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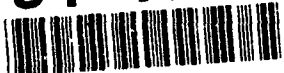
Archaeological Geophysics Investigation of the Wright Brothers 1910 Hangar Site: Wright-Patterson Air Force Base, Ohio

by Dwain K. Butler, Janet E. Simms, Daryl S. Cook

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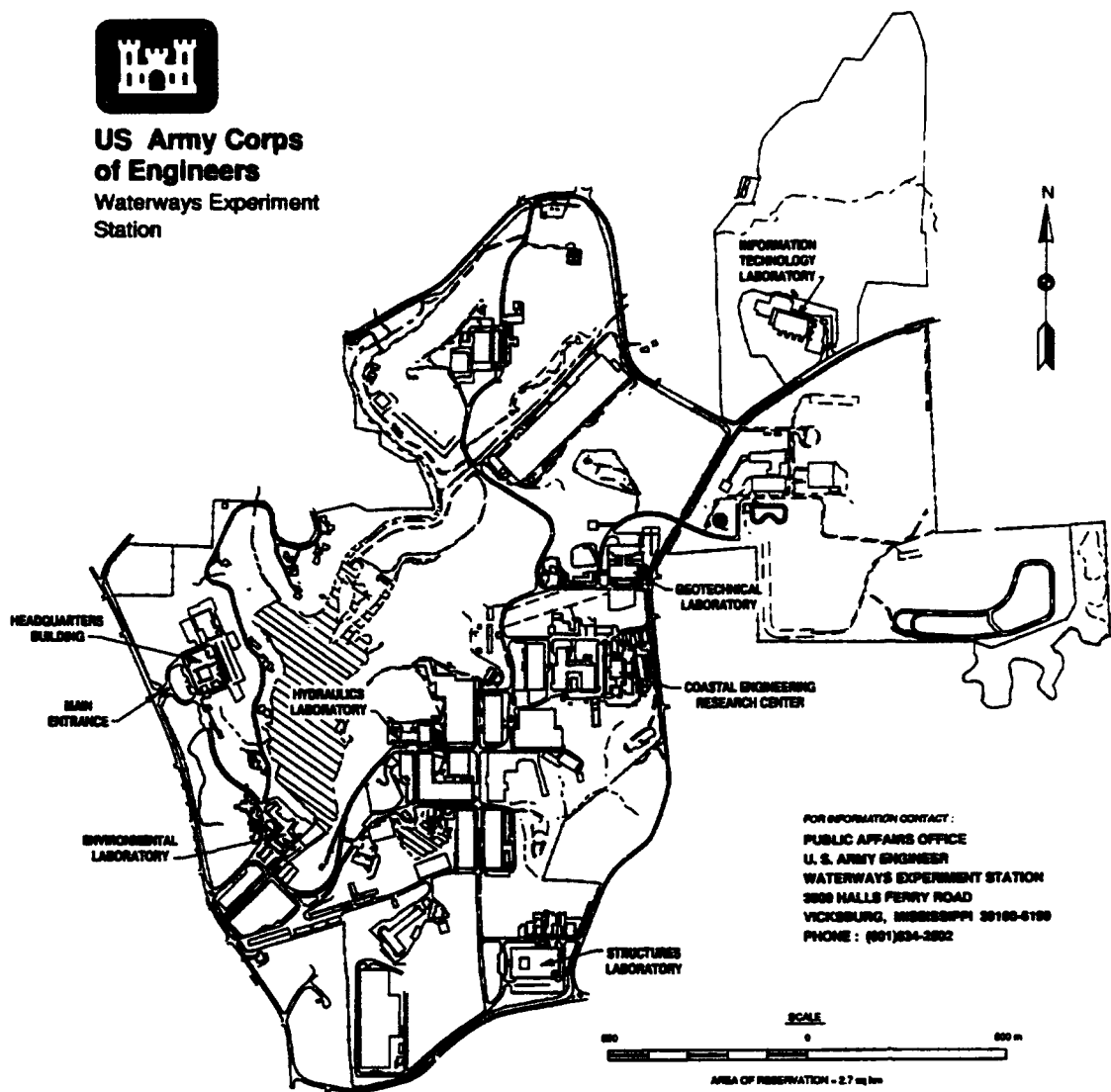
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Preface

A field investigation was conducted at the Wright Brothers 1910 Hangar Site at Wright-Patterson Air Force Base (WPAFB), Dayton, Ohio, during the period 18-23 October 1993, by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. The investigation was performed for the U.S. Army Engineer Construction Engineering Research Laboratory (CERL), Champaign, Illinois. CERL project officers were Messrs. James E. Bowman and Keith K. Landreth. The WPAFB point of contact for this work was Dr. Jan Ferguson.

This investigation was performed by Dr. Dwain K. Butler, Dr. Janet E. Simms, and Mr. Daryl Cook, Earthquake Engineering and Geosciences Division (EEGD). The assistance of the following individuals during the field investigation and preparation of this report is gratefully acknowledged: Dr. Ferguson, WPAFB; Mr. Stephen P. Brown, Architect, Dayton, Ohio; Ms. Jana Colvin, The Miami Conservancy District, Dayton, Ohio. This work was performed under the general supervision of Mr. Joseph R. Curro, Jr., Chief, Engineering Geophysics Branch, Dr. Arley G. Franklin, Chief, EEGD, and Dr. William F. Marcuson III, Director, GL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

1 Introduction

Background

In 1910, Wilbur and Orville Wright constructed a hangar near Dayton, Ohio, that housed their Wright Company School of Aviation and the Wright Exhibition Company. The hangar site is on the Huffman Prairie, location of their earlier flying experiments in 1904 and 1905 and near Simms Station (local interurban trolley stop). The aviation school operated until 1916, and the hangar remained on the Prairie until the late 1930's/early 1940's. In 1924 the hangar was used during the Dayton Air Show and International Air Races to display the Kitty Hawk, the plane that made the world's first sustained, controlled, powered flight in 1903; this is likely the last formal use of the hangar. The hangar was mistakenly destroyed, according to Air Force tradition, as part of "overzealous adherence to general orders to renovate the Base" and destroy all wooden hangars as part of the build-up associated with World War II (Babson 1991; Brown 1993).

The hangar site is on Wright-Patterson Air Force Base (WPAFB) property. Although the site has remained largely undisturbed since the hangar was demolished, notable exceptions include construction of storm drainage lines across the site and installation of a concrete pylon (placed by Orville Wright in 1941) near the site of a smaller 1905 hangar. A bronze marker was placed near the location of the 1910 hangar, probably while surface debris and living memory could accurately locate the site (Babson 1991). The bronze marker was located in 1990 by WPAFB surveyors. Also in 1990, a replica of the 1905 hangar was built in approximately the original location to celebrate the dedication of Huffman Prairie Flying Field as a National Historic Landmark by the U.S. Park Service. Subsequent to 1990, the bronze marker near the 1910 hangar site was removed and replaced by a larger concrete marker located approximately 2 m from the location of the bronze marker.

The 1910 hangar was a larger, more substantial, and longer-lived structure than the 1905 hangar. Some historic records indicate that the 1910 hangar size was 60 ft by 100 ft (nominal 18 x 30 m) in plan section; however, analyses of photographs indicate a likely approximate size of 48 ft by 70 ft (15 x 21 m) for the hangar (Brown 1993). The roof was formed by 5 timber trusses supporting the roof joists, with a 14 ft eave height and 20 ft ridge height. Originally, the hangar was supported by wood post columns (likely 4x4 in or 6x6 in) at the truss locations; however, later photographs show center col-

umns. The wood columns must have been sunk into the ground to provide lateral stability. The hangar originally had a wood floor, which was removed sometime after 1924.

Figure 1 is an aerial photograph of the flying field and 1910 hangar taken in 1911 from a Wright Flyer. Apparent in Figure 1 are the front sliding doors in a fully open position. The support for the overhead sliding "rail" was three vertical wood post columns with diagonal braces; the columns were sunk into the ground and the braces were anchored in some way to the ground. The road behind the hangar in Figure 1 is Symmes Road; and a fence, paralleling Symmes Road, passes immediately behind the hangar. The road crossing Symmes Road in Figure 1 is Marl Road. An aerial photograph taken in 1924 from much higher altitude (Figure 2) shows that Symmes Road "dead ends" at Marl Road, no longer passing behind the hangar. Figure 3 is reproduced from a WPAFB brochure describing present day features of the National Historic Site and a walking trail through the site. Note that Symmes Road, Marl Road, and Hebble Creek Road (evident in Figure 2) still exist, as well as other identifiable features in old aerial photographs. The outline of the Huffman Prairie Flying Field is obvious in Figure 2 by the vegetation patterns; the field boundaries may have been entirely fenced, as indicated in Figure 1 for the part of the boundary immediately adjacent to the hangar.

The present work, as well as the work in the reports by Babson (1991) and Brown (1993), is part of a continued effort to enhance the Huffman Prairie Flying Field National Historic Site. In particular, the most significant activity planned for the Site is the construction of a replica of the 1910 hangar. WPAFB hopes to complete construction of a replica hangar in time for the Dayton Bicentennial celebration in 1996 and the centenary of powered flight in 2003. Construction of the replica in the exact location of the original hangar will enhance the realism. Also it is important to document and preserve to the maximum extent possible any remaining in situ evidence and artifacts of the Wright Brothers occupation of the site prior to construction activity at the site.

The Hangar Site Physiography and Geology

Huffman Prairie Flying Field is flat (see Figure 1), with the only topographic relief provided by numerous ground hog holes. The site is in the floodplain of the Mad River, and is part of the Till Plains section of the Central Lowlands physiographic province. During the time of the geophysical surveys (October 1993), the typical prairie grasses ranged in height from approximately 5 cm on the walking trails to as much as 30 cm elsewhere. Residual stubble from taller plants was soft and friable and posed no constraints on the geophysical surveys. The only trees near the survey area were along Marl Road. Soil and gravel were exposed in the ground hog holes and the excavated material. The soil is a black, very poorly drained organic soil of the Linwood series (Soil Conservation Service classification), and is

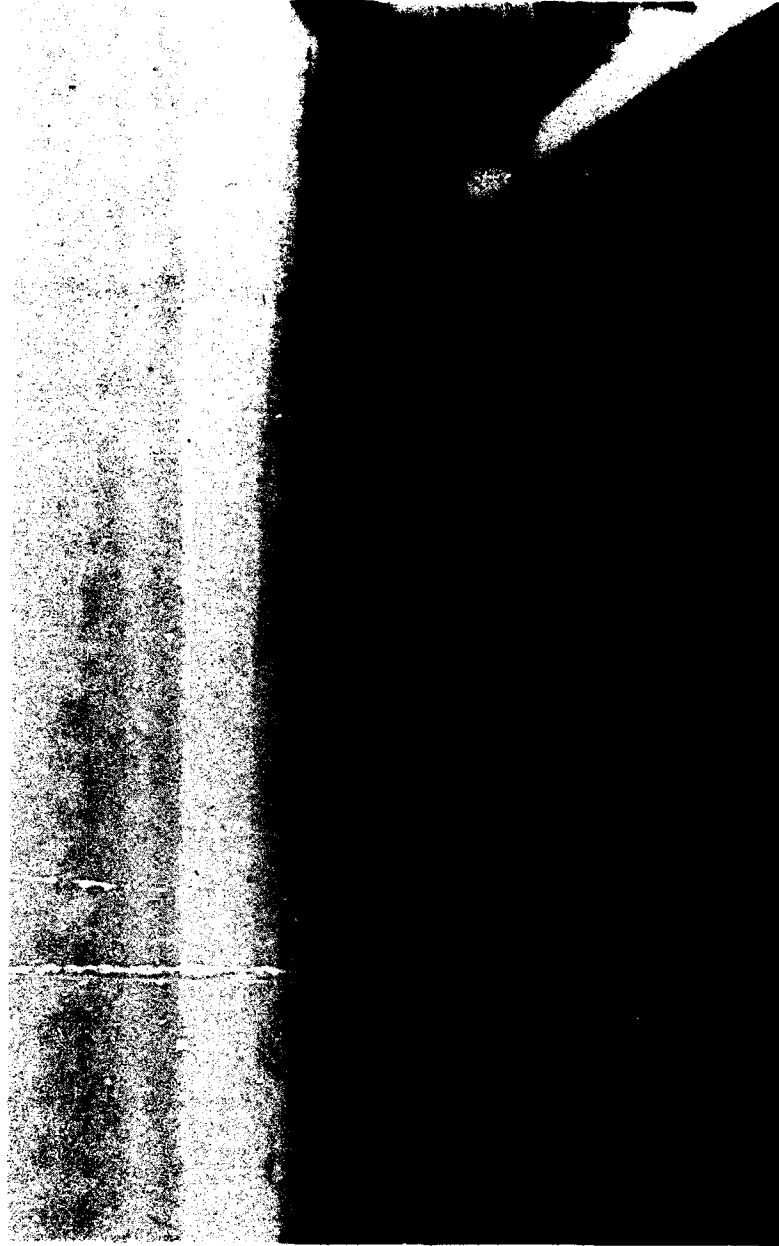


Figure 1. Aerial view of the Wright Brothers' 1910 Hangar, taken from a Wright Flyer in 1911

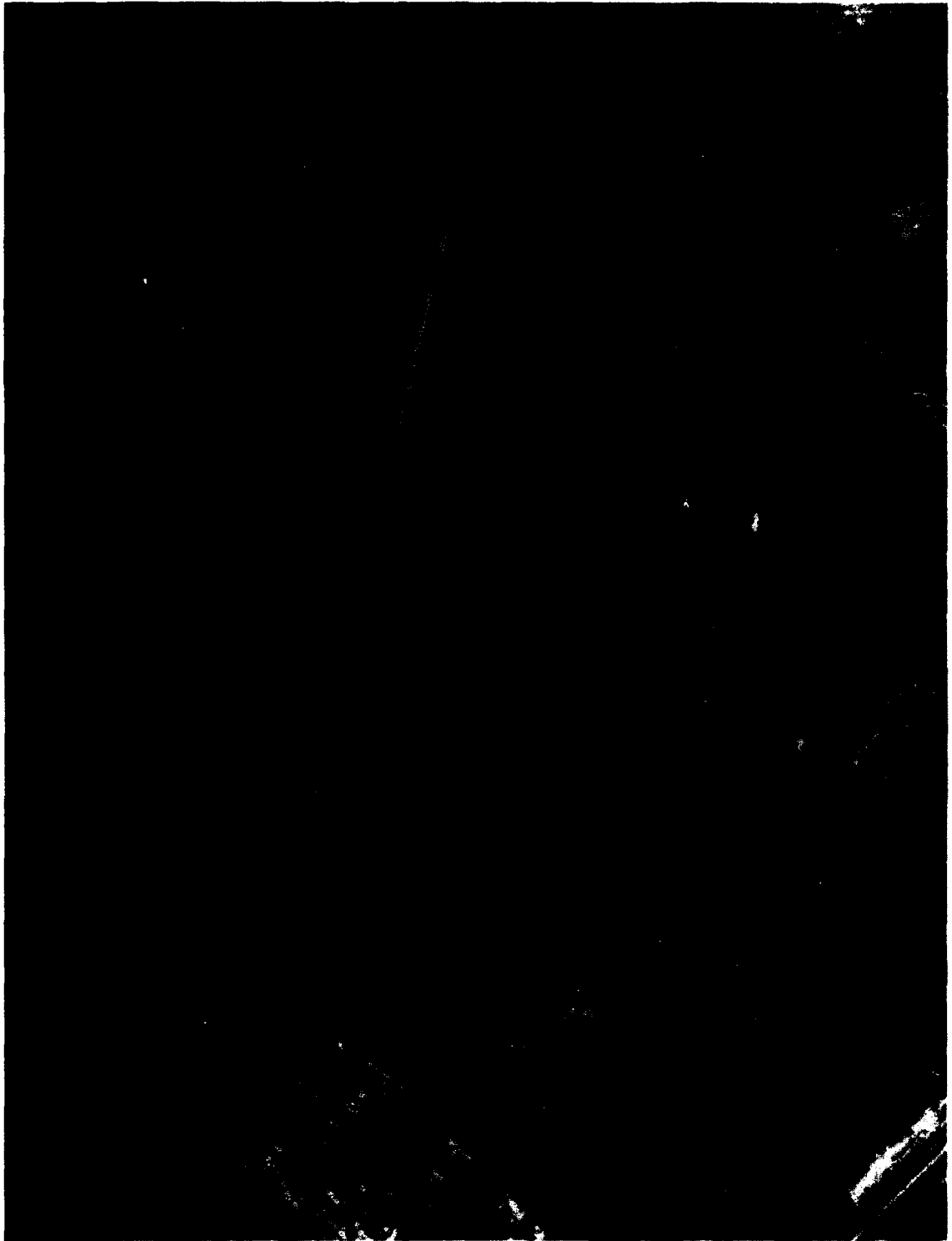
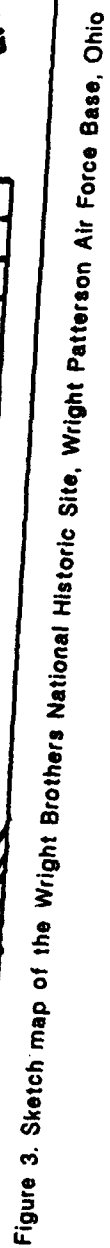


