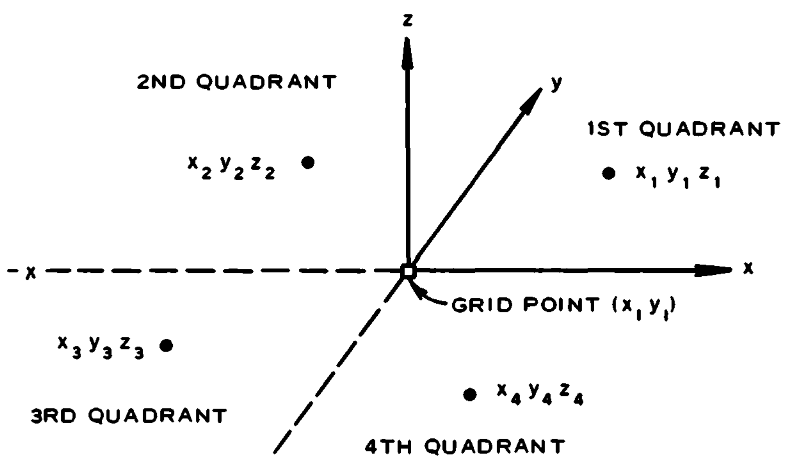


Fig. B1. Nearest neighbors by quadrants

4. The procedure involves three linear interpolations to finally produce the elevation value at the grid position. The first interpolation is performed along a line segment connecting the data point in the first quadrant with the data point in the fourth quadrant as illustraded below.

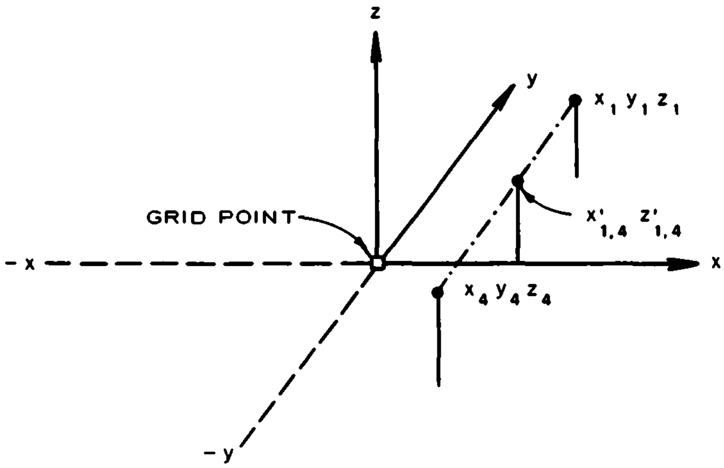


Fig. B2. First linear interpolation

An elevation value is then determined for the point where the line intersects the y-axis as illustrated mathematically below

$$z'_{1,4} = \frac{y_4 z_1 - y_1 z_4}{y_4 - y_1} \qquad \text{(B1)}$$

where

$z'_{1,4}$ = interpolated elevation value along the line segment where it intersects the x axis

y_4 = y coordinate of the data point in the fourth quadrant

z_1 = elevation value of the data point in the first quadrant

y_1 = y coordinate of the data point in the first quadrant

z_4 = elevation value of the data point in the fourth quadrant

The x location of the interpolated elevation value along the line segment is denoted by $x'_{1,4}$, defined mathematically as follows:

$$x'_{1,4} = \frac{y_4 x_1 - y_1 x_4}{y_4 - y_1} \qquad \text{(B2)}$$

where

x_1, x_4 = x coordinates of the data points in the first and fourth quadrants, respectively

The second interpolation is along a line segment connecting the data point in the second quadrant with the data point in the third quadrant as illustrated below.

