United States Department of Agriculture	**Soil Conservation Service**	**Northeast NTC 160 East 7th Street Chester, PA 19013-6092**

Subject: Geophysical surveys on Guam and Saipan; December 10-18, 1990

Date: 18 January 1990

To: Joan B. Perry
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Purpose:
To assist Historic Preservation Offices (HPO) and the International Archaeological Research Institute, Inc., locate burials and to identify the boundaries of burial sites on Guam and Saipan using ground-penetrating radar (GPR) and electromagnetic induction (EM) techniques. Field work will help to demonstrate SCS's commitment to protect and preserve historic and culturally significant sites. In addition, this field study will provide SCS with an opportunity to assess the potential of using these geophysical techniques for conservation practices involving earth movement activities in the western Pacific Basin.

Principal Participants:

Jim Doolittle, Soil Specialist, SCS, Chester, PA
Michael Kaschko, Associate Archaeologist, IARII, Honolulu, HA

Activities:

I arrived in Guam on December 9, 1990. The equipment had arrived the preceding week and had been stored in a suitable location. The archaeological excavation site at the Leo Palace Hotel on Tumon Bay was toured and preliminary plans were made for the radar survey on 9 December. Field work and radar surveys were completed at this site on 10 to 12 December. On 12 December, a field demonstration of the GPR and EM equipment was conducted for SCS and HPO personnel.

The GPR was returned to Philadelphia, Pennsylvania, on the morning of 13 December. The principal participants travelled to Saipan with the EM equipment during the afternoon of 13 December.

Site preparation and EM surveys were completed at the suspected site of a mass grave near Tapapag, Saipan, on 14 to 16 December. On the morning of 17 December, a demonstration of the EM-38 meter was held at the Saipan Experiment Station for SCS and local agricultural personnel. The EM equipment and I returned to Philadelphia on 17 and 18 December 1990.

Discussion:

GUAM

Background

An archaeological data recovery excavation is being completed within the construction area of the Leo Palace Hotel on the north end of Tumon Bay. Archaeological investigations have revealed a concentration of prehistoric, human burials in a portion of the construction area. This portion of the construction area has been designated for permanent preservation. The Historic Preservation Office of Guam had requested a more detailed investigation of this area to determine the extent of burials and whether any other concentration of human burials exist outside the designated preservation area. The use of ground-penetrating radar techniques was recommended as a rapid, non-destructive means for the expanded investigation and analysis of this site.

Equipment

The radar unit used in this study is the Subsurface Interface Radar (SIR) System-8 manufactured by Geophysical Survey System, Inc. The SIR System-8 consists of the Model 4800 control unit, the ADTEK SR 8004H graphic recorder, the ADTEK DT 6000 digital tape recorder, a power distribution unit, a 30 meter transmission cable and the 120 and 500 MHz antennas. The system was powered by a 12-volt vehicular battery.

Soils

The construction area of the Leo Palace Hotel is located in an area of soil map unit 28, Guam-Urban land complex, 0 to 3 percent slopes. [1] The Guam series is a member of the clayey, gibbsitic, nonacid, isohyperthermic Lithic Ustorthents family. Areas of Guam soil are on the limestone plateau which borders the construction site. The excavation site is located on a narrow, coastal strand area of Shioya soil which was included with Guam-Urban land complex, 0 to 3 percent slopes, map unit. The Shioya series is a member of the carbonatic, isohyperthermic Typic Ustipsamments family. This excessively drained soil has formed in water-deposited coral sands and is deep and very deep over coral. Within the excavation site, the Shioya soil contains very gravelly and cobbly layers in the substratum. In some areas of the excavation site, the soil is moderately deep to coral bedrock.

In March of 1990, the GPR was successfully used in coastal areas of Jaucas soils on the Hawaiian Islands. Closely similar to the Shioya soil, the Jaucas soil is also a member of the carbonatic,

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1. Young, Fred J. 1988. Soil Survey of Territory of Guam. USDA Soil Conservation Service. 166 pp.

isohyperthermic Typic Ustipsamments family. Compared with the Jaucas soils observed on Hawaii, the Shioya soil along Tumon Bay contains slightly more fines (loamy sands) in the solum and has very gravelly and cobbly layers in the substratum.

Survey Procedures

After a reconnaissance of excavation site, it was decided that the GPR would be used with the 500 MHz antenna. In areas of Jaucas soils on Hawaii, the 500 MHz antenna provided high resolution of subsurface features and profiled to depths of 3 to 5 meters. Concerns were expressed for the large concentration of gravels and cobbles in the substratum, the variable depth to coral, the disturbance of the site, and the abundance of modern cultural features within the site. All of these features would create undesired subsurface reflections which masked reflections from burials and complicated radar interpretations.

Four grids were established near the excavation site on Tumon Bay. Dimensions of these irregularly shaped, rectangular grids were 11 by 6.5 meters, 4 by 7 meters (two grids), and 10 by 1 to 4 meters. Grid intervals were 1 meter parallel with and 0.5 meters perpendicular to the coastline. These intervals were based upon the size and orientation of the known burials, the desired detection probability, and the available time. The 500 MHz, which has a width of 30 cm and weighs 4 kg, was pulled along each grid line which was parallel with the coast. Traverses were spaced 50 centimeters apart. As the antenna was pulled past each referenced grid intersect (spaced at 1.0 meter intervals), the operator impressed dashed, vertical marks on the radar profile. The GPR provided a continuous profile of the subsurface along each traverse.

Results

The electrically resistive, sandy Shioya soil provided a favorable environment for the operation of the GPR and profiling depth of 3 to 5 meters were attained with the 500 MHz antenna. However, the identification of images on radar profiles was difficult and detection of burials was adversely affected by (i) the size, and shape of the buried artifact, and (ii) the presence of scattering bodies within the soil.

The size, shape, and depth to an artifact affect radar interpretations. Large objects reflect more energy and are easier to detect than small objects. Unless bodies were interred in a coffin, flexed (fetal) position, or with a large concentration of artifacts, their reflective surfaces are small and can easily be missed with the radar. In addition, small, deeply buried remains are difficult to discern on radar profiles. This is because the reflective power of an object decreases proportional to the fourth power of the distance to the object[2].

The presence of scattering bodies in the soil complicated interpretations and adversely affected the radar survey. Stratified soil horizons, layers of stones and cobbles, tree roots, modern cultural features, and disturbed soil conditions produced excessive clutter and undesired reflections which complicated the radar imagery and masked the presence of some and the clear or positive identification of other burials. In addition, the GPR was ineffectual in areas with bamboo roots. The high water and dissolved salt contents within the bamboo roots caused the complete and rapid (very shallow depths of less than 0.4 m) attenuation of the radiated energy from the 500 MHz antenna

In spite of these constraints, several subsurface anomalies and suspected burials were identified on the radar profiles. Burial sites were inferred when all of the following criteria were satisfied: (i) the occurrence of at least three point reflectors arranged in a linear pattern along successive traverse (spaced at 50 cm intervals), (ii) each reflector is located at the same or a closely similar depth, and (iii) the linear pattern of point reflectors is orientated perpendicular to the coast. In some areas, interpretations were confirmed from the burials observed in previously excavated and refilled trenches.

Figure 1 shows the excavation site on Tumon Bay, the surveyed areas, and the locations of open pits, refilled exploratory trenches, and subsurface anomalies suspected to be burials. The large concentration of subsurface anomalies occurring in the upper left-hand corner of this figure are in the preservation area. Many of these subsurface features were identified as burials based on the information obtained from the exploratory trenches (unlabeled) shown in this portion of Figure 1. Some of the subsurface reflections occurring along the upper, left-hand margin of Figure 1 represent a "side effect" (undesired reflection) from the adjoining walls of open trenches.

In Figure 1, anomalies occurring in the extreme lower, right-hand corner are believed to represent rocks and tree roots rather than a concentration of human burials. The concentration of subsurface anomalies occurring in the lower, central portion of this figure are believed to be burials and their locations were marked in the field. Further archaeological studies will excavate these sites to confirm radar interpretations.

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2. Bevan, Bruce and Jeffrey Kenyon. 1975. Ground-probing radar for historical archaeology. MASCA (Museum Applied Science Center for Archaeology) University of Pennsylvania, Philadelphia. Newsletter 11(2):2-7.

Although the profiling depth and the resolution of subsurface interfaces with the 500 MHz antenna was good, the excavation site on Tumon Bay was considered an "interpreters nightmare" because of the large number of scattering bodies in the subsurface. Although stringent ground rules were used for the identification of subsurface anomalies as human burials, the large number of subsurface reflectors confused radar interpretations and made the identification of many burials a "best guess" or "intuitive hunch".

SAIPAN

Background:
Applications for land development permits in the Commonwealth of Northern Mariana islands require the completion of an archaeological site assessment. The purpose of the archaeological site assessment is to determine the distribution and to assess the significance of buried cultural deposits within a site.