Figure 2. Aerial photograph taken in 1924 showing the flying field and hangar



approximately 1 m thick beneath the survey area. Beneath the soil are predominantly sands, gravels and some discontinuous clay layers of the Mad River buried-valley aquifer system (glacial drift deposits). The sand and gravel aquifer is highly permeable, and is in excess of 40 m thick beneath the site. The aquifer is underlain by shale of Ordovician age (Dumouchelle et al 1993). Water table depth beneath the site varies from 1.5 to 1.9 m during a typical year (U. S. Geological Survey 1992).

Objectives and Scope of Work

The present work supports a larger effort by the U.S. Army Engineer Construction Engineering Research Laboratory (CERL) to help develop and implement an archaeological management plan for the Huffman Prairie Site. Previous work at the site by CERL includes archaeological site mapping and excavation. Also CERL has arranged for acquisition of airborne multi-spectral imagery by the National Aeronautics and Space Administration (NASA, Bay St. Louis, Mississippi). The present work applies geophysical methods to survey the area in the vicinity of the 1910 hangar site. The specific objectives of the geophysical surveys are to (1) locate the actual hangar site as accurately as possible, (2) detect any remaining evidence of the hangar foundation, and (3) locate buried artifacts. The geophysical signature (if any exists) of the location of the hangar and its foundation (the wooden columns) is expected to be extremely subtle. Buried artifacts might consist of tools and aircraft parts; location and recovery of such artifacts is a high priority part of the overall effort to document and preserve the site. Artifacts, particularly those containing iron and other metals, that have not totally rusted and disintegrated can generally be located by the geophysical surveys.

2 The Plan of Investigation

Concepts of the Geophysical Survey Methods

General

Geophysical methods used for archaeological investigations provide both qualitative and quantitative information regarding surficial and subsurface materials, processes, and geometric relationships. The surficial and subsurface information can generally be classified in four categories: (1) surface features and their geometric relationships at a given point in time; (2) normal subsurface geology and its variation in vertical and horizontal directions; (3) culture-induced disturbances of the normal geology; (4) cultural artifacts within the normal geology or disturbed areas. Category (1) information includes surface or very-near surface information on topography, geomorphic features, and cultural features. The geophysical signature for category (2) above is considered the normal background for geophysical survey data. Geophysical signatures of categories (3) and (4) represent anomalies that are superimposed in some manner on the normal background. Thus the keys for any archaeological geophysics investigation are to identify and understand the normal background (normal geology) and then to interpret the significance of any anomalies relative to the normal background.

The geophysical methods applicable to archaeological investigations include airborne imagery (photography and multispectral imagery), airborne electromagnetic and magnetic surveying, and surface surveying. This report documents the surface geophysical surveying performed at the site. Surface geophysical surveying methods most applicable and frequently utilized for archaeological investigations can be classified as magnetic methods (total field and vertical gradient), electromagnetic (EM) methods, resistivity methods, and ground penetrating radar (GPR). GPR is an EM method, but it is sufficiently unique in terms of field procedures and data display and interpretation that it is usually considered separately. *Seldom is only one geophysical method used for an archaeological geophysics investigation, rather multiple methods are utilized in a complementary and integrated manner. An anomalous feature or condition in the subsurface may not be detected by one geophysical method, but will often be detected by another method. When an anomalous feature is detected by more than one geophysical method, the significance and interpretation of the anomaly is enhanced and facilitated.* The present investigation included GPR, total field magnetic, and electromagnetic surveys. Brief de-

scriptions of the methods which follow are not intended to be comprehensive; more detail can be found in Scollar et al (1990), Telford et al (1990), Ward (1990), and Heimmer (1992).

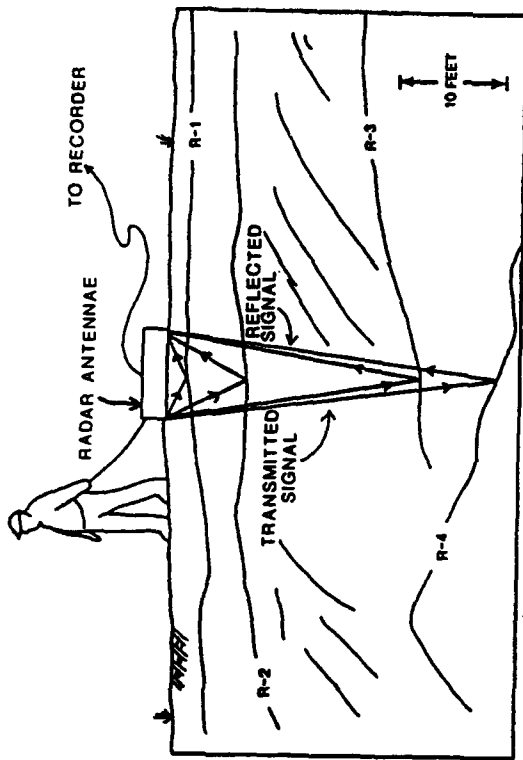
Aerial photography

Aerial photography is used in the present investigation for assessment of the present surface site conditions in relation to conditions at the time of site occupation by the 1910 hangar. An aerial photograph showing the 1910 hangar (Figure 2) was digitally scanned and georeferenced to a digitized current WPAFB facilities map (similar to Figure 3). The digitized imagery and map information can be directly referenced to the site survey grid and geophysical survey anomaly maps.

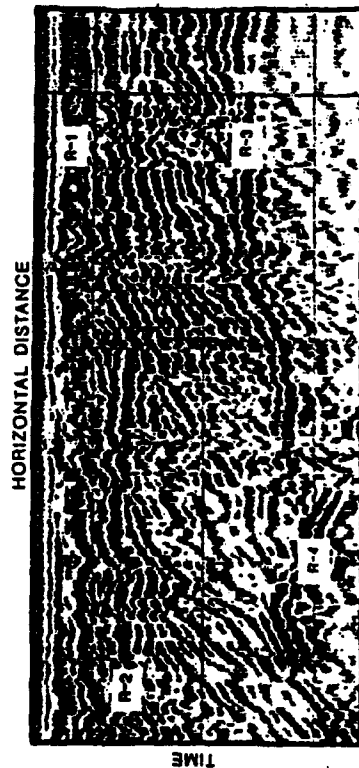
Ground penetrating radar surveying

GPR is an electromagnetic geophysical method typically utilizing electromagnetic frequencies of 50 MHz to 1 GHz. The method includes a transmitter (Tx) and receiver (Rx) that are pulled or moved on the surface a fixed distance apart along profile lines. The Tx emits a short pulse of electromagnetic energy that propagates into the subsurface, reflects from interfaces between different geologic materials or conditions (such as the water table) and objects or other features within the subsurface, and is then recorded (by a graphic recorder or on magnetic tape or computer disk). GPR antennae are commonly classified by the center frequency of the pulse emitted by the Tx. For the present work, a 300 MHz antenna was used. Figure 4a is a cartoon illustrating a GPR survey over some subsurface reflectors and the resulting graphic GPR record. The graphic record represents amplitude of the electromagnetic signal at the Rx as a function of the horizontal distance (from some starting point on a survey line to the center of the Tx-Rx pair) and the two-way (down and up) travel time of the signal. An illustration of the manner in which the electromagnetic signal (amplitude versus time) is converted into what is shown on the graphic record is given in Figure 4b.

The GPR system prints time lines and distance markers on the record. The distance markers are triggered by the surveyor as the Tx-Rx pair passes a flagged or known location. Between the triggered distance marks, the data is acquired virtually continuously, depending on the walking speed of the surveyor and the rate at which the system records Tx pulses. For a typical recording rate of 25 scans/s and a walking speed of 1 m/s, a record will be obtained every 4 cm. To convert the time scale to a depth scale, time must be multiplied by the appropriate propagation velocity for electromagnetic waves in the geologic material (either by directly measuring velocity in some way or by using a typical velocity for the material). An electromagnetic wave velocity of 1×10^8 m/s (corresponding to a dielectric permittivity of 9) is accepted as appropriate for estimating depths for the GPR surveys at the hangar site. An elementary GPR overview, including the above concepts, can be found in Butler (1992).



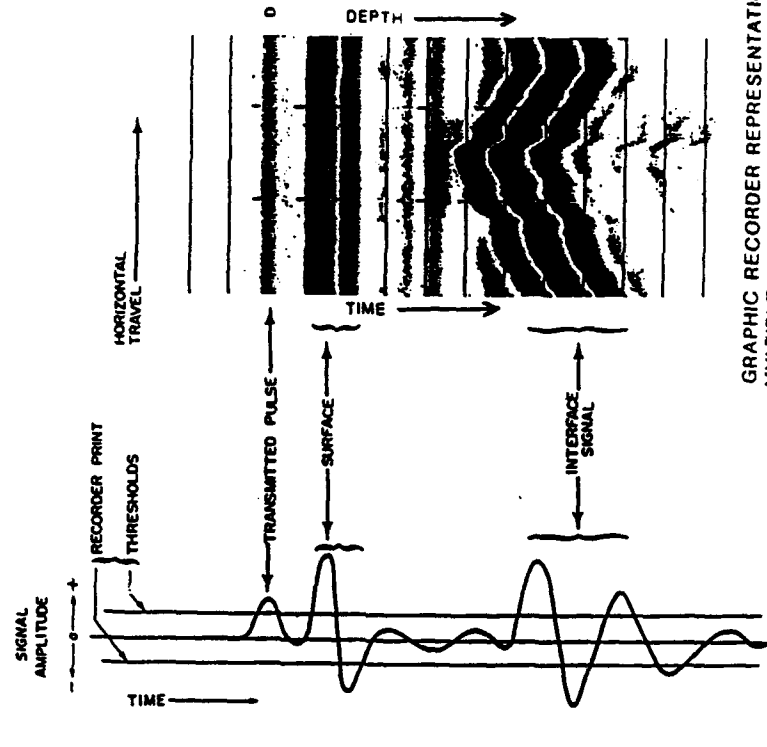
GPR SURVEY OVER GEOLOGIC SECTION, REFLECTORS R-1 -- R-4



GRAPHIC RADAR RECORD FOR ABOVE SECTION

4a. GPR survey concepts

GPR RECEIVED SIGNAL AND GRAPHIC PROFILE DISPLAY



SKETCH OF TYPICAL SINGLE WAVEFORM

GRAPHIC RECORDER REPRESENTATION OF MULTIPLE WAVEFORMS ALONG A PROFILE

4b. GPR graphic record

Figure 4. Ground penetrating radar surveying

Magnetic surveying

Magnetic surveying involves measurements of the total magnetic field strength as a function of position over the survey site. The magnetic survey at the hangar site was conducted using a proton precession magnetometer with a measurement accuracy of ± 1 nT (nanoTesla). The normal earth's magnetic field strength at the site is approximately 55,200 nT. Materials on the surface or in the subsurface containing iron and certain other materials with high magnetic susceptibility or remnant magnetization (for example fired bricks or stones can have remnant magnetization) will produce magnetic anomalies, relative to the normal earth's magnetic field strength, that are detected and mapped by the magnetic survey. The magnetometer was operated in a "walking" data acquisition mode, i. e., data were acquired at fixed time intervals while the surveyor walked along survey lines at a slow rate. A time interval of 1 s was used, resulting in a measurement at least every 1 m along the survey lines. The data are corrected for time variations of the magnetic field by reoccupying base stations frequently during the survey. Magnetic survey data are presented as magnetic field strength anomaly contour maps; the anomaly magnitudes are defined relative to the value 55,200 nT. For well-defined localized magnetic anomalies, it is possible to estimate depths for causative subsurface features based on characteristics of the anomaly (magnitude, spatial extent).

Electromagnetic surveying

Two electromagnetic (EM) instruments were used at the hangar site, both identical in physical concept. One instrument, designated EM38, is a shallow depth of investigation device. The second instrument, designated EM31, has a greater depth of investigation. Both instruments contain a Tx and Rx in a single housing, with the following characteristics:

Instrument	Frequency (kHz)	Tx-Rx Separation (m)	Approximate Depth of Investigation (m)
EM38	14.6	1.00	1.5
EM31	9.8	3.66	5

Figure 5 shows the EM31 during a survey at the hangar site. The approximate depths of investigation given for these instruments should be used only as "rules of thumb" and are for the horizontal coplanar Tx-Rx coil orientation. The rule of thumb depth of investigation for the EM31 accounts for the fact that the instrument is carried approximately 1 m above the ground.