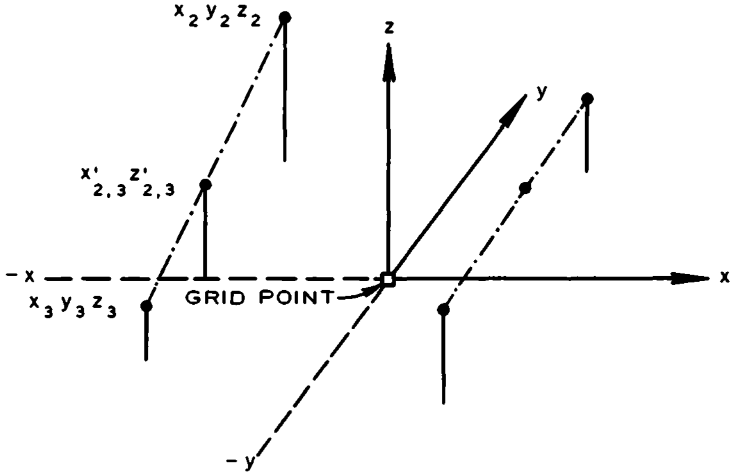


Fig. B3. Second linear interpolation

Again, the elevation value is determined for the point where the line intersects the y-axis. Mathematically, the elevation is defined as follows:

$$z'_{2,3} = \frac{y_3 z_2 - y_2 z_3}{y_3 - y_2} \tag{B3}$$

where

$z'_{2,3}$ = interpolated elevation value along the line segment where it intersects the x-axis

y_3 = y coordinate of the data point in the third quadrant

z_2 = elevation value of the data point in the second quadrant

y_2 = y coordinate of the data point in the second quadrant

z_3 = elevation of the data point in the third quadrant

The x location of the interpolated elevation value along the line segment is denoted by $x'_{2,3}$ and is defined as follows:

$$x'_{2,3} = \frac{y_3 x_2 - y_2 x_3}{y_3 - y_2} \tag{B4}$$

where x_2 and x_3 are the x coordinates of the data points in the second and third quadrants, respectively. The third interpolation is then made along a line segment connecting $x'_{1,4}$ and $x'_{2,3}$ to determine the elevation of the grid point.

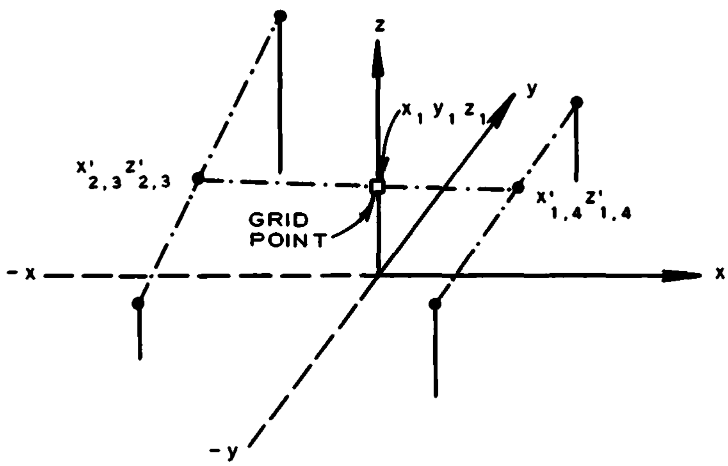


Fig. B4. Third interpolation for elevation of grid point

$$z_i = \frac{z'_{1,4} x'_{2,3} - z'_{2,3} x'_{1,4}}{x'_{2,3} - x'_{1,4}}$$

where z = interpolated elevation value at the grid point.

Three-Variable Interpolation Procedure

5. If the elevation data points are found in only three of the four quadrants, the z coordinate of the grid point is computed using the plan passing through the three points. The equation of the plane is given by

$$z = ax + by + c$$

where a, b, and c are constants to be evaluated. These constants can be determined by writing each of the three equations as follows

$$z_1 = ax_1 + by_1 + c$$

$$z_2 = ax_2 + by_2 + c$$

$$z_3 = ax_3 + by_3 + c$$

These three equations represent three simultaneous linear algebraic equations from which a , b , and c are determined. However, since the grid point being evaluated is at $x = 0$ and $y = 0$ (i.e. origin of coordinate system), only the constant c is required (see equation B6). The determinant form for c (i.e. $z = c$) is given below.

$$c = \frac{\begin{vmatrix} x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \\ x_3 & y_3 & z_3 \end{vmatrix}}{\begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{vmatrix}} .$$

Solving for c gives z_o as follows

$$z_o = c = \frac{x_1(y_2y_3 - y_3z_2) - y_1(x_2z_3 - x_3z_2) + z_1(x_2y_3 - y_2x_3)}{(x_2y_3 - x_3y_3) - (x_1y_3 - x_3y_1) + (x_1y_2 - x_2y_1)}$$

The expression above was used to determine the elevation (z_i) for each grid point that occurred on the boundary of the site.