Earlier this year, International Archaeological Research Institute, Inc., conducted a routine site assessment on a 3.12 hectare parcel of land along the northwest coast of Saipan between the towns of Tanapag and San Roque. Pedestrian surveys and backhoe excavations revealed that the site contained Pre-Latte and Latte Period artifacts (ceramics, shell and soil middens), historic disturbances and intensive land modifications (pre-war Japanese coralline aggregate road, cement culvert, bridge, and a narrow-gauge railroad bed), and numerous artifacts from World War II (ordnance, helmets, bayonets, and canteens). Also uncovered was stratigraphic evidence of a mass grave believed to contain the remains of Japanese soldiers killed during a **Gyokusai** attack on American positions during the battle for Saipan.

The battle for Saipan began on June 11, 1944. The archaeological site assessment was conducted in an area which had been a front line position during a fanatical, **Gyokusai** charge across the Tanapag Plain on July 7, 1944. The word **Gyokusai** means "crushed jewels" and the attack was ordered to "allow the soldiers to face death with honor rather than suffering the disgrace of surrender".[3] During this charge, 4,311 Japanese and 480 Americans were killed. Documents revealed that, following the charge, 1,477 Japanese bodies were hastily collected, laid in an excavated trench, counted, sprayed with sodium arsenite (for sanitation), and covered with fill materials by a bulldozer. A photograph, taken when the mass grave was being excavated, reveals a linear trench nearly parallel with the pre-war road. The mass grave was never marked and evidence of its location has been erased with time.

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3. Swift, Marilyn K., Stephen Wickler, J. Stephen Athens. 1990. Archaeological subsurface investigation of the Gentle Breeze, Inc., Project Area, Achugao, Saipan. International Archaeological Research Institute, Inc. Honolulu, Hawaii.

The presence of a mass grave on this site would be a significant discovery. The site qualifies to be listed on the National Register of Historic Places as it (i) represents traditional cultural values important to an ethnic group, (ii) is associated with an important historical event, and (iii) reveals important information of a historical event[4]. The HPO of the Commonwealth of Northern Mariana Island has requested that additional studies be undertaken in preparation for a full excavation of the mass grave. Furthermore, HPO has recommended that:

> "1. Significant prehistoric deposits are not to be disturbed by the removal of the Japanese remains;
>
> 2. a reasonable program of archaeological recovery of the mass grave is to be attempted to aid in the identification of the individual remains;
>
> 3. the remains are to be turned over to the Japanese government for proper disposition; and
>
> 4. scheduling of and funding for archaeological recovery are to be kept with reasonable bounds."[5]

The use of USDA-SCS field expertise and EM equipment were recommended to determine the extent and perimeter of the mass grave trench as well as to identify any additional areas having high concentrations of interred remains or military artifacts.

<u>Equipment</u>:
The electromagnetic induction meters used in this survey were the Model EM-31DL and the Model EM-38 manufactured by GEONICS, Limited, Mississauga, Ontario. The Model EM-31DL meter, consisting of a 3.66 meter boom and console, weighs 11 kg. With the EM31 placed on the ground surface, measurements of the bulk soil electrical conductivity were made to assumed depths of about 5.5 meters (with the meter in the vertical dipole position) and about 2.75 meters (with the meter in the horizontal dipole position).

The Model EM-38 meter is 1.0 meter long and weighs 2.5 kg. With the EM-38 in the vertical dipole position and placed on the ground surface, measurements of the bulk soil electrical conductivity were made to assumed depths of about 1.5 meters. With the EM-38 in the horizontal dipole position and placed on the ground surface, measurements of the bulk soil electrical conductivity were made to assumed depths of about 0.7 meters.

Measurements made with these meters represent cumulative values of bulk soil electrical conductivity which have been averaged over the

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4. Ibid.

5. Ibid.

scanned profiles. Measurements obtained with these meters are expressed in millisiemens/meter (mS/m).

Electromagnetic methods measure the apparent electrical conductivity of earthen materials. Factors influencing the conductivity of earthen materials include: (i) volumetric water content, (ii) amount and type of salts in solution, (iii) amount and type of clays in the soil matrix, and (iv) soil temperature. As discussed by Benson and others (1984),[6] the absolute EM measurements are not necessarily diagnostic in themselves, but lateral and vertical variations in conductivity are significant. Interpretation of the EM data is based on the identification of spatial patterns in the data set.

Soils

The site is located in an area of soil map unit 43, Saipan clay, 0 to 5 percent slopes.[7] The Saipan series is a member of the fine, mixed, isohyperthermic Oxic Haplustalfs family. This deep, well drained soil is on limestone plateaus. Within the study site, most areas of Saipan soil have been disturbed. Also included within the study site are areas of Shioya soil on coastal strand areas and fill materials. The Shioya series is a member of the carbonatic, isohyperthermic Typic Ustipsamments family. This excessively drained soil has formed in water-deposited coral sands and is deep and very deep over coral.

Survey Procedures

Stratigraphic evidence (military artifacts and human skeletal remains) from four backhoe excavations provided information concerning the approximate depth to and location of the mass grave within the site. A 70 by 30 to 35 meter grid was established across the area suspected to contain the mass grave. The long axis (70 meters) of the grid was established essentially parallel with the coastline. Because of a large concentration of very dense vegetation no measurements were taken along column X = 25 meters (see enclosed figures). The constructed grid interval was 5 meters.

The grid included four excavations (3A, 3B, 3C, and 4A) which were believed to have intercepted portions of the mass grave. Human bones and military artifacts were encountered in the lower (on the vertical or y-axis in these plots) 1 meter portion of trench 3A, throughout the length of trench 3B, and the lower (on the vertical

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6. Benson, R. C., R. A. Glaccum, and M. R. Noel. 1984. Geophysical techniques for sensing buried wastes and waste migration: an application review. p. 533-566. IN: D. M. Nielsen and M. Curl (eds.) Surface and Borehole Geophysical Methods in Ground Water Investigations. NNWA/EPA Conference, San Antonio, Texas.

7. Young, Fred J. 1989. Soil Survey of the Islands of Aguijan, Rota, Saipan, and Tinian, Commonwealth of the Northern Mariana Islands. USDA Soil Conservation Service. 166 pp.

or y-axis in these plots) 4 meters of trench 4A. For trench 3C, the following description was made:

> "Strombus shell, sherds, and charcoal occur in the A horizon, along with grenades, cartridges, an eroded coin, and a human patella fragment in trench 3C. It is possible that this trench intersects the southern edge of the mass grave. The profile did not, however, clearly indicate a pit outline.[8]"

Human bones and other evidence for the mass grave were observed to be buried under about 10 to 25 cm of overburden. The observed thickness of the layer containing human bones, military artifacts, and other materials associated with the mass grave ranged from 25 to >60 cm thick.

The EM meters will continuously indicate the conductivity of the underlying soil. However, data was recorded only at the grid intersects. At each grid intersect, measurements were obtained with the EM meters in both the vertical (v) and horizontal (h) dipole positions. Measurements were obtained with the EM-31DL meter at the 5 meter grid intersects. This provided a total of 105 observations to an assumed depth of about 5.5 meters (with the meter in the vertical dipole position) and 105 observations to an assumed depth of about 2.75 meters (with the meter in the horizontal dipole position).

Measurements were obtained with the EM-38 meter at 1 meter intervals along each column. Columns were either 30 or 35 meters in length and were spaced 5 meters apart. This provided a total of 452 observations to an assumed depth of about 1.75 meters (with the meter in the vertical dipole position) and 452 observations to an assumed depth of about 0.70 meters (with the meter in the horizontal dipole position).

The data obtained with these meters were plotted on two-dimensional contour plots using the SURFER software program. These plots were constructed using a kriging interpolation and octant search methods.

Results

Table 1 and Figure 2 summarizes the observations taken with the EM-31DL and the EM-38 terrain conductivity meters within the study area. Generally, in areas of Saipan soils, bulk soil electrical conductivity values increase with increasing soil depth. This can be attributed to increased clay, moisture, and/or soluble salt contents with depth. In addition, the observed range of the EM

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8. Swift, Marilyn K., Stephen Wickler, J. Stephen Athens. 1990. Archaeological subsurface investigation of the Gentle Breeze, Inc., Project Area, Achugao, Saipan. International Archaeological Research Institute, Inc. Honolulu, Hawaii.

values decreased with increasing soil depth and thickness profiled. This can be attributed to the large number of small, metallic artifacts and disturbances near the soil surface, to variations in the sensitivities of the meters, and to the cumulative areas scanned by each meter (EM-31DL vs EM-38) and orientations (horizontal vs vertical).

TABLE 1

Basic Statics of Bulk soil electrical conductivity Measurements at the Mass Grave Site (all measurements are in mS/m)

	EM-38h	EM-38v	EM-31h	EM-31v
Average	59	63	66	69
Median	60	64	68	70
Minimum	6	10	16	31
Maximum	210	115	110	100
Number	452	452	105	105

Within the upper 0.70 meters (EM-38H measurements) of the soil profile, the average and median bulk soil electrical conductivity values were 59 and 60 mS/m, respectively. One half of the EM-38(H) observations had values between 50 and 69 mS/m.