The Tx generates a time-varying magnetic field (the primary field) that interacts with subsurface materials to induce electrical currents and secondary magnetic fields. Secondary magnetic fields from subsurface materials are detected by the Rx along with the primary field. Figure 6a illustrates the concept of operation of the EM instruments. Tx and Rx are shown as horizontal coplanar coils at or near the surface, and the Rx is shown being

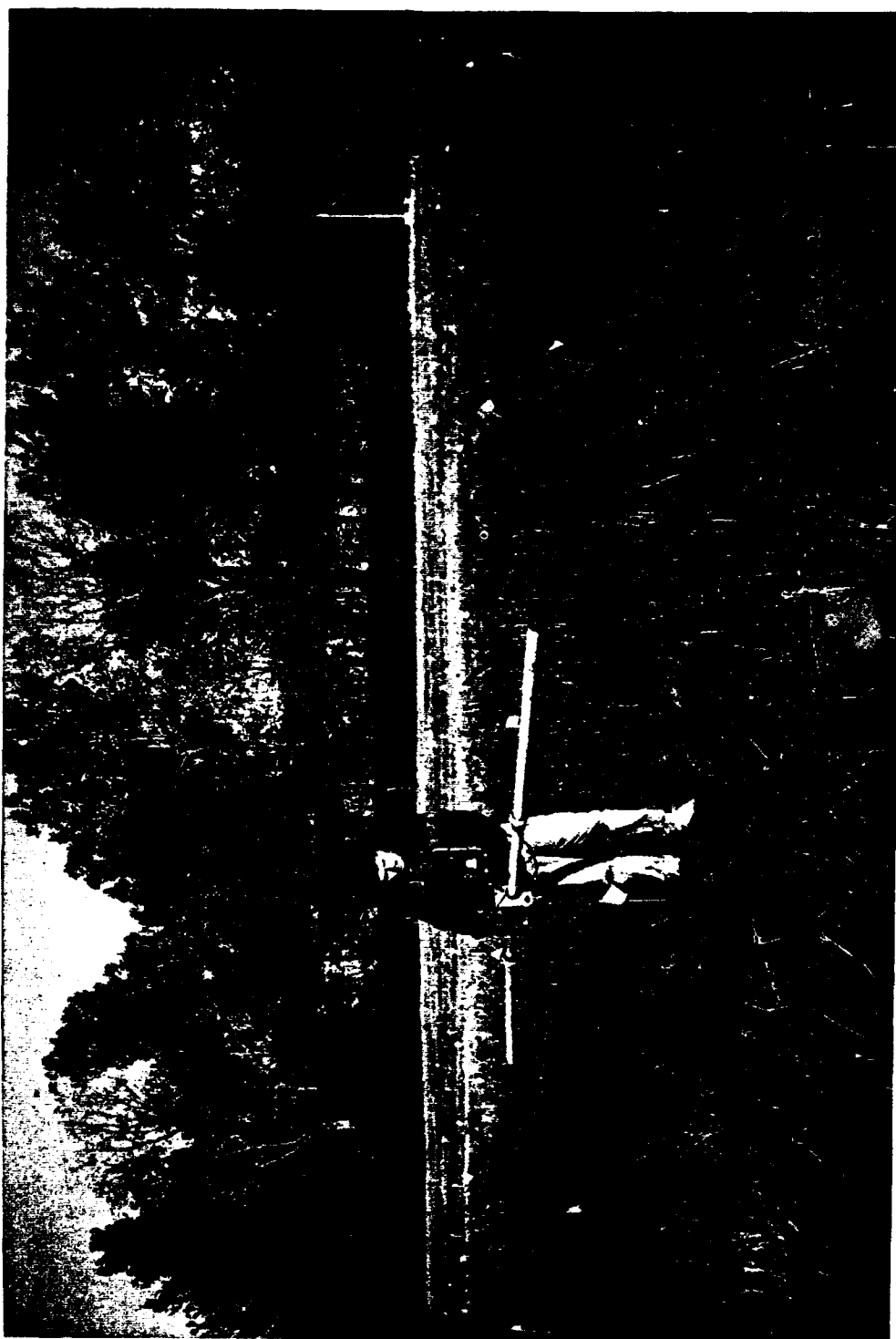
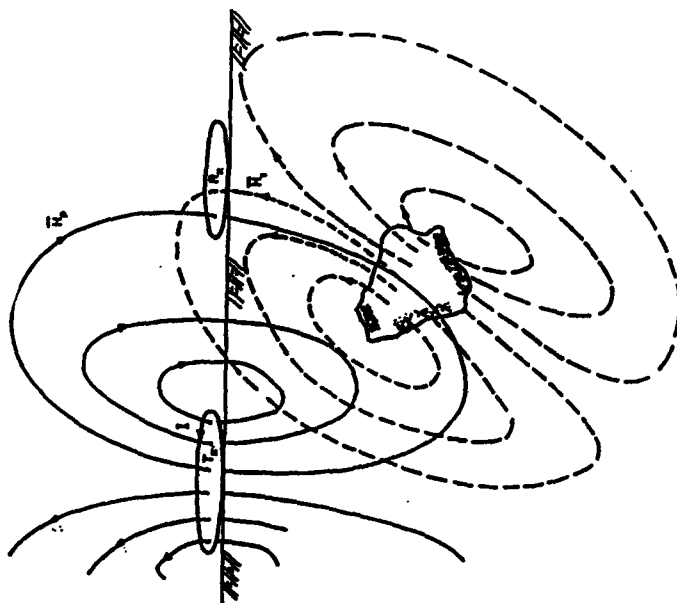
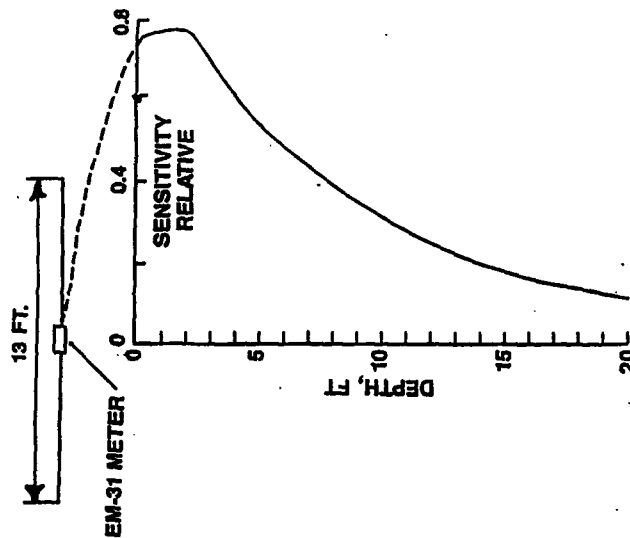


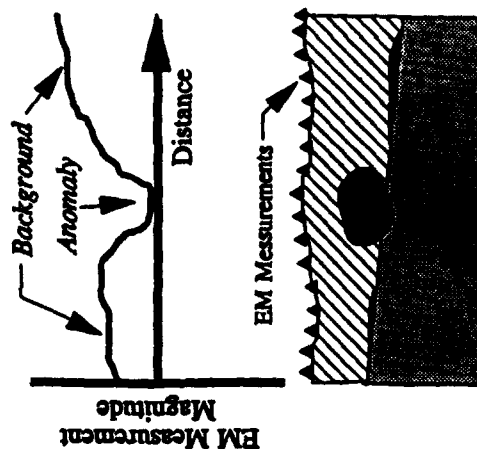
Figure 5. The EM31 during a survey at the hangar site. Flying Field Flag #6 is shown in the background.
The small flags define a 4 x 4 m grid over the 100 x 68 m survey area



6a. EM induction. Tx--transmitter;
Rx--receiver; I--current; Hp--primary field;
Hs--secondary or induced field



6b. EM31 response versus depth, for
instrument carried at "hip-height"



6c. Concept of EM anomaly and
background for a hypothetical
geologic section

Figure 6. Concepts of EM induction surveying

influenced by both the primary magnetic field and the secondary magnetic field. The EM instruments can measure both a component in-phase with the primary field and a component 90° out-of-phase (called the quadrature component) with the primary field. The quadrature component is directly proportional to the electrical conductivity of the subsurface feature and is expressed in mS/m (milliSiemen/meter), while the in-phase component is expressed in ppt (parts per thousand) of the primary field. Conductivity measured by the EM instruments is properly termed an apparent conductivity and represents a weighted volume average of true conductivity of materials within the volume of investigation of the instruments; Figure 6b illustrates the depth weighting (relative sensitivity) for the EM31. The in-phase component is primarily used for detection of subsurface metallic objects. Magnitude and spatial width of the secondary field detected by the Rx depends on the electrical conductivity of the subsurface anomalous feature as well as its size and depth. When the Tx and Rx are moved together along a surface profile over a subsurface anomalous feature, an anomaly will be detected (1) if the subsurface feature is within the depth of investigation of the instrument and (2) if the feature is sufficiently large relative to the spacing between surface measurement points; the anomaly will be relative to the normal background (Figure 6c). EM data are acquired on profile lines, and then processed to give EM anomaly contour maps.

The Site Survey Grid

After review of historical documents, WPAFB base maps, and aerial photographs, a survey area was selected to encompass the most likely location of the 1910 hangar and locations indicated on base maps (some discrepancies exist). The area, 100 m x 68 m, was approximately centered on the likely location. The northeast corner of the survey area was co-located with Flag #6 of the present Huffman Flying Field markers (Figure 7), and the northern, long side of the area is along a line from Flag #6 to Flag #7. The survey area is shown in Figure 8. The area was flagged on a 4-m grid with plastic (nonconductive) pin flags. Establishing the survey grid required approximately 1/2-day for a two-person crew. Location coordinates (0E,0N) are assigned to the southwest corner of the area; consequently, the coordinates of the northeast corner are (100E,68N). *Grid north (along the short dimension of the survey area) is rotated by approximately 18° relative to geographic north.*

Semi-permanent features noted on the site map (Figure 8) are the concrete marker, Flag #6 (Figure 7), and walking tour pole markers. All of these features are connected by mowed walking paths, also shown on the map. Transient features noted on the map are ground hog holes. The holes are as large as 30 cm in diameter and many apparently extend well into the glacial gravels beneath the soil (based on considerable amounts of gravel in excavated material). Both semi-permanent and transient features are important for reference and for correlation with locations of geophysical anomalies. For reference completeness, the CERL archaeological excavations of 1990 assign location coordinates (500N,400E--*geographic north and east*) to the location of

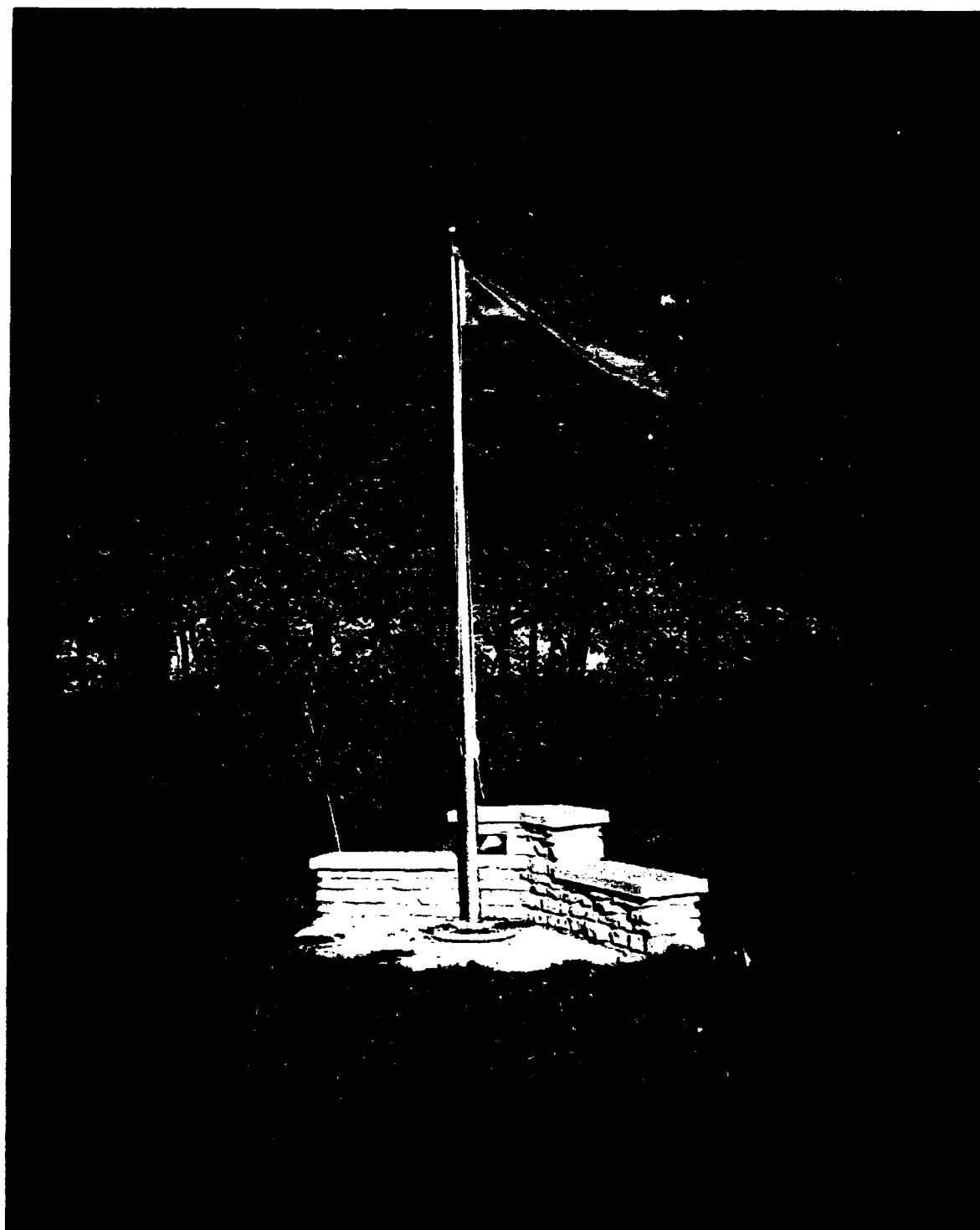


Figure 7. Flying field flag #6; survey grid coordinates (0E,68N)

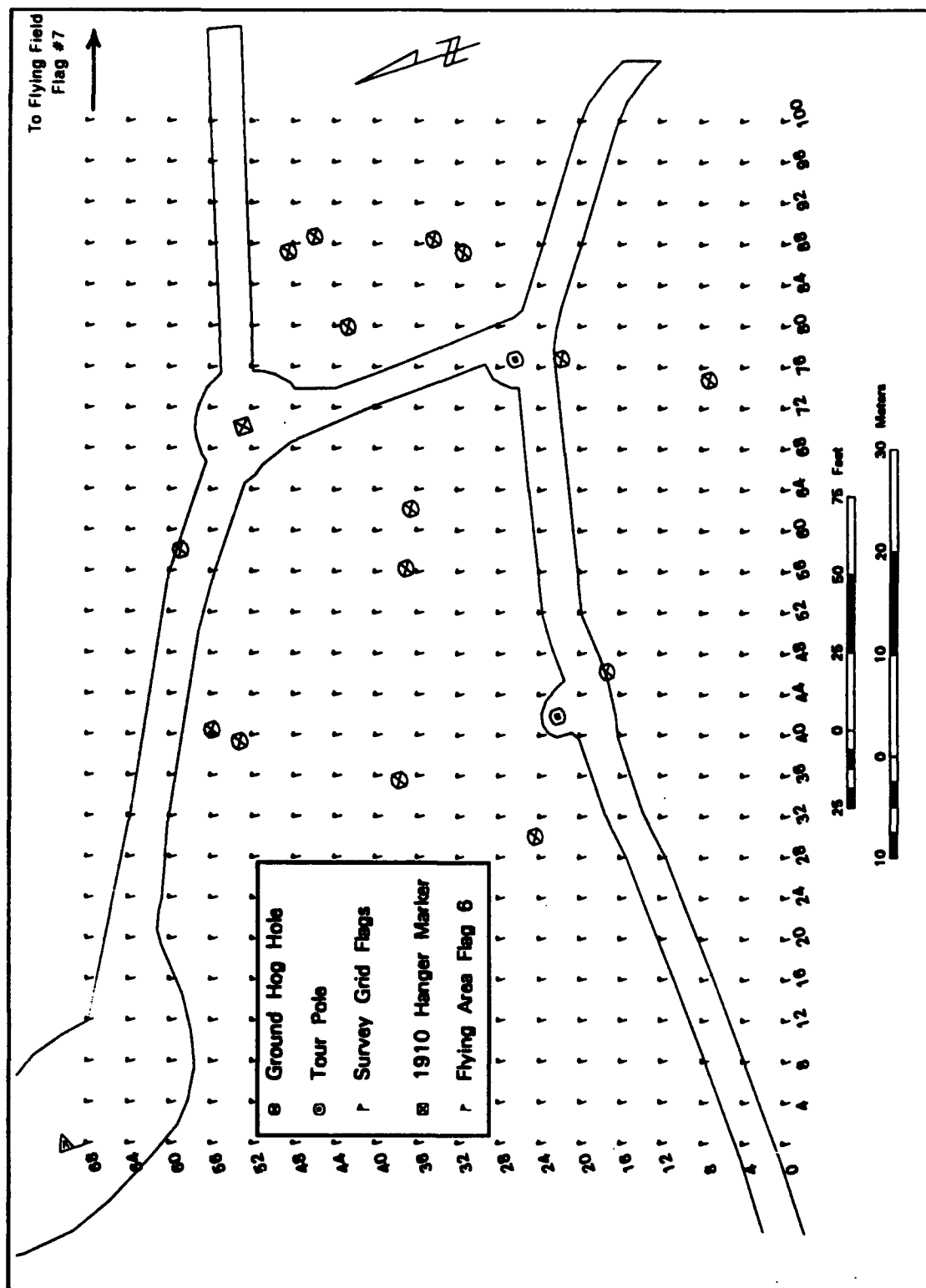


Figure 8. Site survey grid showing semi-permanent and transient features

the original bronze marker; this corresponds approximately to location (68E,52N) in the present grid coordinates.