6. If for any reason a point(s) falls on a quadrant line, it is assumed to be in the quadrant that preceded the line. For example, if a point fell in the $\pi/2$ line, it is assumed to be in the first quadrant; whereas if it fell in the 2π line it is assumed to be in the fourth quadrant.

APPENDIX C: EXAMPLE OF OUTPUT OF SHIELDING MODEL

1. The tabular output of the shielding model consisted of four parts:

   a. Percent shielding of 300-cm-tall one-dimensional target; burst heights 0, 100, 200, 300, 400, and 500 cm.

   b. Percent shielding of 300-cm-tall, one-dimensional target; burst heights 10, 25, 50, and 75 cm.

   c. Probability of shielding of target for each 30-cm height interval; burst heights 0, 100, 200, 300, 400, and 500 cm.

   d. Probability of shielding of target for each 30-cm height interval; burst heights 10, 25, 50, and 75 cm.

2. Examples of tabular output for each of the four parts are shown in figs. C1-C4.

3. The total tabular output of the shielding model has been published in Volume II in a limited number of copies. However, copies of Volume II are available on loan. Persons interested may borrow copies by writing the U. S. Army Engineer Waterways Experiment Station, ATTN: WESFE, Vicksburg, Miss. 39180.

SHIELDING OF TARGET AT POSITION A
RANGE 10 M

AZIMUTH DEG	TARGET CONTACT ANGLE* DEG	HEIGHT OF BURST** 0 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 100 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 200 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 300 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 400 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 500 CM
18	96	30.00	87	0.	81	0.	76	0.	71	0.	66	0.
36	91	10.00	85	0.	80	0.	74	0.	69	0.	64	0.
54	90	0.	84	0.	78	0.	73	0.	68	0.	63	0.
72	90	0.	84	0.	78	0.	73	0.	68	0.	63	0.
90	91	0.	85	0.	80	0.	74	0.	69	0.	64	0.
108	92	0.	86	0.	80	0.	75	0.	70	0.	65	0.
126	97	20.00	90	0.	84	0.	78	0.	73	0.	68	0.
144	98	10.00	92	0.	87	0.	81	0.	76	0.	70	0.
162	101	10.00	95	0.	89	0.	84	0.	78	0.	73	0.
180	91	0.	85	0.	80	0.	74	0.	69	0.	64	0.
198	101	10.00	96	0.	90	0.	84	0.	79	0.	73	0.
216	100	10.00	94	0.	88	0.	83	0.	77	0.	72	0.
234	97	10.00	91	0.	85	0.	80	0.	74	0.	69	0.
252	94	0.	88	0.	82	0.	77	0.	71	0.	66	0.
270	92	0.	86	0.	81	0.	75	0.	70	0.	65	0.
288	92	0.	86	0.	81	0.	75	0.	70	0.	65	0.
306	92	0.	86	0.	80	0.	75	0.	70	0.	65	0.
324	94	20.00	87	0.	81	0.	76	0.	70	0.	66	0.
342	97	30.00	88	0.	82	0.	77	0.	71	0.	66	0.
360	99	40.00	88	0.	82	0.	77	0.	71	0.	66	0.
AVERAGE SHIELDING		10.00		0.		0.		0.		0.		0.
AVERAGE TARGET CONTACT ANGLE	95		88		83		77		72		67	

* 90 MEANS NORMAL CONTACT; 0 MEANS NO CONTACT
** THE FRACTIONAL PART OF THE TARGET WHICH IS SHIELDED BY THE GROUND SURFACE (EXPRESSED AS PERCENT)