Bulk soil electrical conductivity values increased slightly when the upper 1.5 meters (EM-38V measurements) of the soil profile were scanned. The average and median bulk soil electrical conductivity values for the upper 1.5 meters of the soil profile were 63 and 64 mS/m, respectively. One half of these observations had values between 54 and 74 mS/m.

Bulk soil electrical conductivity values increased when the upper 2.75 meters (EM31H measurements) of the soil profile were scanned. The average and median bulk soil electrical conductivity values for the upper 2.75 meters were 66 and 68 mS/m, respectively. One half of these observations had values between 58 and 76 mS/m.

Two-dimensional contour plots using the SURFER software program were prepared (Figures 3 to 8). The contour interval used in these plots were 5 mS/m. Figures 3 to 6 have been arranged in order of decreasing soil depth profiled with the EM meters.

Figures 3A to 6A are two-dimensional contour plots of the bulk soil electrical conductivity values for the different depths scanned.

Figures 3B to 6B are two-dimensional contour plots showing only the isoline having bulk soil electrical conductivity values greater than 70 mS/m. The plotting of these higher isoline was done in an attempt to simplify the plots and to define the boundary of the mass grave. It was hypothesized that bulk soil electrical conductivity values should be higher in areas containing the mass grave because of the large concentration of metallic objects (helmets, buckles, bayonets, and canteens) buried with the remains of the Japanese soldiers.

EM-31DL Survey

Figures 3 and 4 are two-dimensional contour plots of bulk soil electrical conductivity values obtained with the EM-31DL meter. Because of the length of the boom (3.66 m) and the depth scanned, the resolution of the EM-31DL was rather coarse and was about 1 to 2 meters.[9] Figure 3 and 4 show the distributions within the study site of bulk electrical conductivity values for scanned depths of 5.5 and 2.75, respectively.

In Figure 3, two large and one small, irregularly shaped areas of high conductivities are evident. These patterns are more apparent in Figure 3B. It is inferred that these areas of relatively high bulk electrical conductivity values are principally related to the occurrence of (i) greater soil depths, and (ii) higher amounts and/or thickness of fines (clays and silts) within the 5.5 meter profile.

A distinct zone of higher (>90 mS/m) bulk electrical conductivity values is apparent in the central portion of Figures 3A and 3B. This anomaly forms a linear feature which is about 20 meter long and varies from 3 to 7 meters wide. As it was assumed that the mass grave would form a linear pattern of higher EM measurements, the anomaly was suspected. However, because of the large depth scanned (5.5 meters) and the failure of this anomaly to directly underlie any of four excavations (3A, 3B, 3C, and 4A) which were believed to have intercepted portions of the mass grave, the pattern was not immediately suspected. It was hypothesized that this pattern may reflect increase fines (clays and silts) and depths.

Areas of Shioya soils and the coarser-textured subgrade materials used in the construction of the pre-war road are evident along the upper margins of Figures 3A. Generally, areas of Shioya soils and the fill materials have lower bulk electrical conductivity values. The lower values were assumed to reflect the lower clay contents of the Shioya soils and the materials used in the construction of the road.

Figure 4 depicts the distribution of bulk electrical conductivity values averaged for a 2.75 m profile. A narrow arch containing

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9.Bevan, Bruce W. 1983. Electromagnetics for mapping buried earth features. J. Field Archaeology 10:47-54.

higher bulk electrical conductivity values forms a distinct pattern which sweeps across Figures 4A and 4B. This zone of higher conductivities includes the four excavations (3A, 3B, 3C, and 4A) which were believed to have intercepted portions of the mass grave. The anomalous nodes of higher conductivity values which occur within this narrow arch, as well as along the upper and lower left margins, are believed to be related to the presence of metallic objects in the upper part of the 2.75 meter profile.

Lower bulk electrical conductivity values are evident in the area of the pre-war road along the upper margin of Figure 4A. Compared with the 5.5 meter profile (Figure 3A), values for the 2.75 meter profile are generally lower and more variable over short distances (implied by steeper gradients). This implies that more resistive materials occur between depths of 0 to 2.75 meter than between depths of 2.75 to 5.5 meters. This inference is supported by observations of coarser-textured soil and fill materials overlying coral or finer textured soil materials.

A comparison of the lower right-hand corners of Figures 3 and 4 reveals a noticeable increase in bulk electrical conductivity values with increasing depth. This relationship is caused by the presence of more conductive materials between depths of 2.75 to 5.5 meters than between depths of 0 to 2.75 meters. Because of the irregular shape and excessive depth (>2.75 meters) to the more conductive materials, it is most unlikely that the observed relationship has been caused by concentrations of artifacts.

EM-38 Survey

Figures 5 and 6 are two-dimensional contour plots of bulk soil electrical conductivity values obtained with the EM-38 meter. Measurements obtained with the EM-38 are considered to be the most critical and telling for the detection of the mass grave. As previously discussed, layers containing concentrations of human bones and other evidence for the mass grave were observed between depths of 10 to >60 cm. Figure 5 and 6 show the distributions of bulk soil electrical conductivity values for scanned depths of 1.5 and 0.70 meters, respectively.

Three major patterns are evident in Figures 5 and 6: one produced by variations associated with changes in soil type (Saipan versus Shioya) and texture (sands versus clays); one produced by the sporadic occurrence of military artifacts and other small subsurface anomalies; and one produced by variations in electromagnetic properties associated the suspected mass grave.

Variations in the electromagnetic properties exist between areas of the fine-textured Saipan and the coarse-textured Shioya soils or the coarse-textured fill materials used in the construction of the pre-war Japanese coralline aggregate road. Areas of Saipan soils have higher clay contents, higher cation exchange capacities, and higher bulk soil electrical conductivity values than areas of Shioya soils. In areas of Saipan soils, bulk soil electrical conductivity averaged 59 mS/m and 63 mS/m for the 1.5 and the 0.70

meter profiles, respectively. The slightly higher vertical dipole measurement (1.5 meters) is believed to reflect increases in clay content with depth in areas of Saipan soils. In areas of Saipan soils, bulk soil electrical conductivity values appear to reflect variations in the thickness, depth to, and amount of clays in the profile.

Areas of Shioya soils and the coarser-textured subgrade materials used in the construction of the pre-war road occur along the upper margins of Figures 5A, and 6A. In this area, bulk soil electrical conductivity values average 41 mS/m and 38 mS/m for the 0.70 and the 1.5 meter profiles, respectively. These values reflect the lower clay contents of the Shioya soils and the materials used in the construction of the road.

Also apparent in Figures 5 and 6 are patterns produced by variations in electromagnetic properties associated with small concentrations of widely and irregularly disseminated, metallic artifacts within the soil and on the soil surface. At these sites, EM-38 values changed significantly when the meter was rotated 90 ^{o} in the x- plane. At sites underlain by metallic objects, the average of the high and low values was recorded. Typically, these sites displayed elevated values, however, at some sites, the limited space to rotate the EM-38 meter (dense and restricting vegetation) resulted in slightly depressed values. Elevated EM values caused by the presence of metallic objects are evident along the right and left margins and within the linear feature in the central portion of Figures 5 and 6.

Measurements taken with the EM-38 meter indicate that the highest bulk soil electrical conductivity values (greater than 70.0 mS/m) were principally confined within a long, narrow delineation in the central portion of the study area. This delineation varies in width from about 5 to 15 meters and can be divided into three segments (see Figure 5A and 6A). The longest segment is parallel with the pre-war road and is about 33 meters long. The long segment is intersect by two shorter segments (about 23 and 24 meters long). The shorter segments appear to be parallel with each other and have axes which intersect the axis of the long segment at a 74 ^{0} angle. One segment extends beyond the study area. Portions of the four trenches which are believed to have intercepted the mass grave are included within these segments.

The anomaly which occurs in the central portion of Figure 5 and 6 is believed to be the mass grave. However, unlike the photograph taken when the trench was being excavated (July 1944), which indicates only a single trench, the results of the EM survey, if correct, suggest a more complexed trench consisting of three interconnected segments. In addition, the anomalously high values occurring along the upper right-hand margin of Figure 5B and 6B may be from an additional concentration of military artifacts and human remains.
The suspected trench is best expressed in Figures 5B which plots the bulk soil electrical conductivity values for the 0 to 1.5 meter

profile. In Figures 7 and 8 only areas with bulk soil electrical conductivities greater than 70 mS/m have been plotted. These figures have been included to help summarize the expression and depth distribution of anomalous EM measurements.

Conclusions

The goals of this field study were accomplished. The performance of the GPR was hampered by excessive scattering bodies within the soil at the Leo Palace Hotel site. However, signals from several subsurface anomalies suspected of being burials were identified and located in the field. In addition, the GPR helped to define the boundaries of the burial sites. On-going archaeological investigations will help to confirm these interpretations.

The EM survey is believed to have located and defined the boundaries of the mass grave. Two-dimensional plots of the EM data have characterized the suspected site of the mass grave and with some additional field work the interpretations can be confirmed. If interpretations are correct, the EM survey will provide invaluable information concerning not only the location, but the shape and extent of the trench.

Field work and demonstrations have hopefully fostered a greater appreciation of SCS's commitment to protect and preserve historic and culturally significant sites.