Geophysical Surveys

The geophysical surveys conducted at the 1910 hangar site are detailed in the following tabulation.

GPR Surveys (see Figure 9):

Along E-W lines spaced by 4 meters, from 0N to 60N

Along N-S lines spaced by 8 meters, from 8E to 96E

Based on anomalous indications, additional lines were surveyed—50N; 54N; 52E; 54E; 60E; 68E

Magnetic Surveys:

Along N-S lines spaced by 2 meters, from 0E to 100E, with measurement spacing ≤ 1 m along the lines, for a total of approximately 4660 measurements

Electromagnetic Surveys:

EM31. Along E-W lines spaced by 4 meters, from 0N to 68N, with measurement spacing of 4 meters, for a total of 368 measurements of both in-phase and quadrature components

EM38. Along E-W lines spaced by 2 meters, from 0N to 68N, with measurement spacing of 2 meters, for a total of 1785 measurements of quadrature component

The geophysical data acquisition required approximately 2 days for a three-person crew.

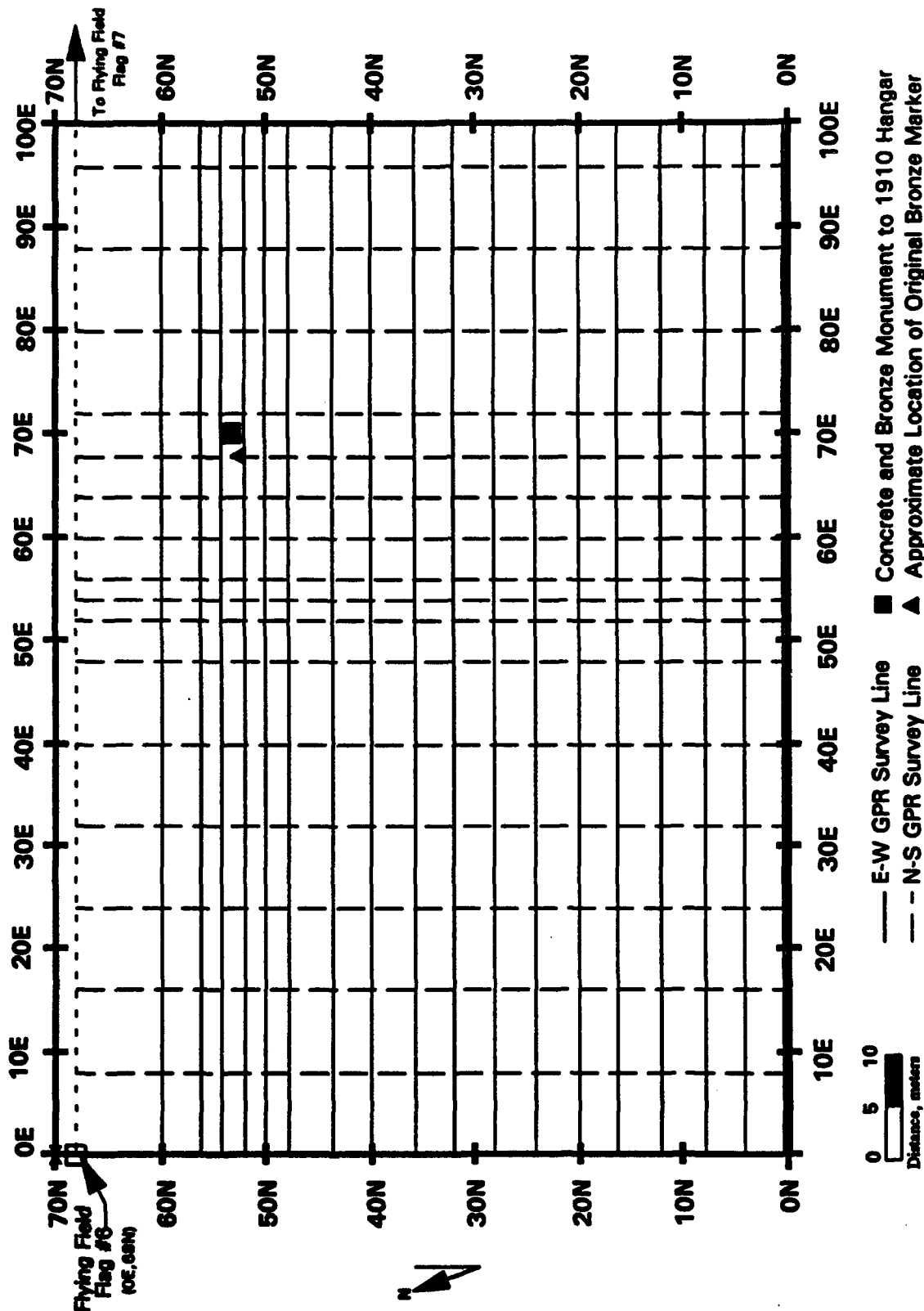


Figure 9. GPR survey lines

3 The Investigation Results

Geophysical Anomaly Maps

Magnetic survey results

Magnetic anomaly contour maps are shown in Figures 10 and 11. With a contour interval of 5 nT, the contour map in Figure 10 is "visually distressing." The major problem exhibited by the data in Figure 10 is a north-south alignment ("striping") of contours, that is quite pronounced in the right third of the map (70E-100E). The most likely cause for the striping is the performance of the contouring software and not with any condition at the site itself¹. Where true anomalies exist, they are apparent in spite of the striping. Specific anomalies are labeled with symbols A-K on Figure 10. In Figure 11 the contour interval is 30 nT, and the striping is not apparent; locations of anomalies A-G are still apparent in Figure 11. Anomaly A is caused by metal associated with Flying Field Flag 6 (Figure 7, flagpole and reinforced concrete); the remainder of the magnetic anomalies have unknown causes. Anomaly B is particularly significant; the object causing the anomaly is at depth 3.5 m or shallower and located approximately at (47.5E,47N). Table 1 gives grid locations for the magnetic anomalies A-K.

¹ There are several possible explanations for the striping. One explanation relates to the facts that (1) the magnetic sensor is carried on the back of the surveyor, (2) the instrument keypad and controller is carried in front of the surveyor, and (3) there is an inherent lag time between measurement initiation and recording. Since the lines are surveyed in alternating directions, a herringbone pattern can result in the contoured data due to positioning discrepancies on alternating lines; there is some evidence of this in Figure 10. Another possible explanation is the different data density along north-south lines (approximately 1 measurement per meter) compared to the east-west direction (1 measurement per 2 meters), although this is not an extreme case of data density differences; this factor can produce striping and/or herringboning. The most likely explanation is a coupling of the data density difference with the large areas of the survey grid where measurements vary by a only a small amount about a background value; the contouring algorithm in apparently cannot handle this situation adequately.

TOTAL FIELD MAGNETIC SURVEY

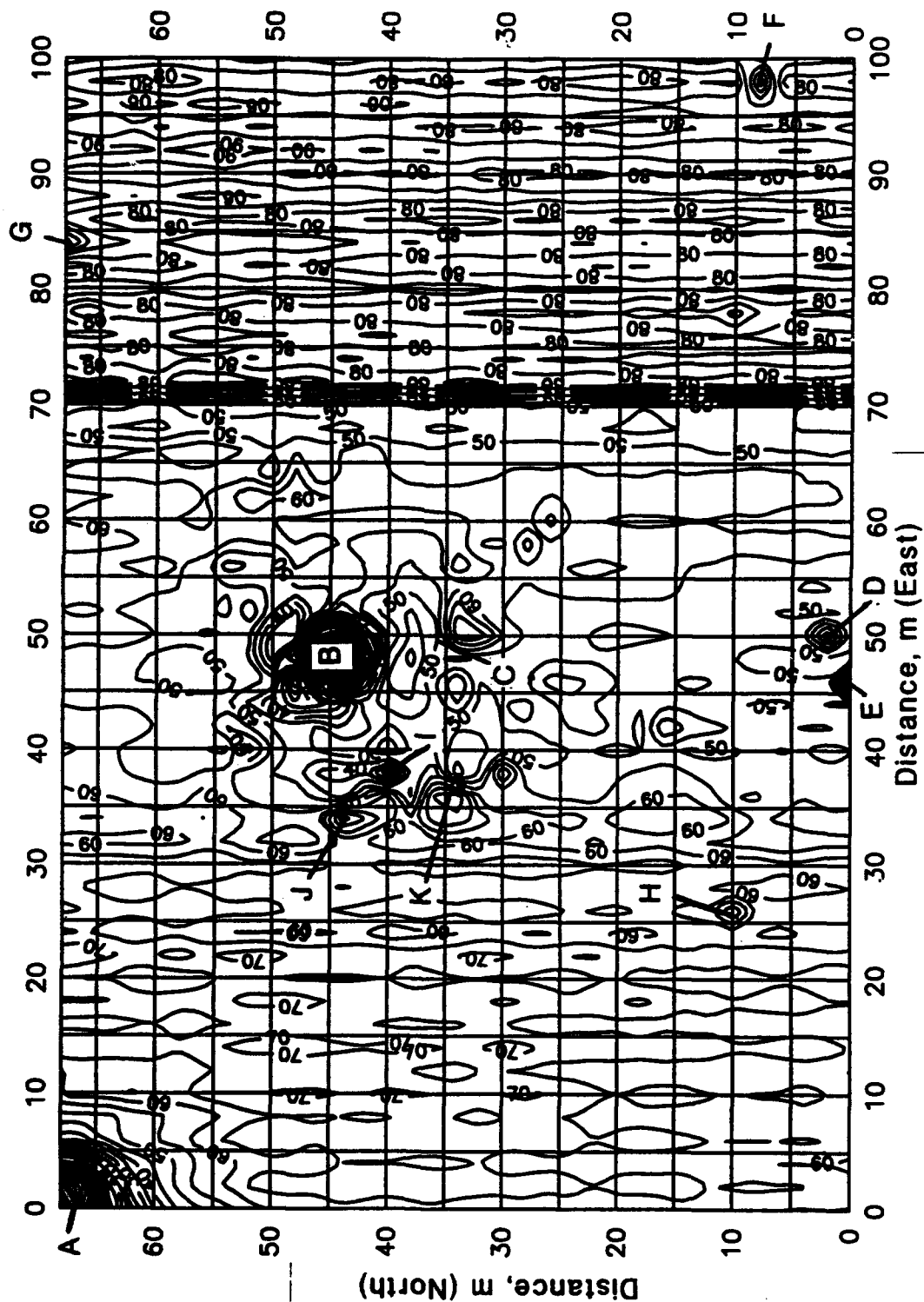


Figure 10. Magnetic total field contour map; 5 nT contour interval

TOTAL FIELD MAGNETIC SURVEY

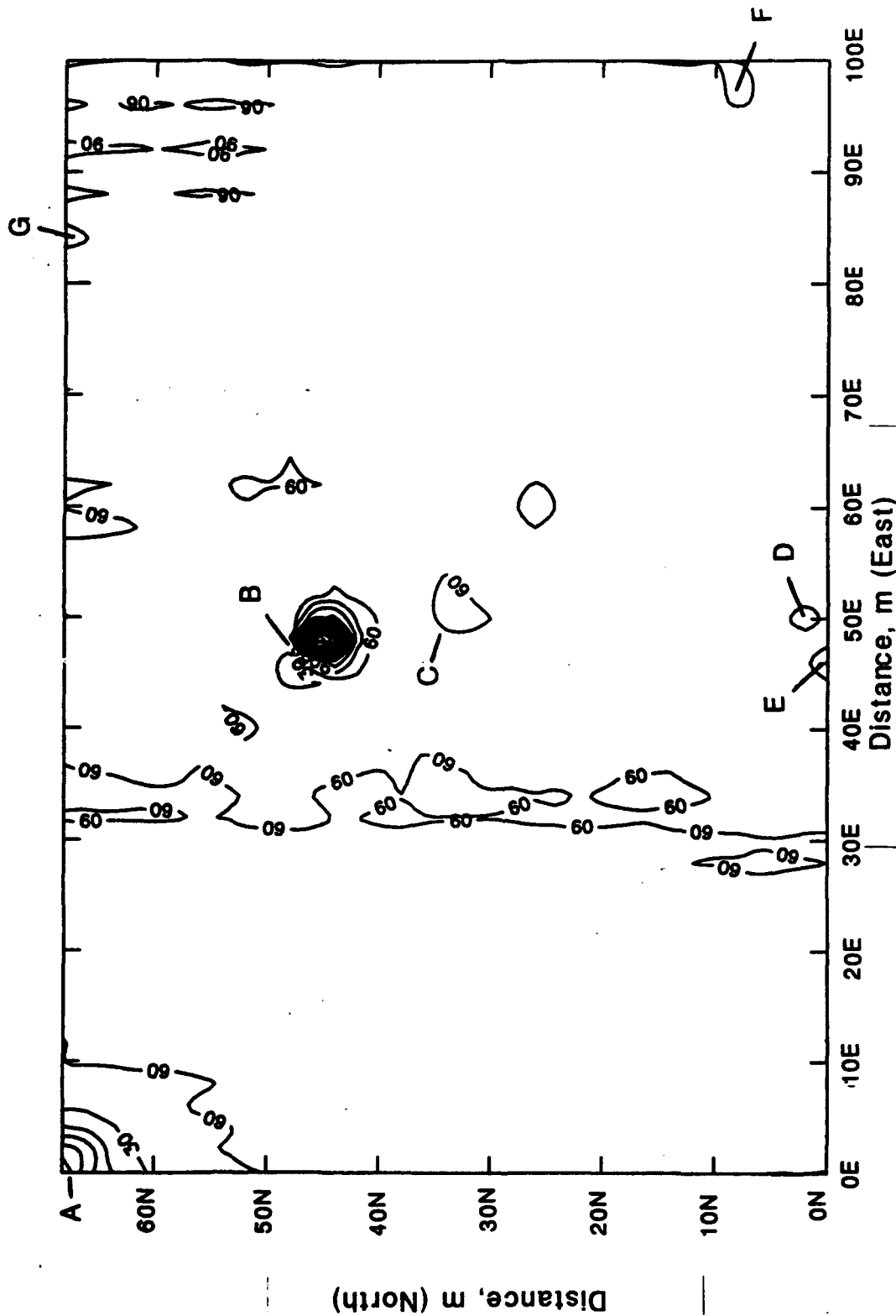


Figure 11. Magnetic total field contour map; 30 nT contour interval

Table 1. Magnetic Anomaly Locations

Magnetic Anomaly	Location	Comments
A	0E,68N	Flying Field Flag 6
B	47.5E,47N	Maximum Depth 3.5 m
C	50E,35N	< 2 m depth
D	50E,2N	< 1 m depth
E	46E,0N	< 1 m depth
F	98E,13N	< 1 m depth
G	84E,68N	< 1 m depth
H	26E,10N	< 1 m depth
I	38E,40N	< 1 m depth
J	34E,44N	< 1 m depth
K	36E,34N	< 2 m depth

Electromagnetic survey results

Results of the EM31 electromagnetic survey are shown in Figures 12 and 13. Figure 12 is a contour map of apparent conductivity in mS/m and reveals relatively uniform conditions over the site on a scale of 4-5 m (4 m measurement spacing and 5 m depth of investigation). The apparent conductivity varies slowly spatially from 8-12 mS/m except for anomaly A at (0E,68N), where conductivities as high as 15 mS/m are measured, due to metals associated with Flying Field Flag 6 (Figure 7). Slightly higher conductivities occur in the central and center-right areas of the survey grid, suggesting (1) a slight change in soil composition, (2) an increase in water content, or (3) perhaps an increase in occurrence of small, scattered, conductive cultural artifacts. Three anomalies are labeled on the in-phase contour map in Figure 13: (1) anomaly A is caused by Flying Field Flag 6; (2) anomaly B corresponds in location to magnetic anomaly B; (3) anomaly C corresponds in location to the concrete and bronze monument at (68E,52N).