Fig. C1. Example of part a

SHIELDING OF TARGET AT POSITION A
RANGE 10 M

AZIMUTH DEG	TARGET CONTACT ANGLE* DEG	HEIGHT OF BURST** 10 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 25 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 50 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 75 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 0 CM	TARGET CONTACT ANGLE DEG	HEIGHT OF BURST 0 CM
18	94	20.00	91	10.00	90	0.	89	0.	0	0.	0	0.
36	90	0.	90	0.	88	0.	87	0.	0	0.	0	0.
54	89	0.	88	0.	87	0.	85	0.	0	0.	0	0.
72	89	0.	88	0.	87	0.	85	0.	0	0.	0	0.
90	91	0.	90	0.	88	0.	87	0.	0	0.	0	0.
108	91	0.	90	0.	89	0.	87	0.	0	0.	0	0.
126	95	10.00	98	0.	93	0.	91	0.	0	0.	0	0.
144	98	0.	97	0.	95	0.	94	0.	0	0.	0	0.
162	100	10.00	99	10.00	98	0.	96	0.	0	0.	0	0.
180	91	0.	90	0.	88	0.	87	0.	0	0.	0	0.
198	101	10.00	100	10.00	99	0.	97	0.	0	0.	0	0.
216	99	10.00	98	0.	97	0.	95	0.	0	0.	0	0.
234	96	0.	95	0.	94	0.	92	0.	0	0.	0	0.
252	93	0.	92	0.	91	0.	89	0.	0	0.	0	0.
270	92	0.	91	0.	89	0.	88	0.	0	0.	0	0.
288	91	0.	90	0.	89	0.	88	0.	0	0.	0	0.
306	91	0.	90	0.	89	0.	87	0.	0	0.	0	0.
324	92	0.	91	0.	90	0.	88	0.	0	0.	0	0.
342	95	20.00	92	10.00	91	0.	89	0.	0	0.	0	0.
360	97	30.00	92	10.00	91	0.	89	0.	0	0.	0	0.
AVERAGE SHIELDING		5.50		2.50		0.		0.		0.		0.
AVERAGE TARGET CONTACT ANGLE		94		93		91		90		0		0

* 90 MEANS NORMAL CONTACT; 0 MEANS NO CONTACT
** THE FRACTIONAL PART OF THE TARGET WHICH IS SHIELDED BY THE GROUND SURFACE (EXPRESSED AS PERCENT)

Fig. C2. Example of part b

PROBABILITY OF SHIELDING
TARGET POSITION A
RANGE 10 M

TARGET HEIGHT INCREMENT, CM	HEIGHTS OF BURST, CM					
	0	100	200	300	400	900
300 - 270	0.	0.	0.	0.	0.	0.
270 - 240	0.	0.	0.	0.	0.	0.
240 - 210	0.	0.	0.	0.	0.	0.
210 - 180	0.	0.	0.	0.	0.	0.
180 - 150	0.	0.	0.	0.	0.	0.
150 - 120	0.	0.	0.	0.	0.	0.
120 - 90	0.050	0.	0.	0.	0.	0.
90 - 60	0.150	0.	0.	0.	0.	0.
60 - 30	0.250	0.	0.	0.	0.	0.
30 - 0	0.550	0.	0.	0.	0.	0.

Fig. C3. Example of part c

PROBABILITY OF SHIELDING
TARGET POSITION A
RANGE 10 M

TARGET HEIGHT INCREMENT, CM	HEIGHTS OF BURST, CM					
	10	25	50	75	0	0
300 - 270	0.	0.	0.	0.	0.	0.
270 - 240	0.	0.	0.	0.	0.	0.
240 - 210	0.	0.	0.	0.	0.	0.
210 - 180	0.	0.	0.	0.	0.	0.
180 - 150	0.	0.	0.	0.	0.	0.
150 - 120	0.	0.	0.	0.	0.	0.
120 - 90	0.	0.	0.	0.	0.	0.
90 - 60	0.050	0.	0.	0.	0.	0.
60 - 30	0.150	0.	0.	0.	0.	0.
30 - 0	0.350	0.250	0.	0.	0.	0.