The potential for using ground-penetrating radar and EM techniques for conservation practices involving earth movement activities in the western Pacific Basin is good. The use of GPR techniques should be restricted to areas of coarse-textured soils. These soils are of minor extent. However, these coarse-textured soils occur on coastal strand areas whose significance to tourism and development far outweighs their extend. In areas of coarse textured soils, such as the Shioya series, results of GPR surveys will generally be good. However, depending on the purpose of the survey and the nature of the subsurface feature being investigated, conducting surveys in areas which contain numerous scattering bodies or are disturbed (similar to the excavation site at the Leo Place Hotel) may produce complex and "noisy" interpretations which restrict the use of the GPR.

The use of EM techniques are particularly well suited to locating and defining the extent of refilled trenches, middens, air-filled voids, and contaminant plumes emanating from animal waste holding ponds. This study has demonstrated the speed and efficiency of EM techniques. This geophysical tool is relatively less expensive, requires few field personnel, and can be used in poorly accessible and bushy areas. Results from EM surveys can provide a high density map and help to characterize study areas. However, neither GPR or EM techniques will resolve or answer all site problems.

I wish to thank you for your assistance in making this study a "happening." I regret that I did not have the opportunity to meet you. Hopefully our paths will cross in the not too distance future. Your staff was most helpful and friendly.

With kind regards.

James A. Doolittle
Soil Specialist

cc:
R. Arnold, Director, SOI Division, SCS, Washington, D.C.
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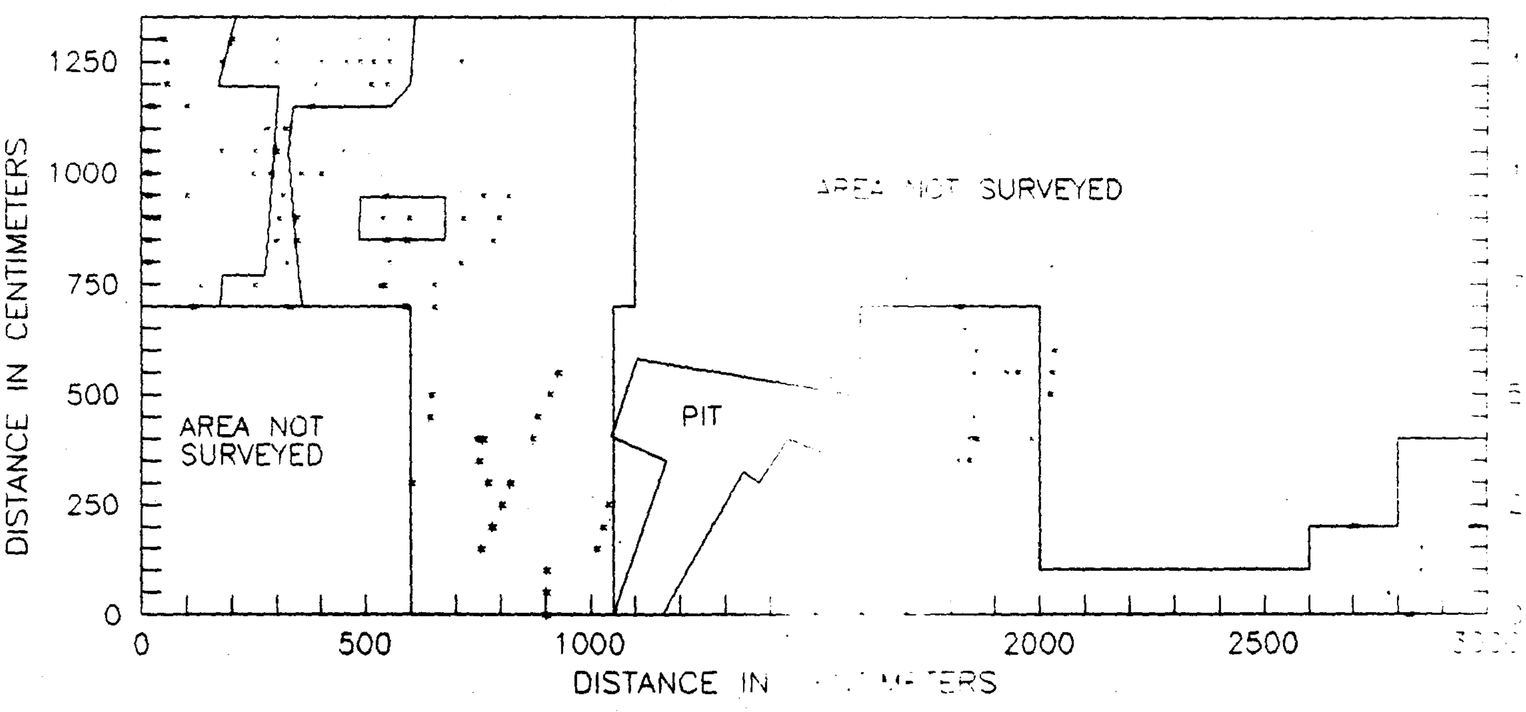
M. Kaschko, Archaeologist, International

FIGURES

FIGURES (continued)

FIGURE-1

EXCAVATION SITE, TUMON BAY, GUAM



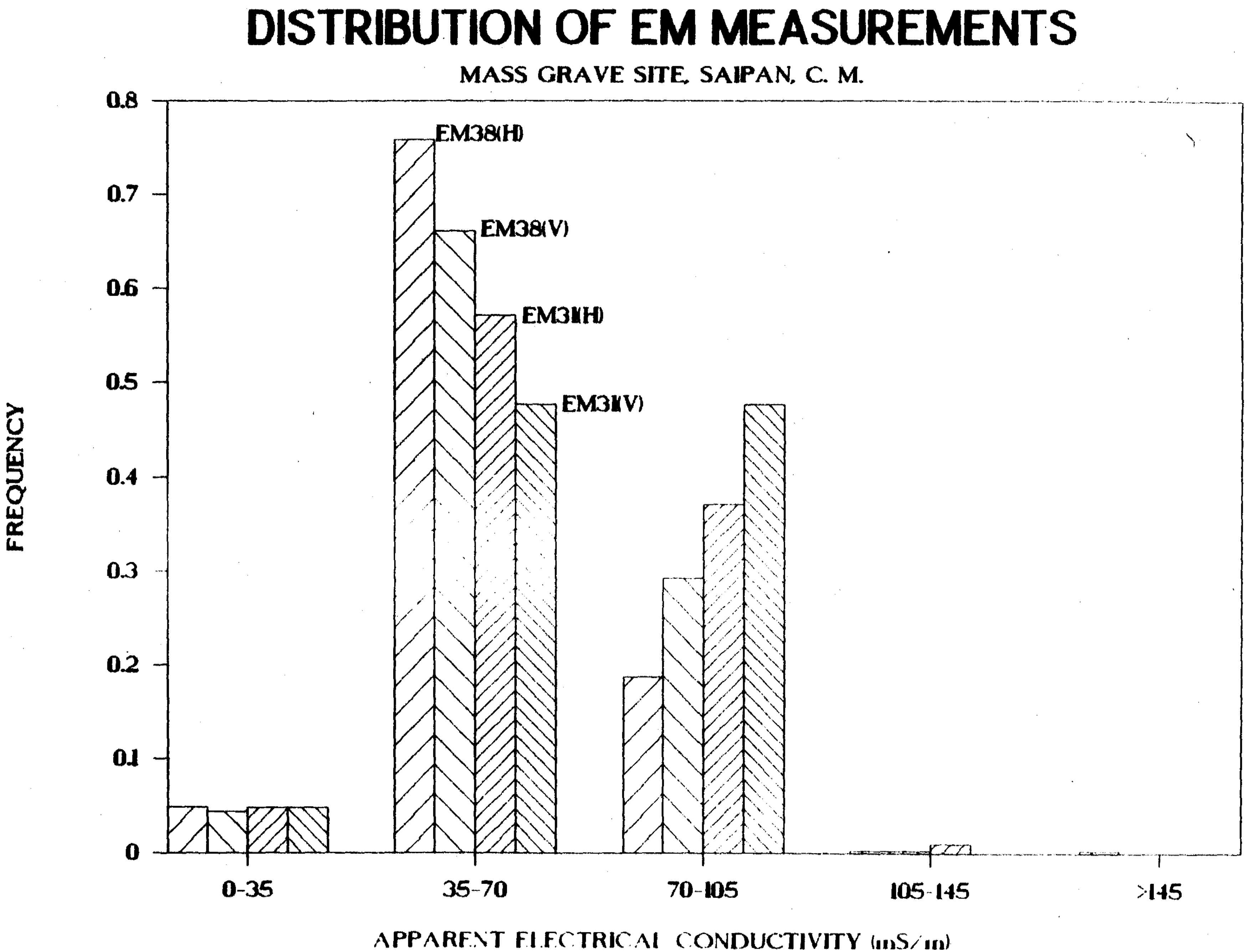
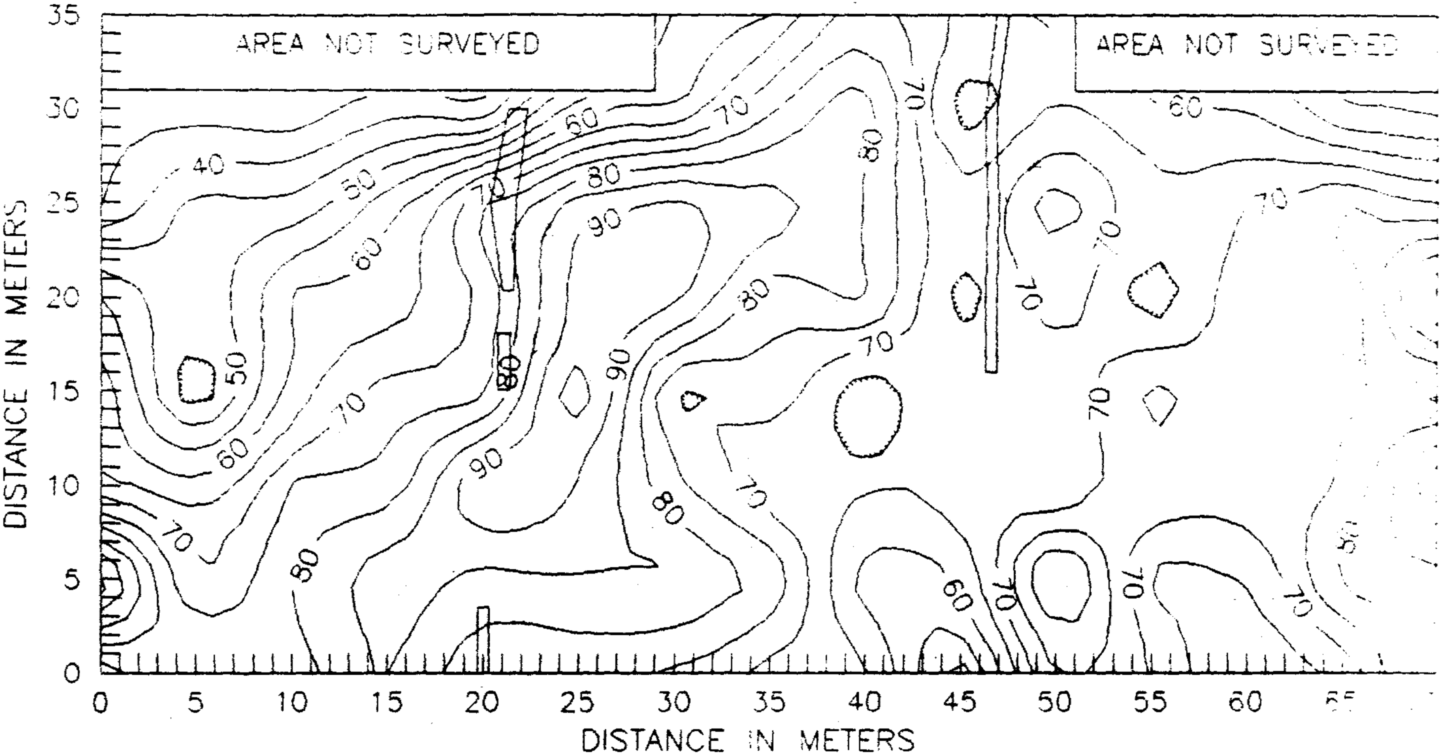