The EM38 survey results are shown in Figure 14, where the contours are apparent conductivity in mS/m over the site on a scale of 1-2 m (2 m measurement spacing and 1.5 m depth of investigation). The map contains many localized anomalies, indicated by labels I-XIV, and general background conductivity varying between 8 and 12 mS/m in agreement with the EM31 results. Table 2 gives location coordinates for the localized anomalies. As indicated in Table 2, only anomaly I is caused by a known feature. Features causing anomalies II-XIV are < 1.5 m deep and very likely < 1 m deep. Nine of the labeled, localized anomalies are in a rectangular area bounded approximately by coordinate lines 25N, 48N, 33E, and 55E; this area is shown in Figure 15. Other localized anomalies with smaller magnitude are not included in Table 2, and several of them are in the rectangular area.

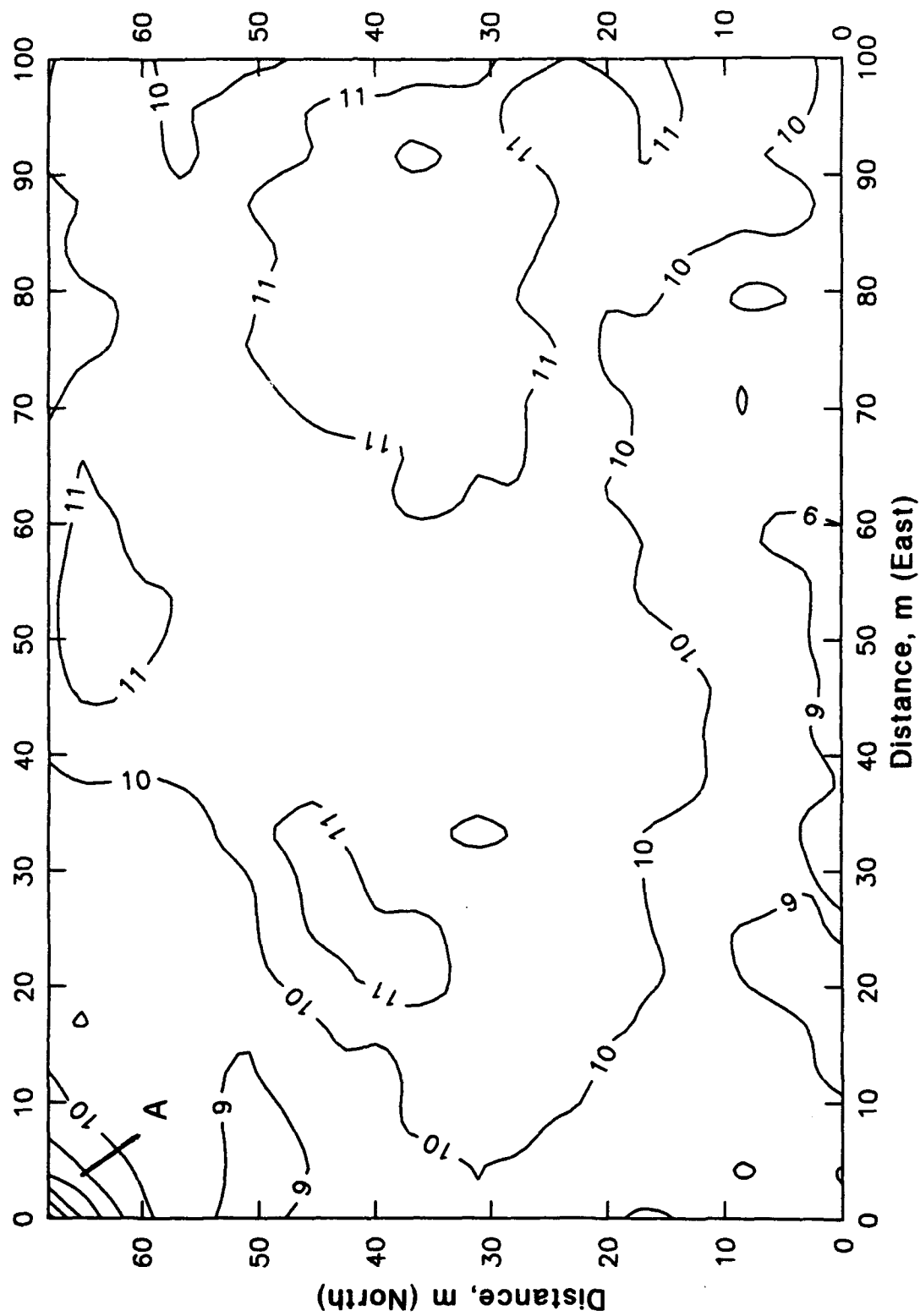


Figure 12. EM31 conductivity contour map; contour interval 1 mS/m

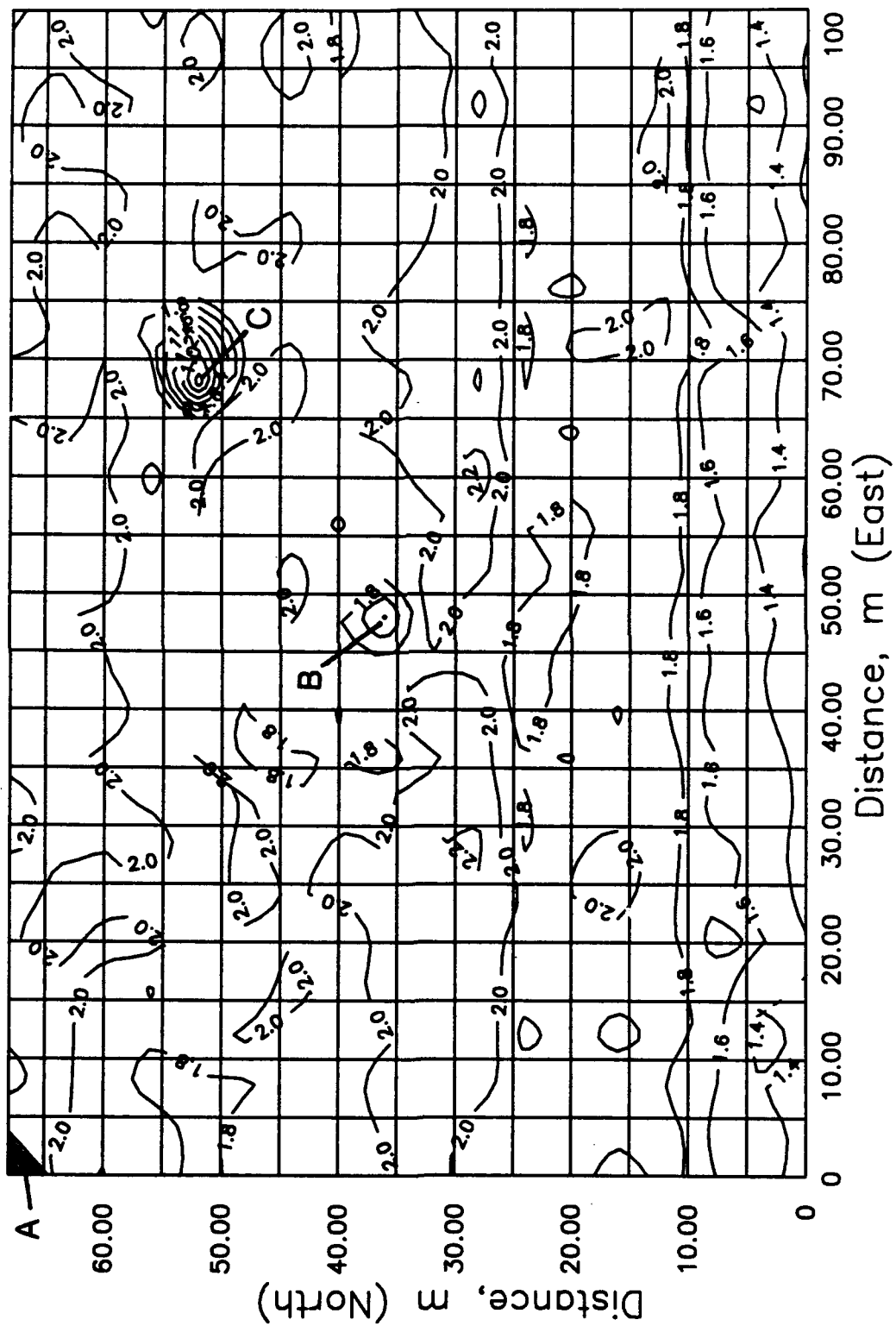


Figure 13. EM31 in-phase contour map; contour interval 0.2 ppt

EM38 CONDUCTIVITY

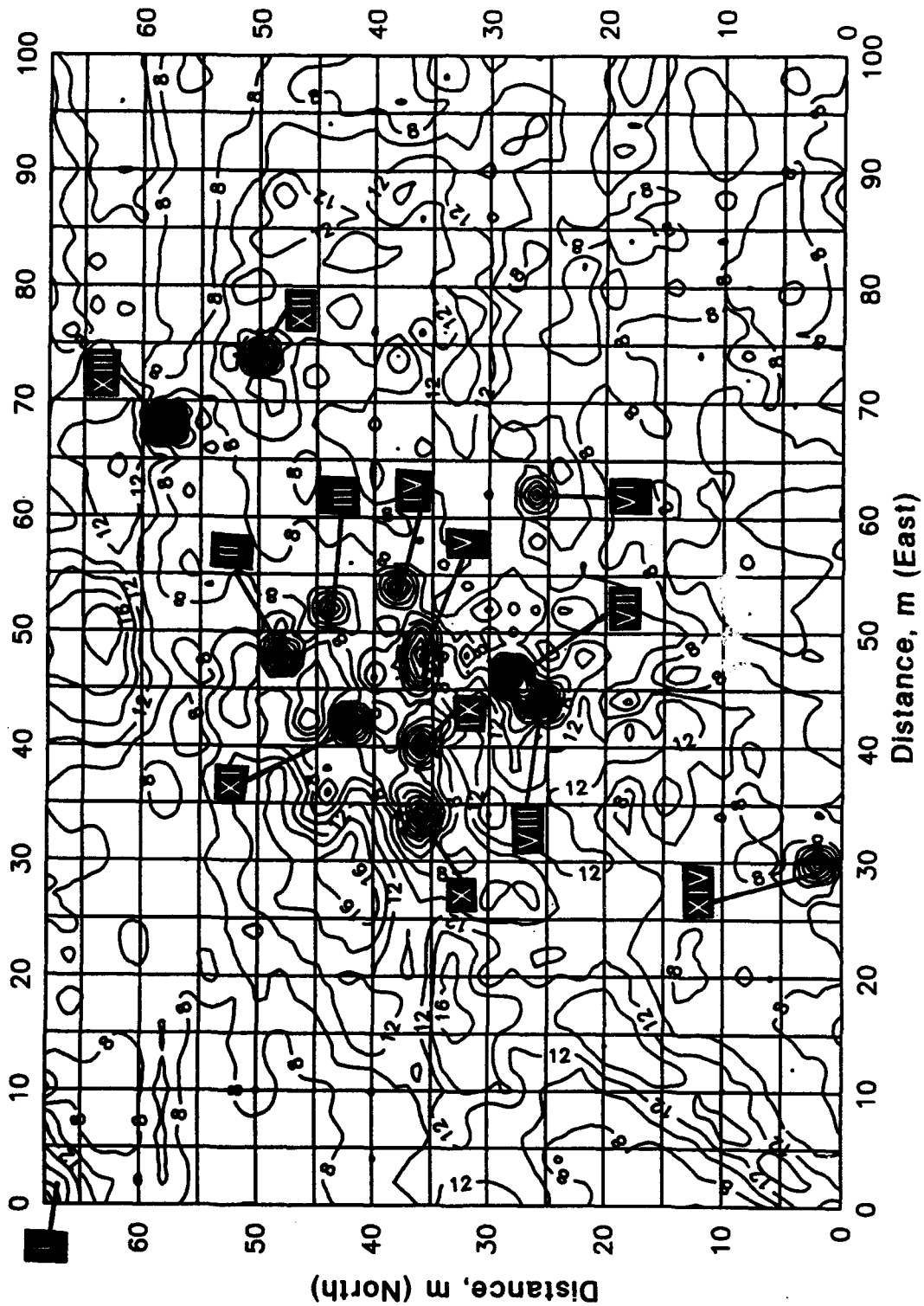


Figure 14. EM38 conductivity contour map; contour interval 2 mS/m

Table 2. EM38 Conductivity Anomaly Locations

Conductivity Anomaly	Location	Comments
I	0E,68N	Flying Field Flag 6
II	48E,47.5N	Magnetic Anomaly B
III	52E,44N	
IV	54E,37.5N	
V	48E,36N	
VI	62E,26N	
VII	46E,28N	
VIII	44E,26N	
IX	40E,36N	
X	34E,36N	
XI	42E,42N	
XII	74E,50N	
XIII	68E,58N	
XIV	30E,2N	

The localized anomalies in Table 2 are low or negative anomalies, which indicates that the likely cause of the anomalies are shallow, buried metallic objects. In addition, there is a significant positive anomaly trend (> 12 mS/m), beginning at approximately 0E,0N and extending to the vicinity of (55E,68N). The positive anomaly trend is shown in Figure 15, where the conductivity contours are for magnitudes ≥ 12 mS/m. Whether this high conductivity trend is due to geologic origins or to some relic of previous site use is unknown. The source of the anomaly is broad, shallow and not continuous along the trend.