Fig. C4. Example of part d

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Engineer Waterways Experiment Station Vicksburg, Miss.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

ANALYTICAL STUDY OF GROUND-SURFACE SHIELDING CHARACTERISTICS OF SELECTED ROAD TERRAINS; Volume I, DEVELOPMENT OF SHIELDING MODEL AND ANALYSES OF RESULTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Volume 1 of 2 volumes

5. AUTHOR(S) (First name, middle initial, last name)

Harold W. West
Phillip L. Doiron
Judith A. Parks

6. REPORT DATE	7a. TOTAL NO OF PAGES	7b. NO OF REFS
June 1974	187	None

8a. CONTRACT OR GRANT NO b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report M-74-4 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U. S. Army Materiel Systems Analysis Agency Aberdeen Proving Ground, Maryland

13. ABSTRACT

The mathematical model presented herein allows the user to determine the amount of shielding from munition bursts offered by the ground surface to targets (vehicles, personnel, etc.) on and moving along roads or in cross-country terrains. In the shielding model it is assumed that fragments and projectiles travel in straight-line trajectories; therefore, the amount of shielding offered by the ground surface to a target is calculated along the optical paths between the burst point and selected points on the target. The shielding values given by the model are maximum values. Shielding characteristics in terms of probability of shielding for a point(s) on a target, or in terms of average shielding for a one-dimensional target of a specified height, can be obtained. The model variables include target height, number of target height intervals, locations of five target positions, elevations of six munition height of bursts (HOB), and eight horizontal target-to-HOB ranges. Shielding results are provided for six road sites near Vicksburg, Miss., selected to be representative of a wide range of road configurations known to occur in various geographical regions. The ground-surface shielding results obtained for the six road sites show that shielding of a one-dimensional vertical target is significantly affected by both distance (or range) and burst height, and that shielding does not change appreciably for the different target positions that were evaluated along the center line of the road. However, since five target locations were in relatively uniform areas, it is believed that target location would have a significant effect on shielding on those roads that contain closely spaced cuts and fills. Of the six sites for which shielding calculations were made, site 6 contained the greatest amount of shielding; this amount increased with increasing range and decreased only slightly with increasing burst height. At sites 1 through 5, the shielding of the target varied between 0 and 25 percent for the different ranges and burst heights equal to and greater than 100 cm. For a burst height of 0 cm (i.e. ground burst), the shielding of the target varied between 10 and 55 percent for the different ranges. Appendix A describes the general procedures used in the acquisition and recording of on-site three-dimensional topographic data and presents the topographic data that were collected at the six road sites. Appendix B describes the interpolation procedure used in determining a fine grid of equally spaced discrete elevation (i.e. 2-m grid points) from a set of randomly located (field measured) elevation points. Appendix C presents examples of the tabular output of the shielding model. Volume II (published in limited quantity) contains the total tabular output of the shielding model.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE

Unclassified

Security Classification

Unclassified

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Mathematical models						
Munition bursts						
Roads						
Shielding						
Targets						
Terrain						

Unclassified

Security Classification

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

West, Harold W
Analytical study of ground-surface shielding characteristics of selected road terrains, by H. W. West, P. L. Doiron ₍and₎ J. A. Parks. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1974.
2 v. illus. 27 cm. (U. S. Waterways Experiment Station. Technical report M-74-4)
Sponsored by U. S. Army Materiel Systems Analysis Agency, Aberdeen Proving Ground, Maryland.
Contents.-v.1. Development of shielding model and analyses of results.-v.2. Output of shielding model.

1. Mathematical models. 2. Munition bursts. 3. Roads. 4. Shielding. 5. Targets. 6. Terrain. I. Doiron, Phillip L., joint author. II. Parks, Judith A., joint author. III. U. S. Army Materiel Systems Analysis Agency. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report M-74-4)
TA7.W34m no.M-74-4