DISTRIBUTION OF EM MEASUREMENTS
MASS GRAVE SITE, SAIPAN, C. M.
FREQUENCY
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
EM38(H)
EM38(V)
EM31(H)
EM31(V)
0-35
35-70
70-105
105-145
>145
APPARENT ELECTRICAL CONDUCTIVITY (mS/m)

FIGURE 2

FIGURE 3

A


AREA NOT SURVEYED
AREA NOT SURVEYED
DISTANCE IN METERS
DISTANCE IN METERS
0
5
10
15
20
25
30
35
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60
70
80
90

B

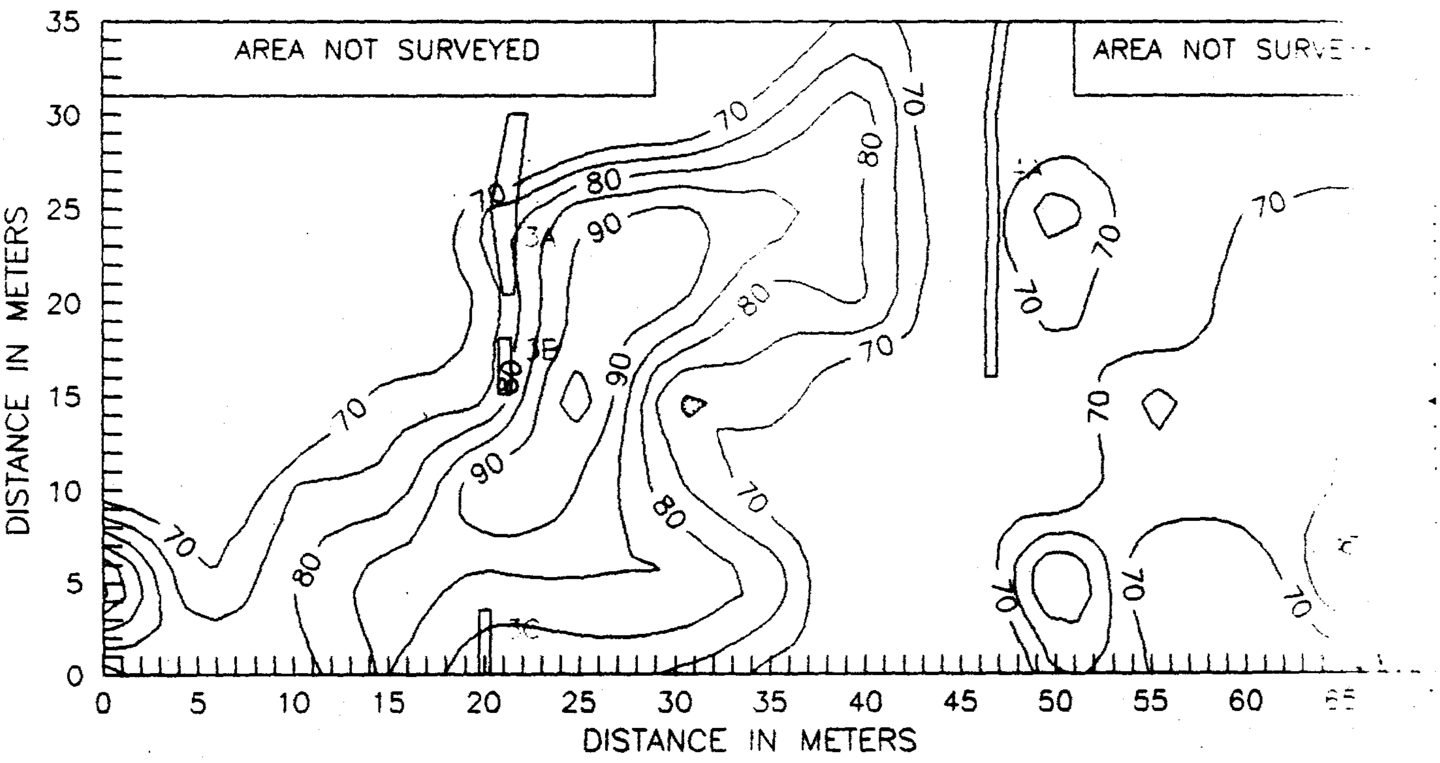
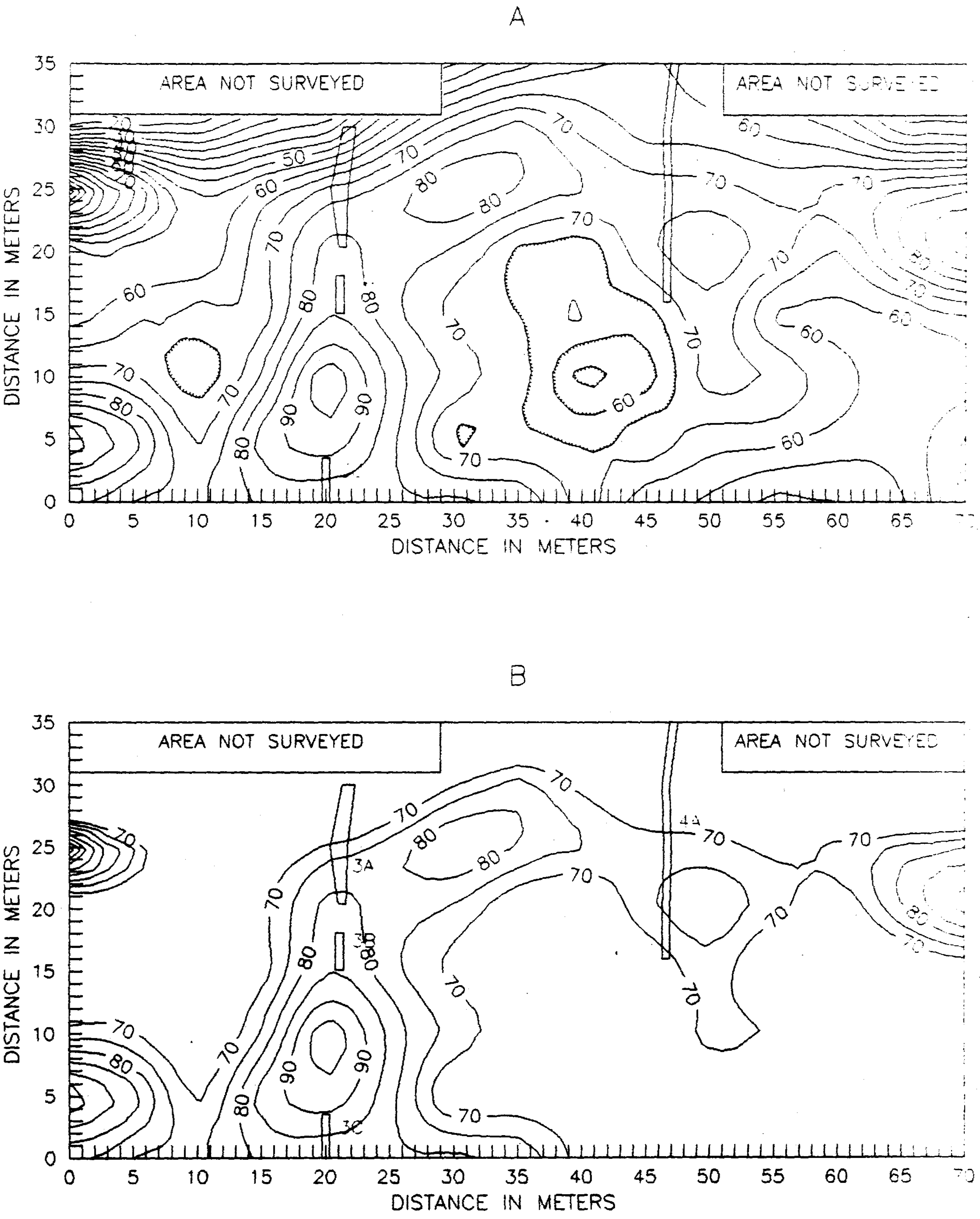