GPR survey results

GPR survey records from this site are typically 0.28 by 1.35 m in size; and, since 34 different lines were surveyed, reproducing all the GPR records in a convenient size is impractical. Only selected portions of the GPR records that illustrate typical features are included here. The GPR records were examined and classified by the following criteria: (1) undisturbed areas; (2) 'shallow', extensively disturbed areas (< 1 m); (3) 'deep', extensively disturbed areas (> 1 m); (4) anomalous area or feature; (5) localized anomaly. Undisturbed areas have no significant, identifiable anomalous subsurface conditions, i.e., uniform conditions laterally and also vertically, except for near-horizontal strata (Figure 16-18). Localized anomalies appear as hyperbolic signatures opening downward (Figure 17); the size of the hyperbola depends the size and depth of the subsurface feature relative to the wavelengths of the GPR. The 1 m depth selected to classify 'shallow' versus 'deep' disturbed areas is arbitrary. An example of a shallow, extensively disturbed area is shown in Figure 17; individual, localized anomalies can sometimes be identified in disturbed areas, but in general they are too small and closely spaced for individual identification. An anomalous area and a deep, extensively disturbed area are shown in Figure 18. The anomalous area in Figure 18 has a definite signature that extends over approximately 10 m laterally and is also identifiable on other survey lines (0N, 8N, 12N, 16N); anomalous areas like this one may be geologic in origin.

HIGH CONDUCTIVITY ZONES (≥ 12 MS/M)

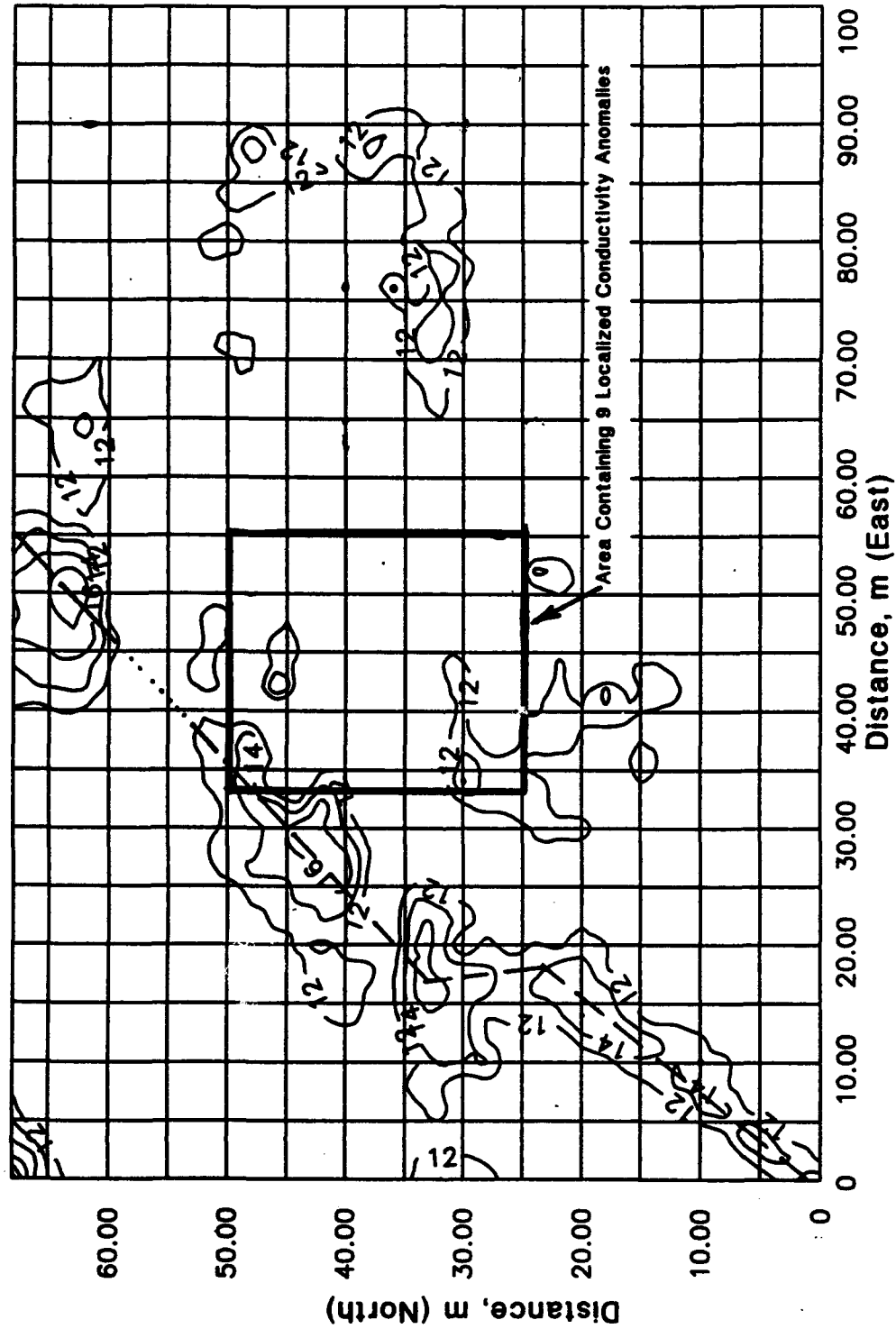


Figure 15. EM38 high conductivity zones (> 12 mS/m) and rectangular area enclosing 9 localized anomalies; contour interval 2 mS/m

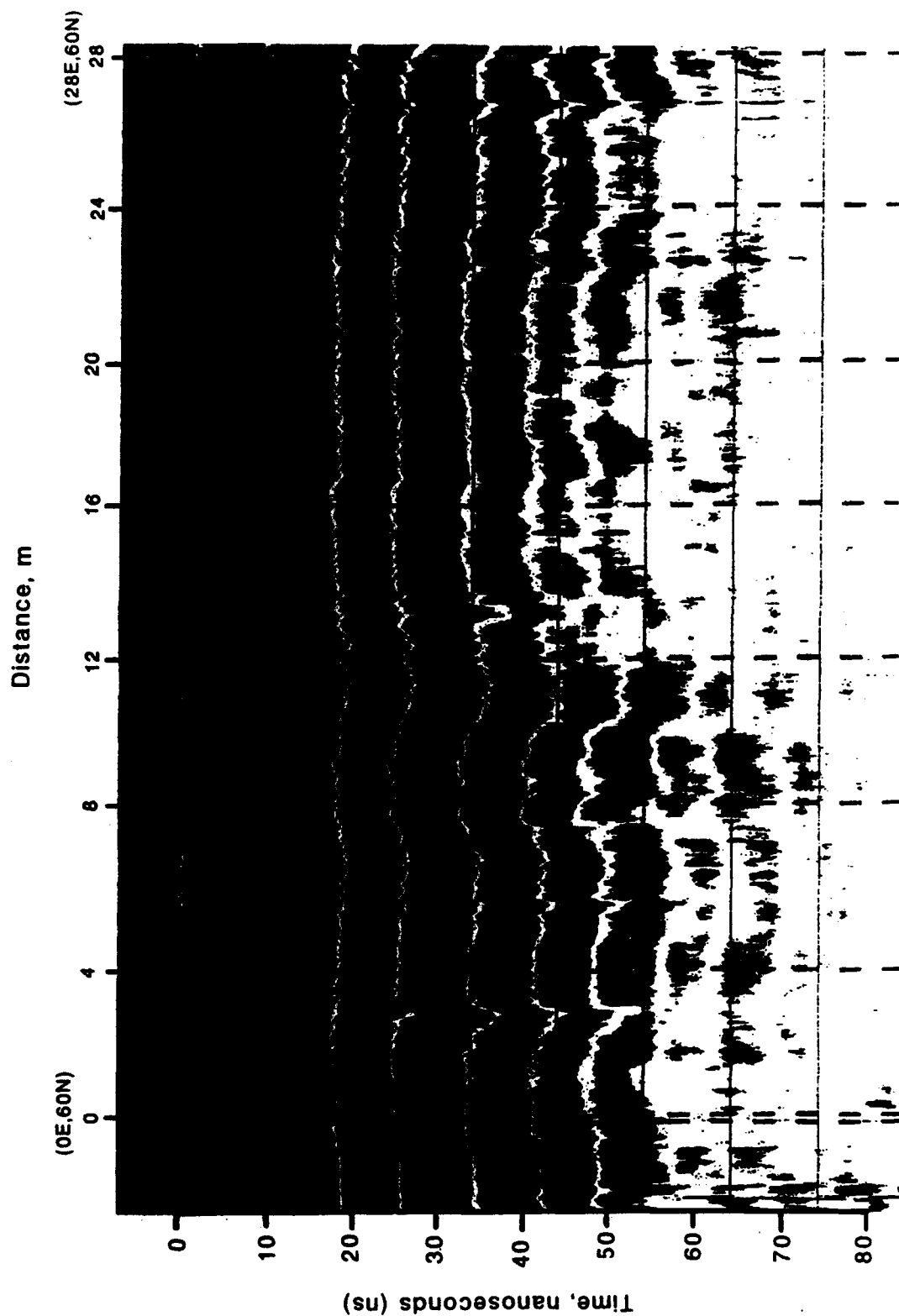


Figure 16. GPR survey line 60N, from 0E to 28E, illustrating appearance of record for relatively uniform or undisturbed conditions (300 MHz antenna)

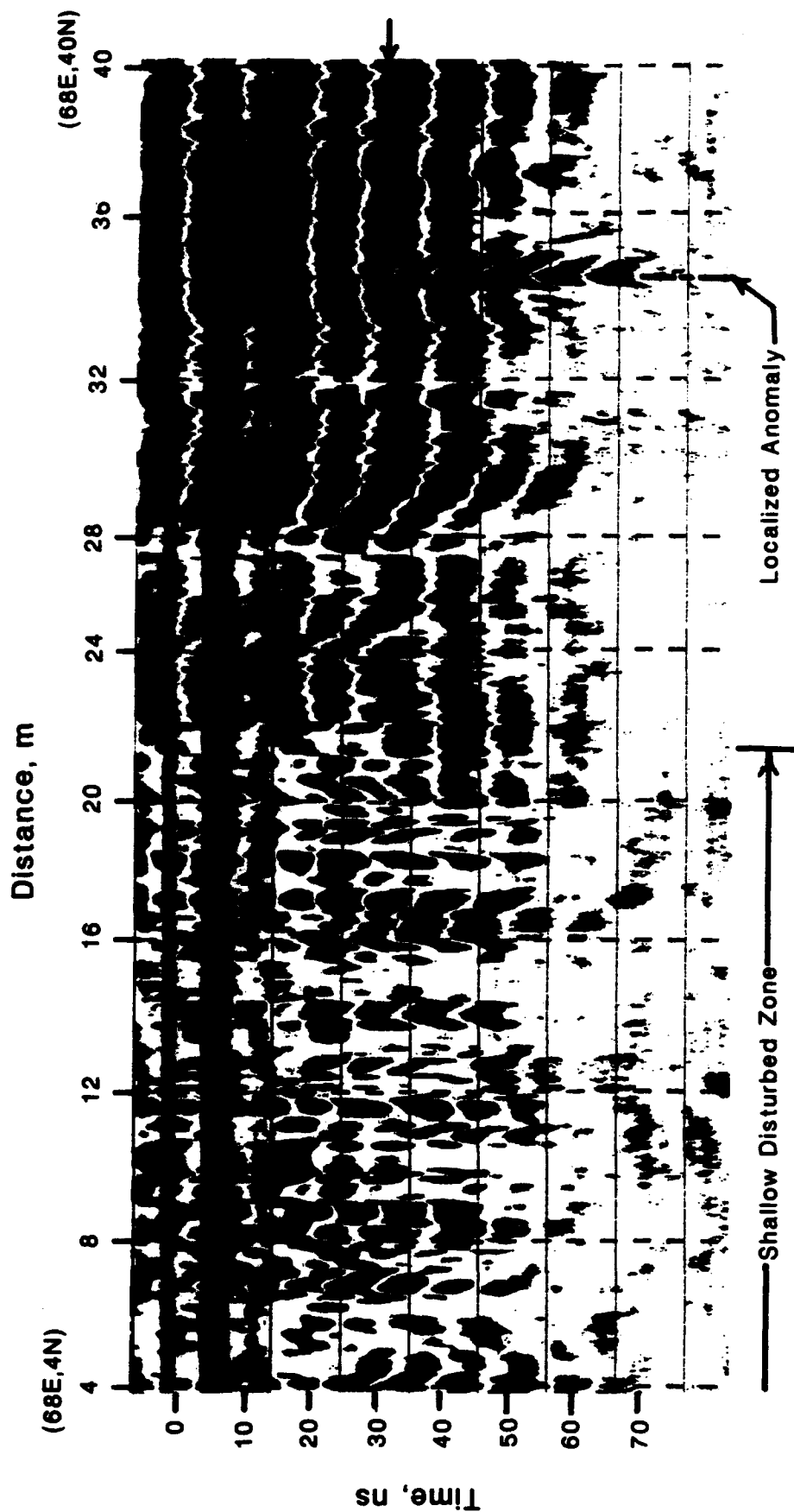


Figure 17. GPR survey line 68E, from 4N to 40N, illustrating appearance of record for a shallow extensively disturbed zone and a localized anomaly (18 in. storm drain)

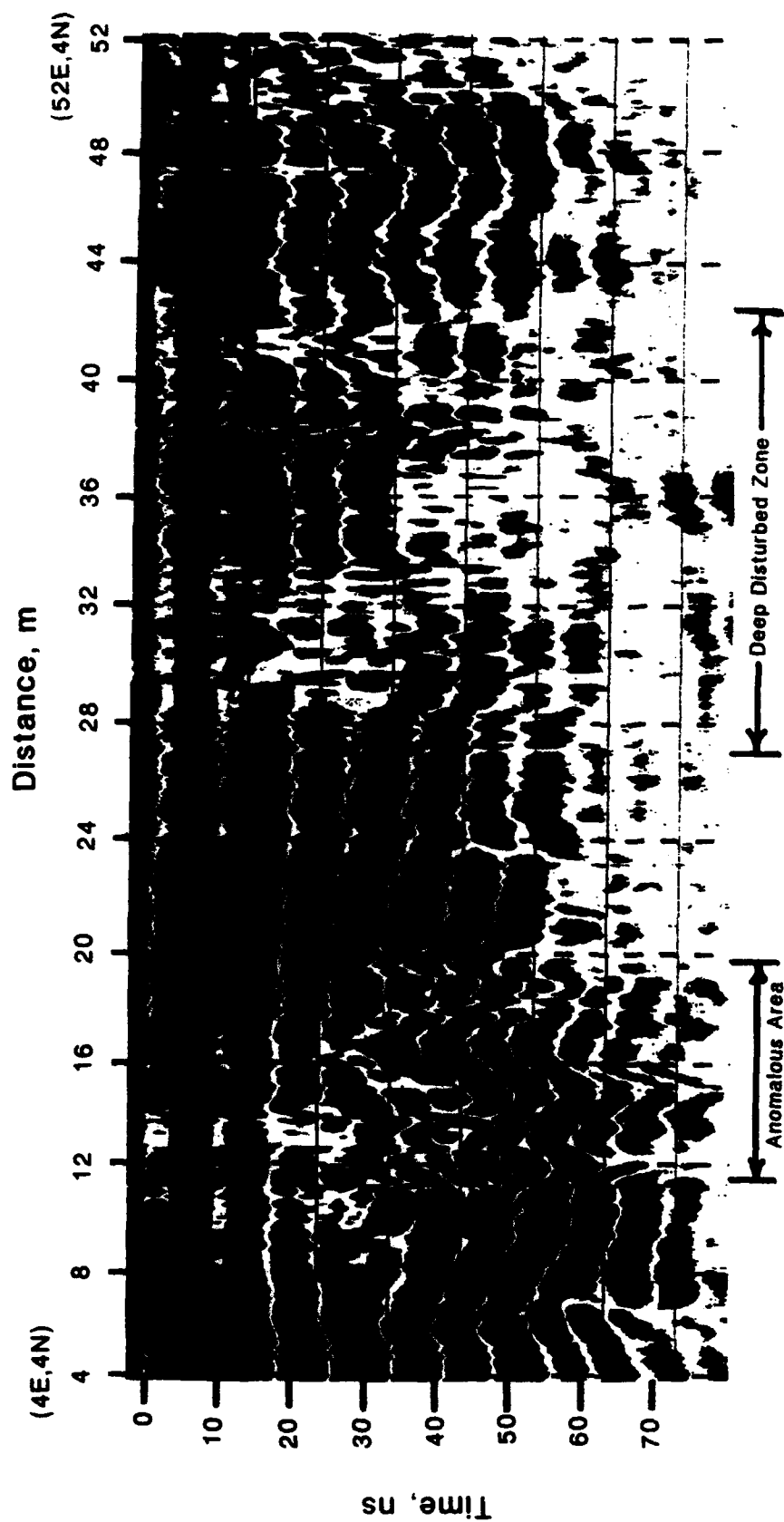


Figure 18. GPR survey line, from 4N to 52N, illustrating appearance of record for an anomalous area and a deep extensively disturbed zone