AREA NOT SURVEYED
AREA NOT SURVE
DISTANCE IN METERS
DISTANCE IN METERS
0
5
10
15
20
25
30
35
40
45
50
55
60
3A
3B
70
80
90

FIGURE 4



A
AREA NOT SURVEYED
AREA NOT SURVEYED
DISTANCE IN METERS
DISTANCE IN METERS
B
AREA NOT SURVEYED
AREA NOT SURVEYED
3A
4A
3C
DISTANCE IN METERS
DISTANCE IN METERS

IGURE 5

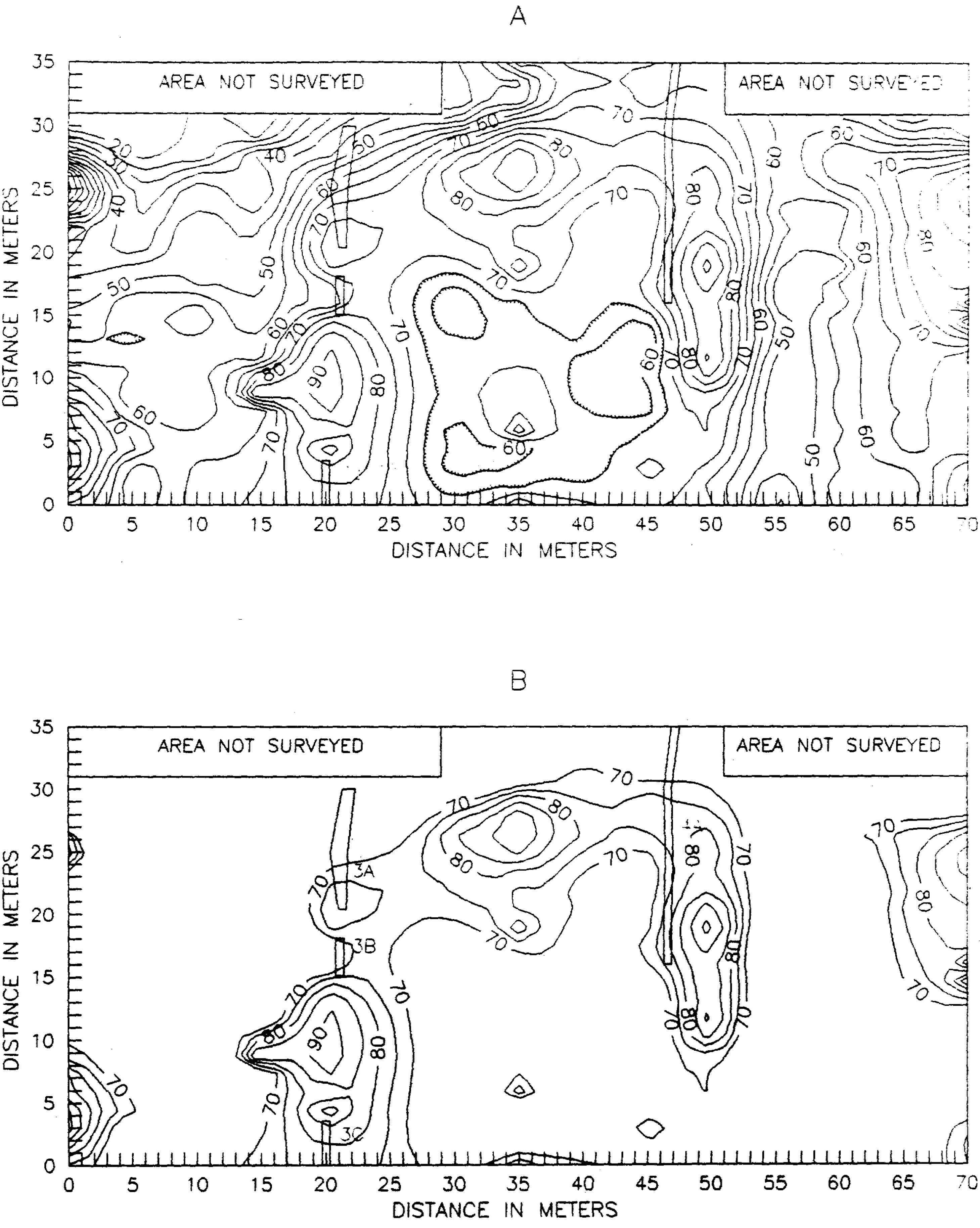

A
AREA NOT SURVEYED
AREA NOT SURVEYED
DISTANCE IN METERS
DISTANCE IN METERS
B
AREA NOT SURVEYED
AREA NOT SURVEYED
3A
3B
3C
DISTANCE IN METERS
DISTANCE IN METERS

FIGURE 6

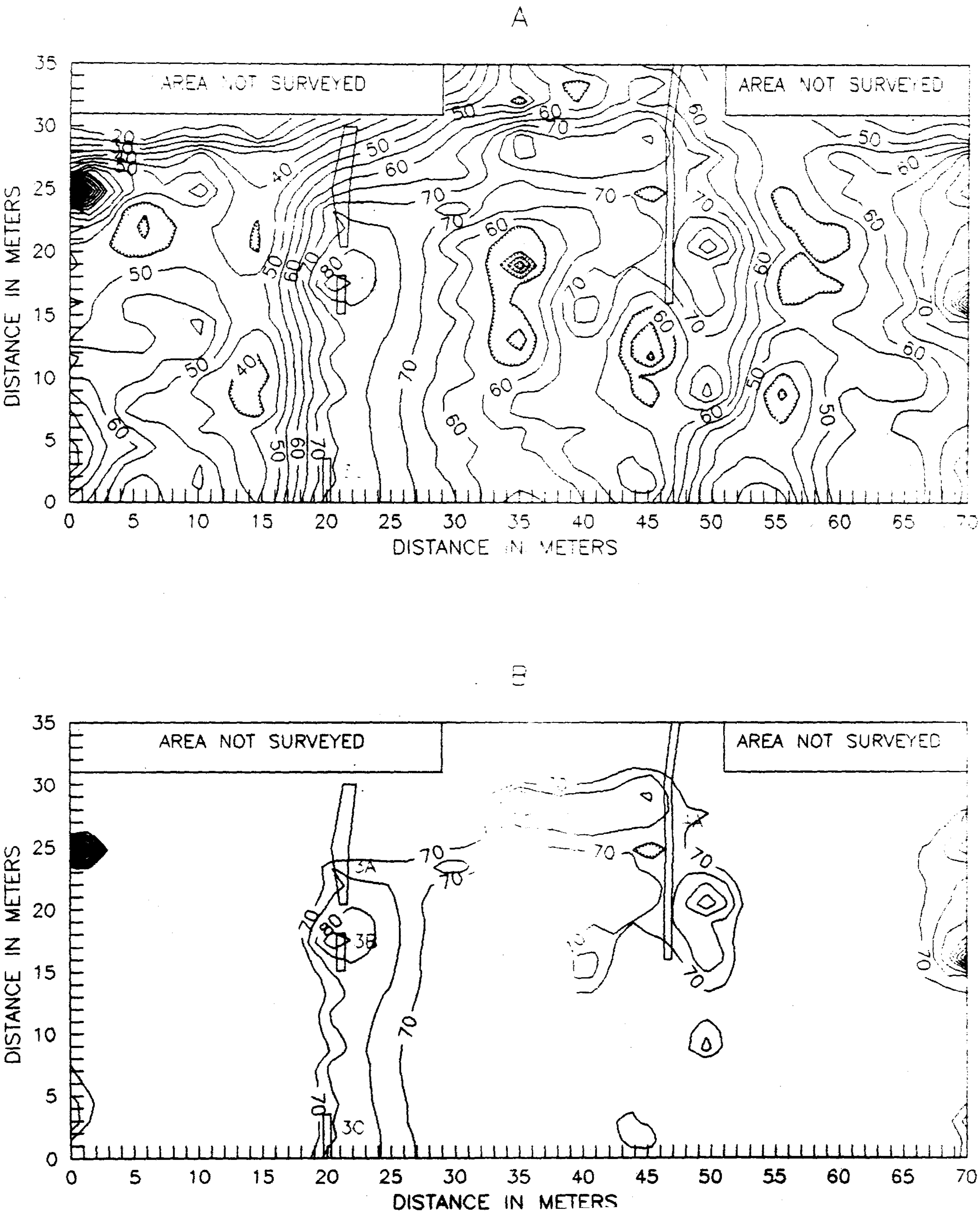
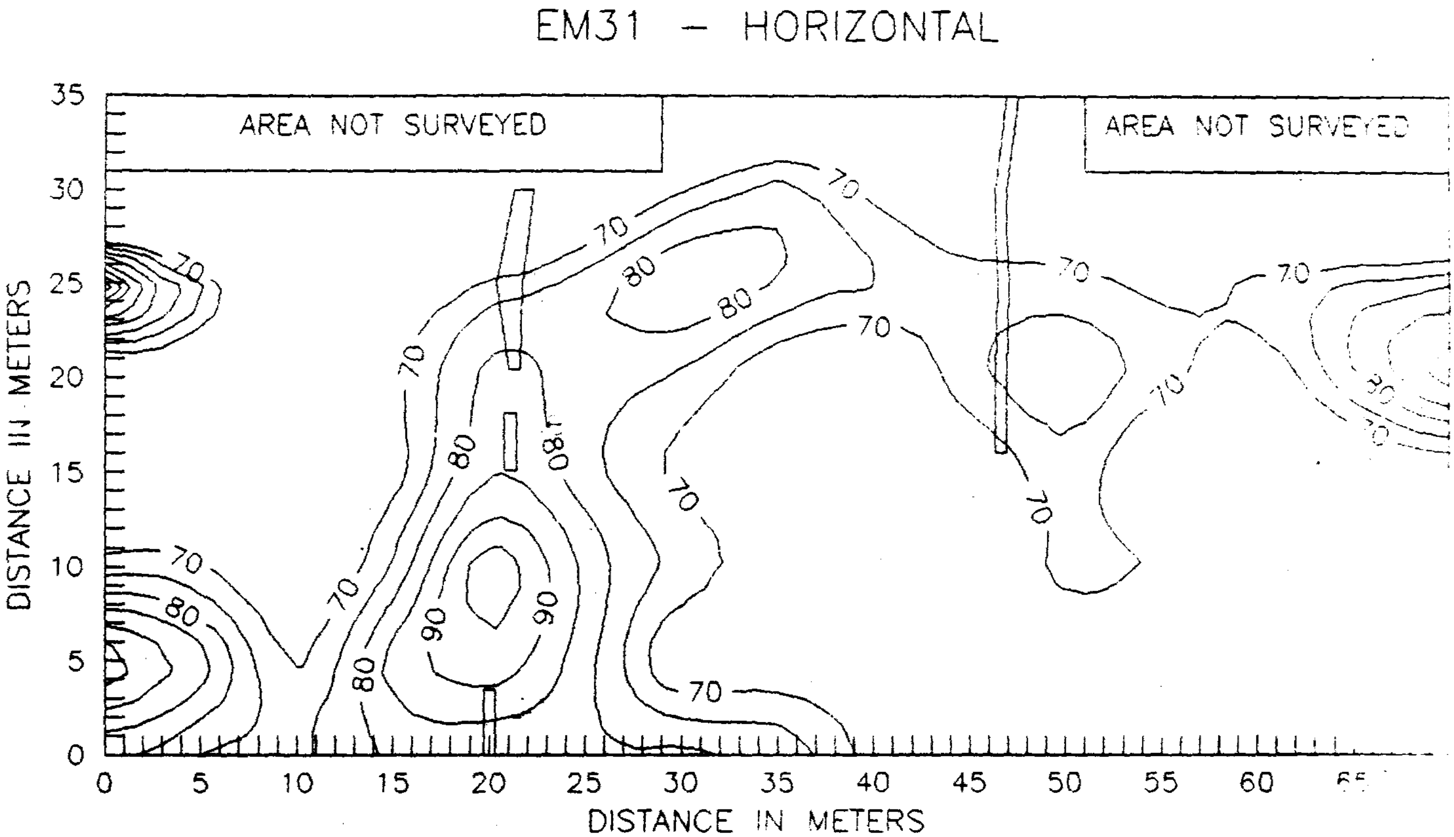

A
AREA NOT SURVEYED
AREA NOT SURVEYED
DISTANCE IN METERS
DISTANCE IN METERS
B
AREA NOT SURVEYED
AREA NOT SURVEYED
3A
3B
3C
DISTANCE IN METERS
DISTANCE IN METERS