Localized anomalies are potential cultural artifacts; buried tools and aircraft parts could produce localized GPR anomalies. The most obvious and significant localized anomalies are indicated in Figure 19; the figure also shows two anomalous areas (see Figure 18) and shallow and deep disturbed areas. The number associated with each localized anomaly marker is the approximate depth in meters. During the conduct of the GPR surveys, a "significant anomalous area" was detected; the GPR signature of this anomalous area is shown in Figure 20 for east-west survey along line 52N. This anomalous area was detected on east-west lines as well as north-south survey lines and defines an *approximately* rectangular area (see Figure 19). Even during the conduct of the surveys, the possibility that the anomalous area could be the location of the hangar was suggested. The GPR signature is complex, as indicated in Figure 20. A large number of localized anomalies are within the rectangular area. The localized anomaly on north-south survey line 68E (Figure 17) is interpreted to be caused by the concrete storm drain (18 in dia.) which crosses the site. The storm drain is detected on at least 10 of the north-south survey lines, and its interpreted location is shown as the dashed line (approximately east-west across the survey area) in Figure 19 and other figures which follow.

Airborne photography and facilities map integration

Results of scanning the 1924 aerial photograph (Figure 2) and georeferencing to digitized current WPAFB facilities map information (e.g., Figure 3) is shown in Figure 21. The hangar location shown on a current facilities map and the current site survey area are shown relative to the image of the hangar. An enlarged version of the hangar image is shown in Figure 22, superimposed on the site survey grid and site features (Figure 8).

Integration of the Results

Figure 23 represents an attempt to display the key results in a concise form. Included in Figure 23 are GPR anomalies, magnetic anomalies, in-phase EM anomalies, EM conductivity anomalies, ground hog holes, location of the existing 1910 hangar monument, the anomalous GPR rectangular area (from Figure 19), a possible extension of the rectangular anomalous area, the rectangular area with a high concentration of EM anomalies (from Figure 15), and an outline of the hangar as revealed in the 1924 aerial photograph. The rectangular/quasi-rectangular areas are shown in Figure 24 without the clutter of the other anomalies. The possible extension of the rectangular GPR anomalous area was deduced from a detailed examination of the GPR records subsequent to georeferencing the 1924 aerial photograph of the hangar to the site survey grid, and may not have been noted otherwise.

Several of the localized GPR anomalies are possibly caused by ground hog holes; these GPR anomalies are indicated in Figure 23 by yellow squares.

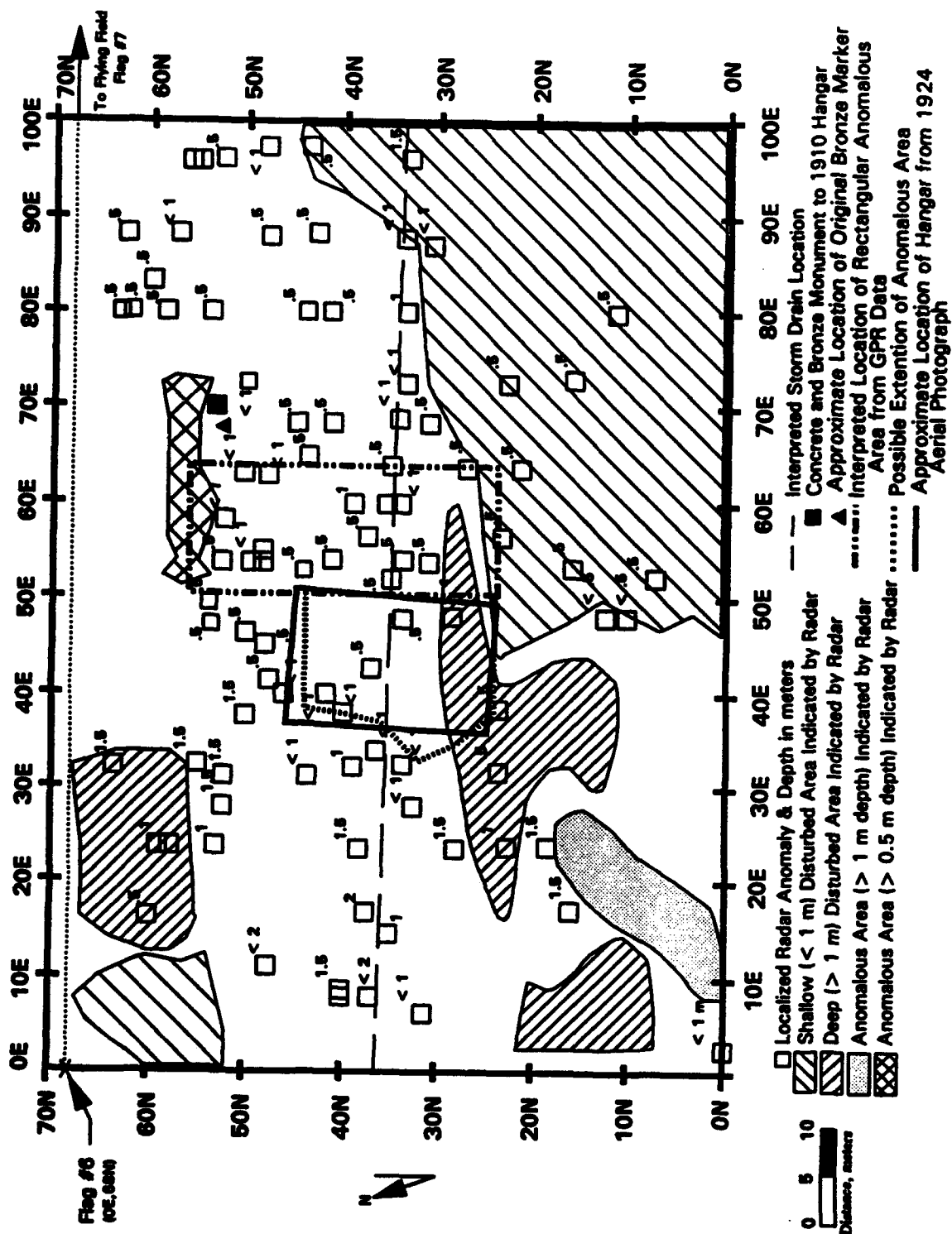


Figure 19. Summary location map of GPR anomalies

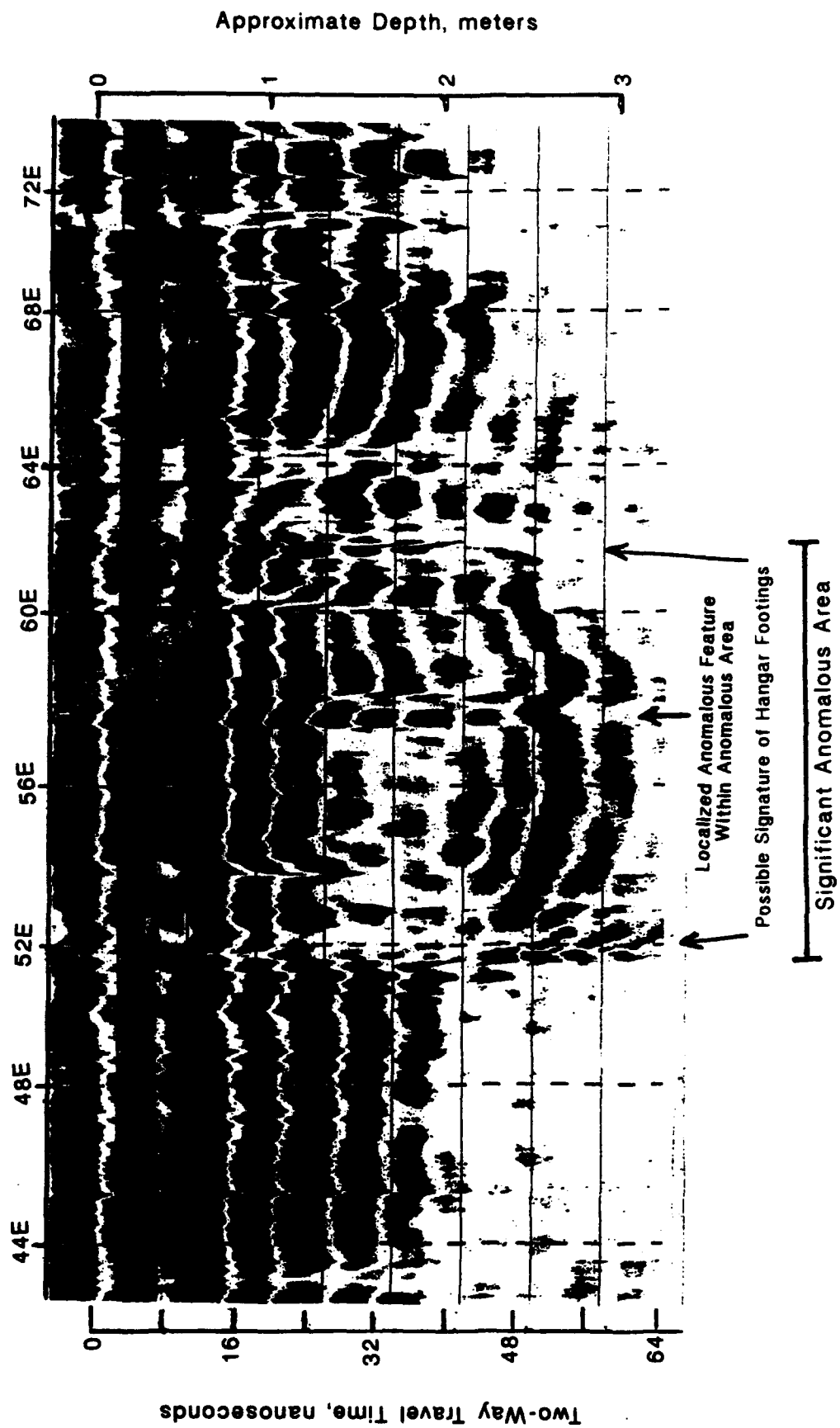


Figure 20. GPR survey line 52N, showing the "significant anomalous area", initially interpreted as the hangar foundation