FIGURE 7


EM31 - HORIZONTAL
AREA NOT SURVEYED
AREA NOT SURVEYED
70
80
90
DISTANCE IN METERS
DISTANCE IN METERS

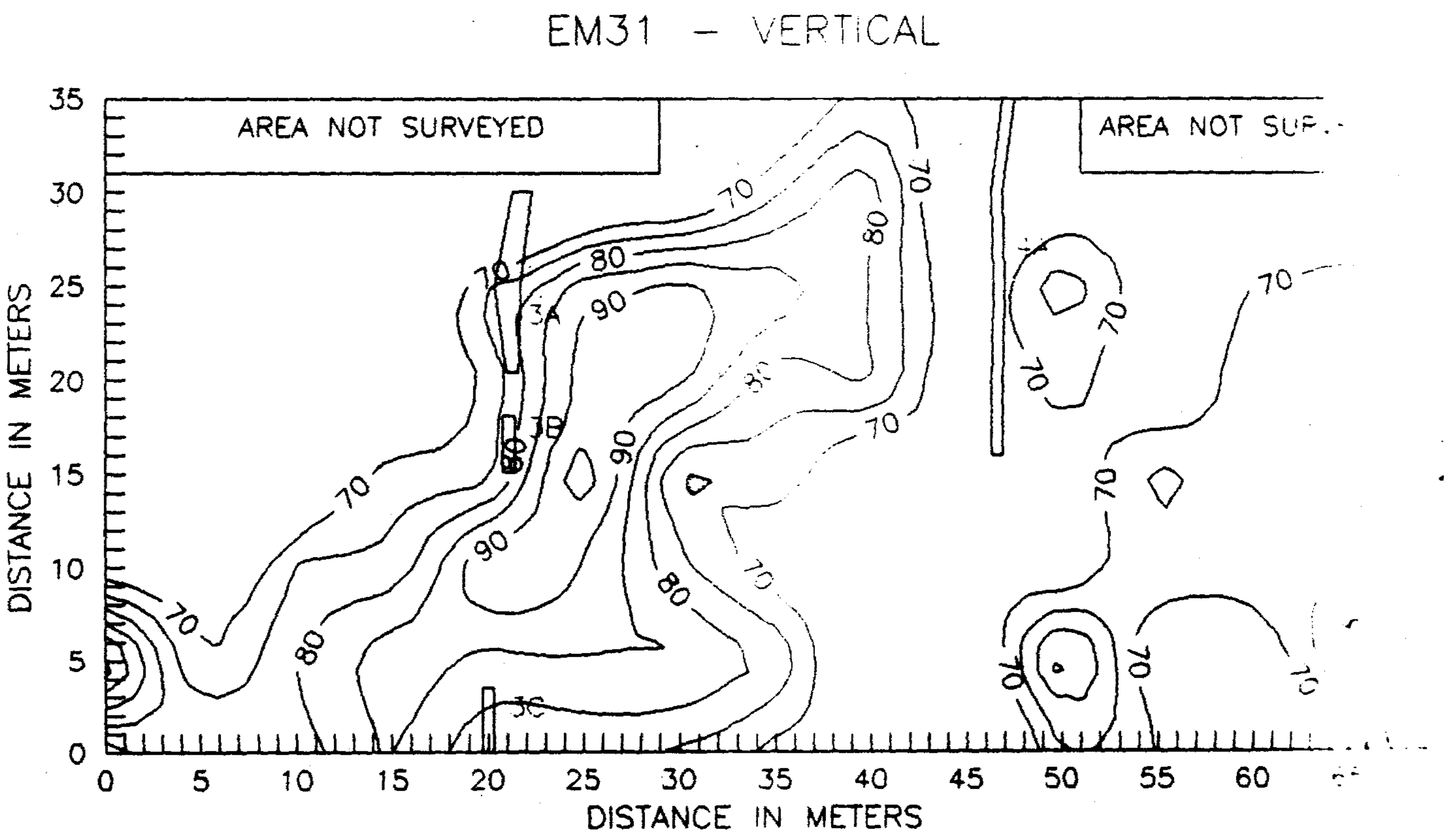
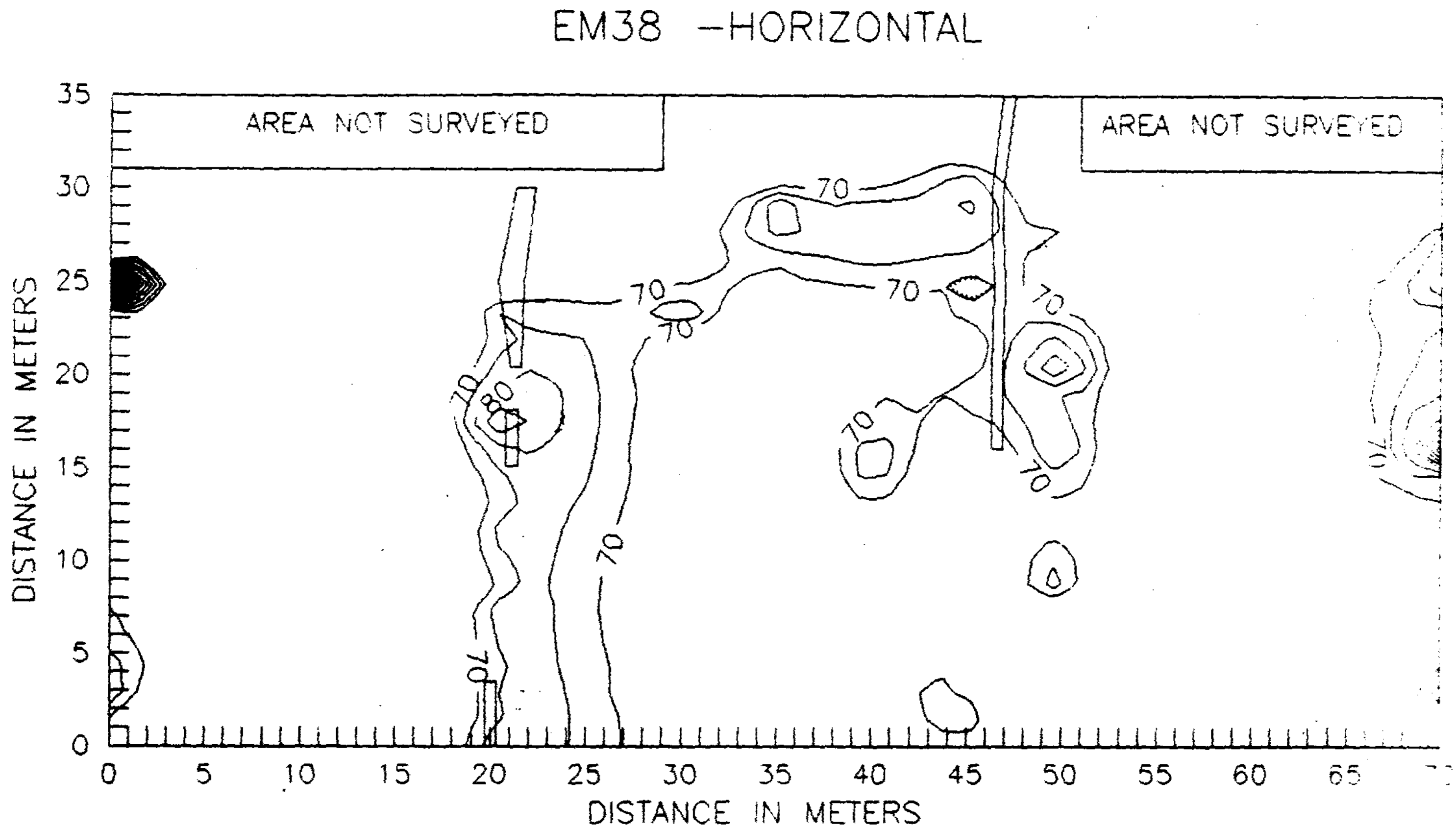
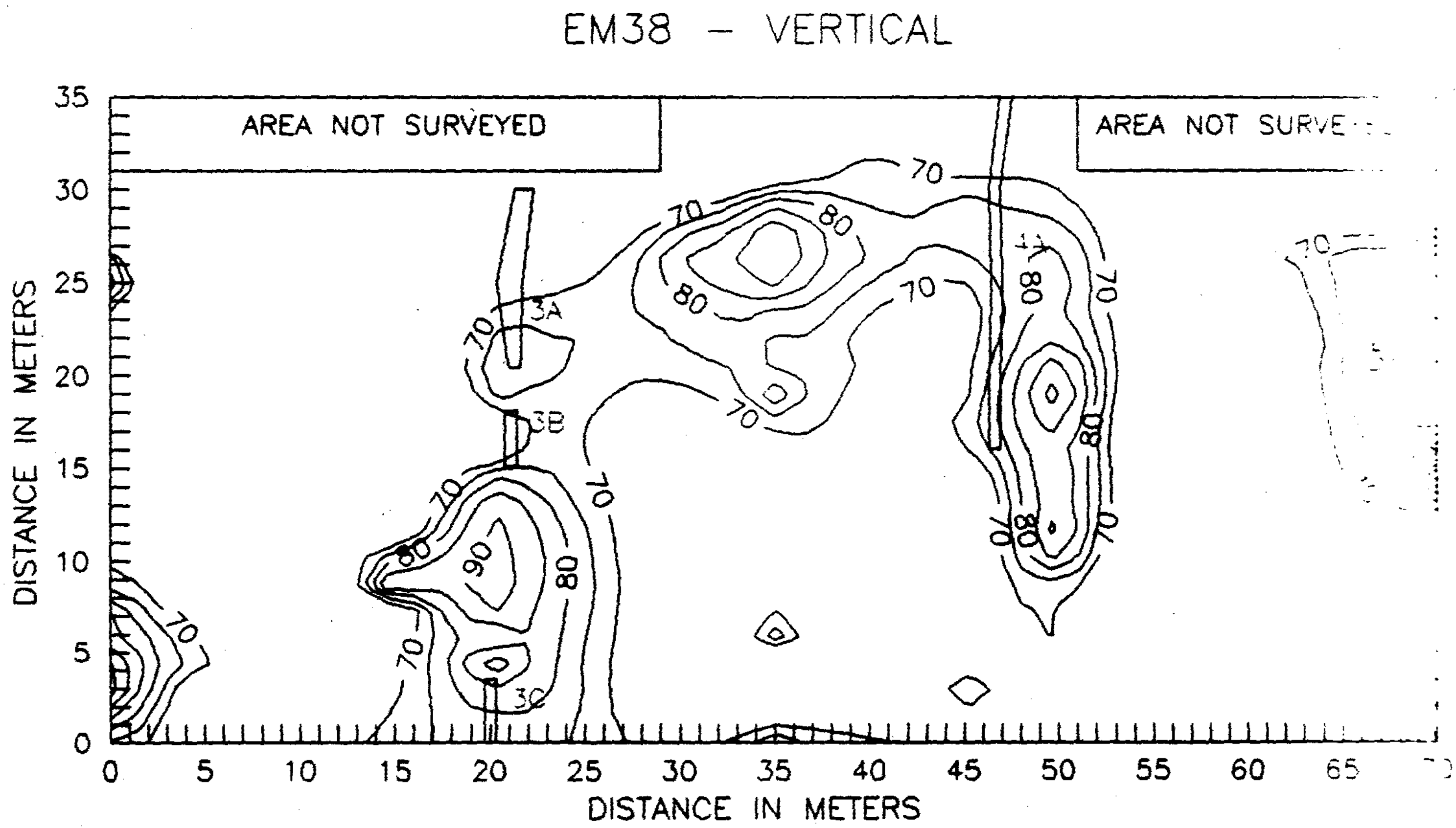

EM31 - VERTICAL
AREA NOT SURVEYED
3A
3B
70
80
90
DISTANCE IN METERS
DISTANCE IN METERS

FIGURE 8


EM38 -HORIZONTAL
AREA NOT SURVEYED
AREA NOT SURVEYED
70
80
DISTANCE IN METERS
DISTANCE IN METERS
0
5
10
15
20
25
30
35
40
45
50
55
60
65


EM38 - VERTICAL
AREA NOT SURVEYED
AREA NOT SURVE
70
80
90
3A
3B
3C
DISTANCE IN METERS
DISTANCE IN METERS
0
5
10
15
20
25
30
35
40
45
50
55
60
65