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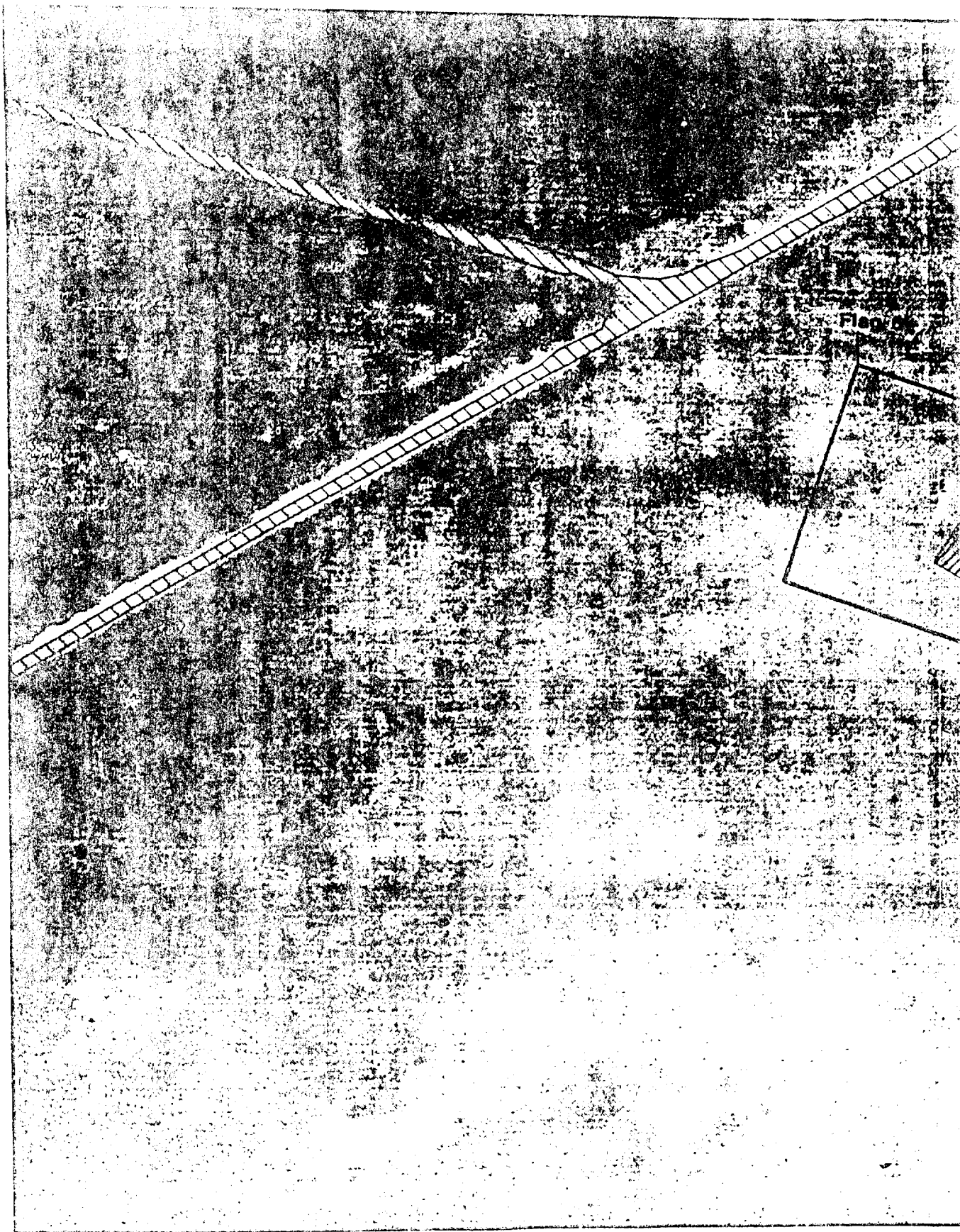
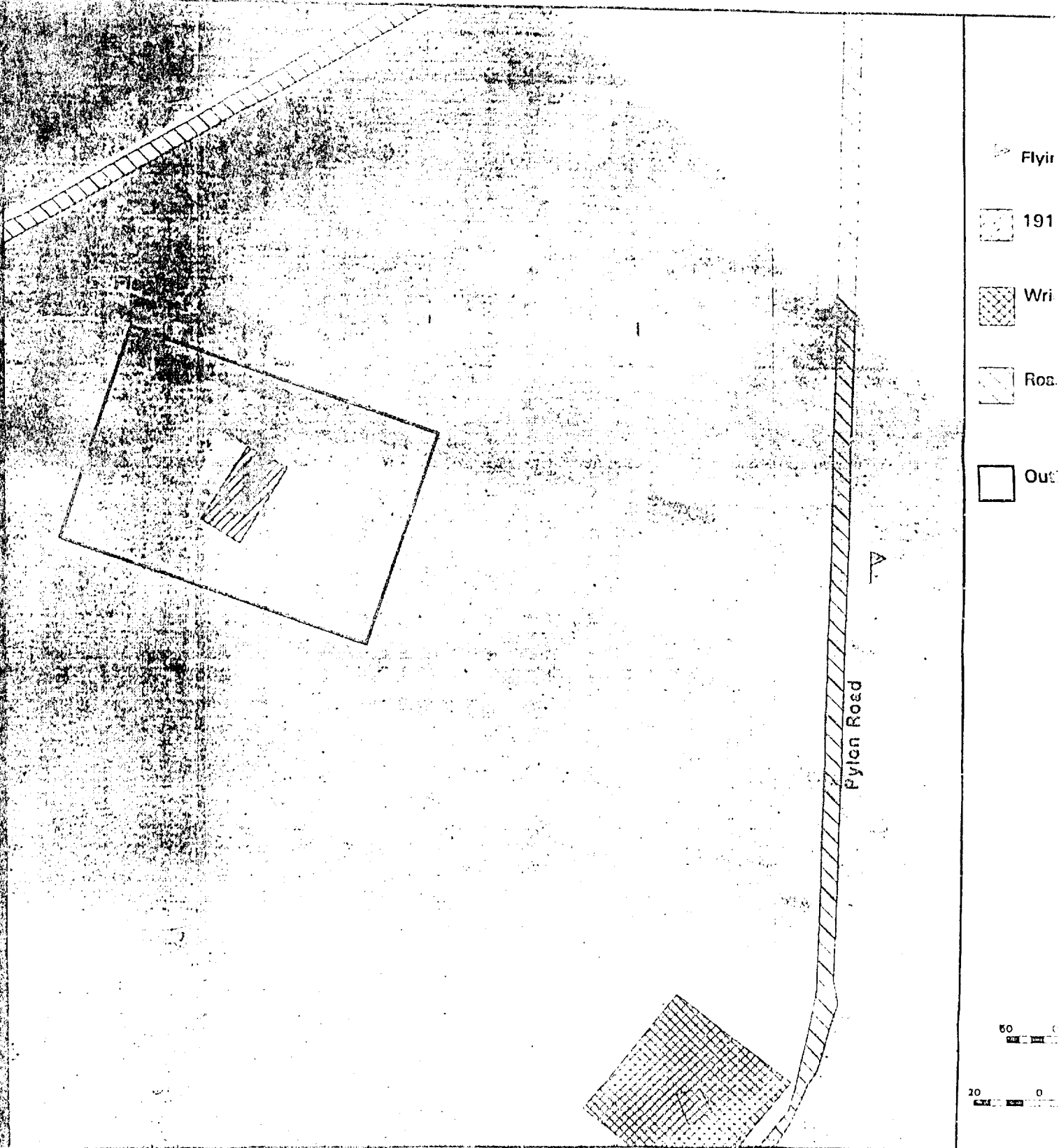


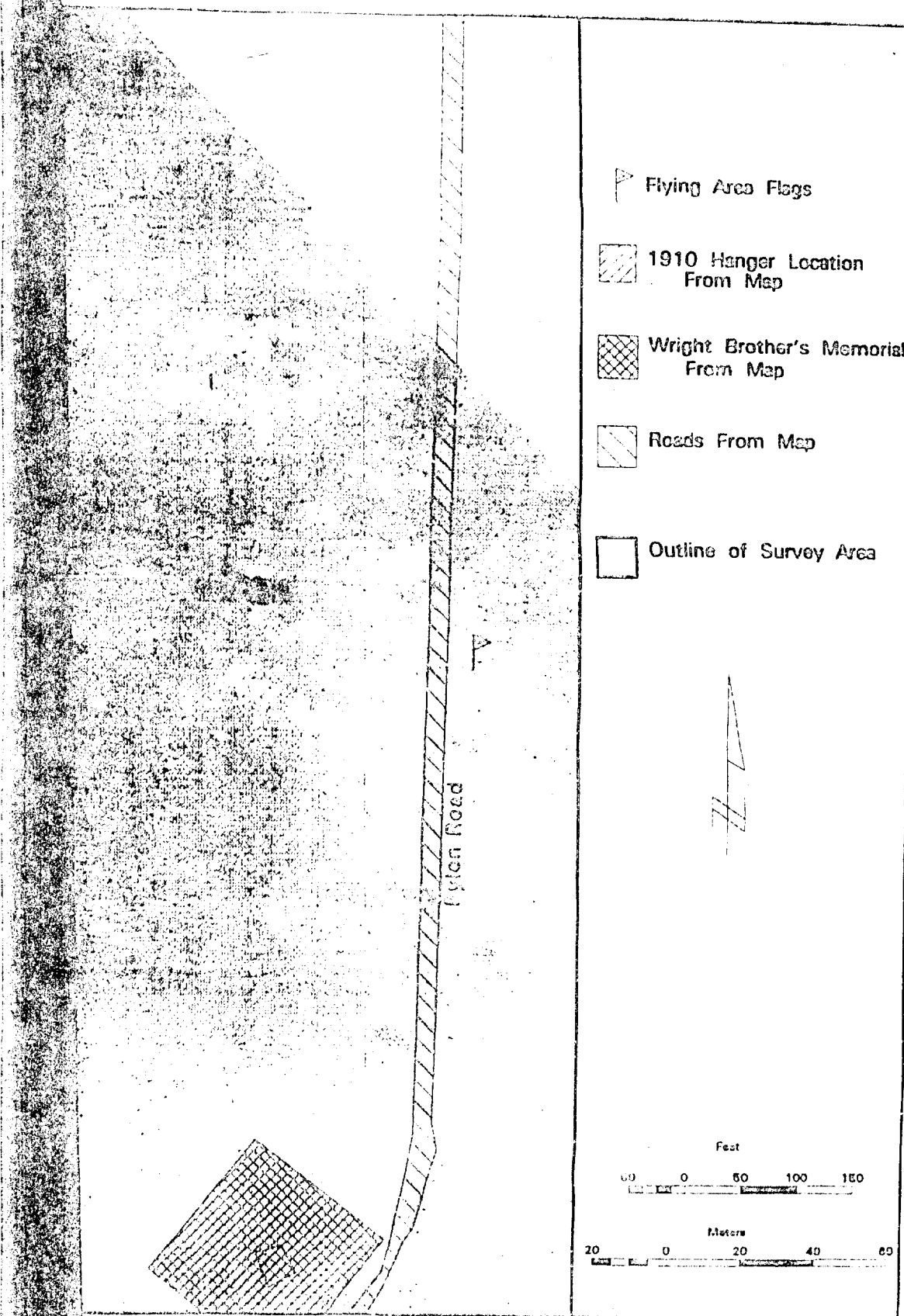
Figure 21. Scanned version of 1924 aerial photograph of

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24 aerial photograph of flying field area showing the 1910 hangar

(2)



1910 hangar

(3)

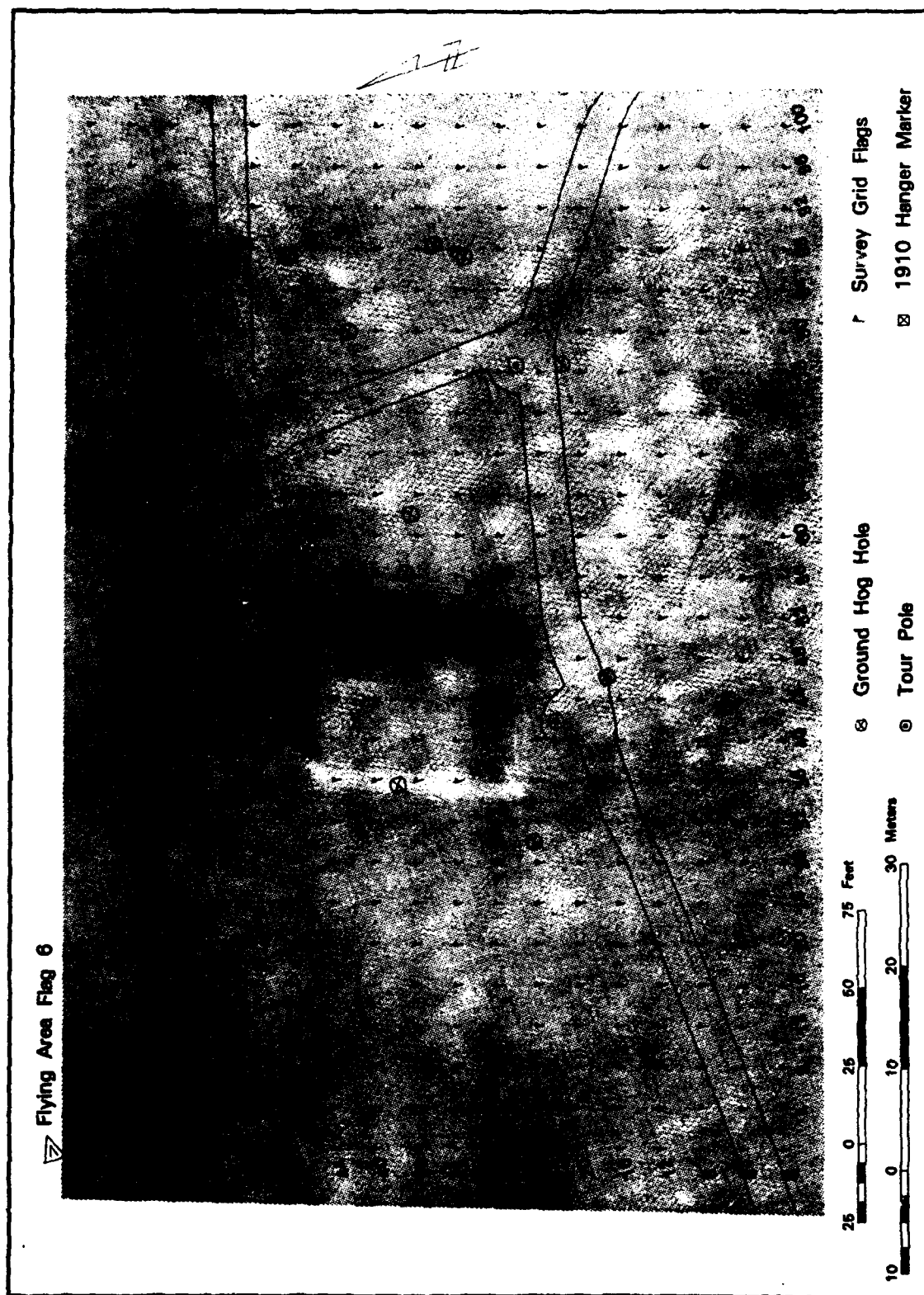


Figure 22. The survey grid superimposed on 1924 aerial photograph of the hangar

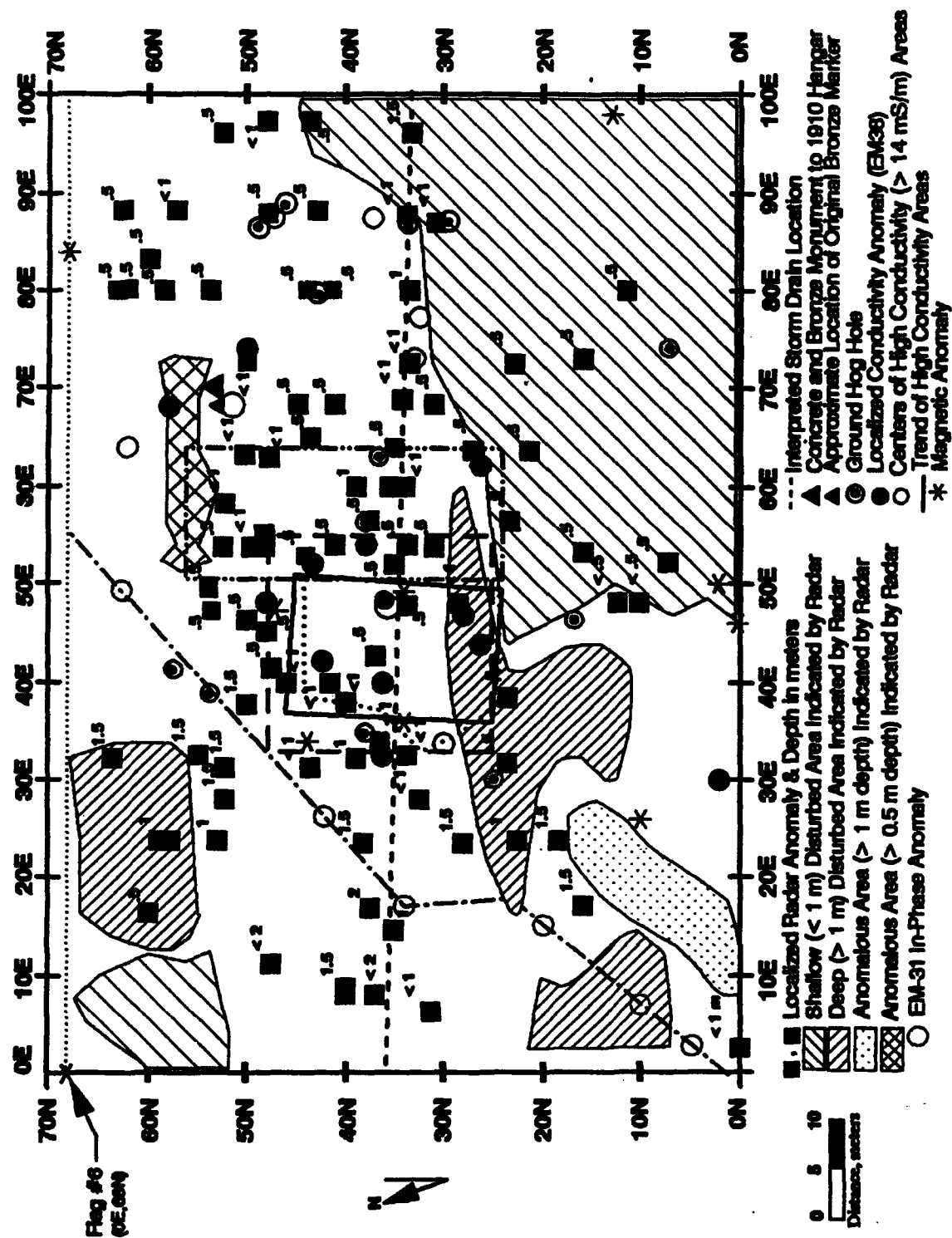


Figure 23. Integrated location map of geophysical anomalies and site features

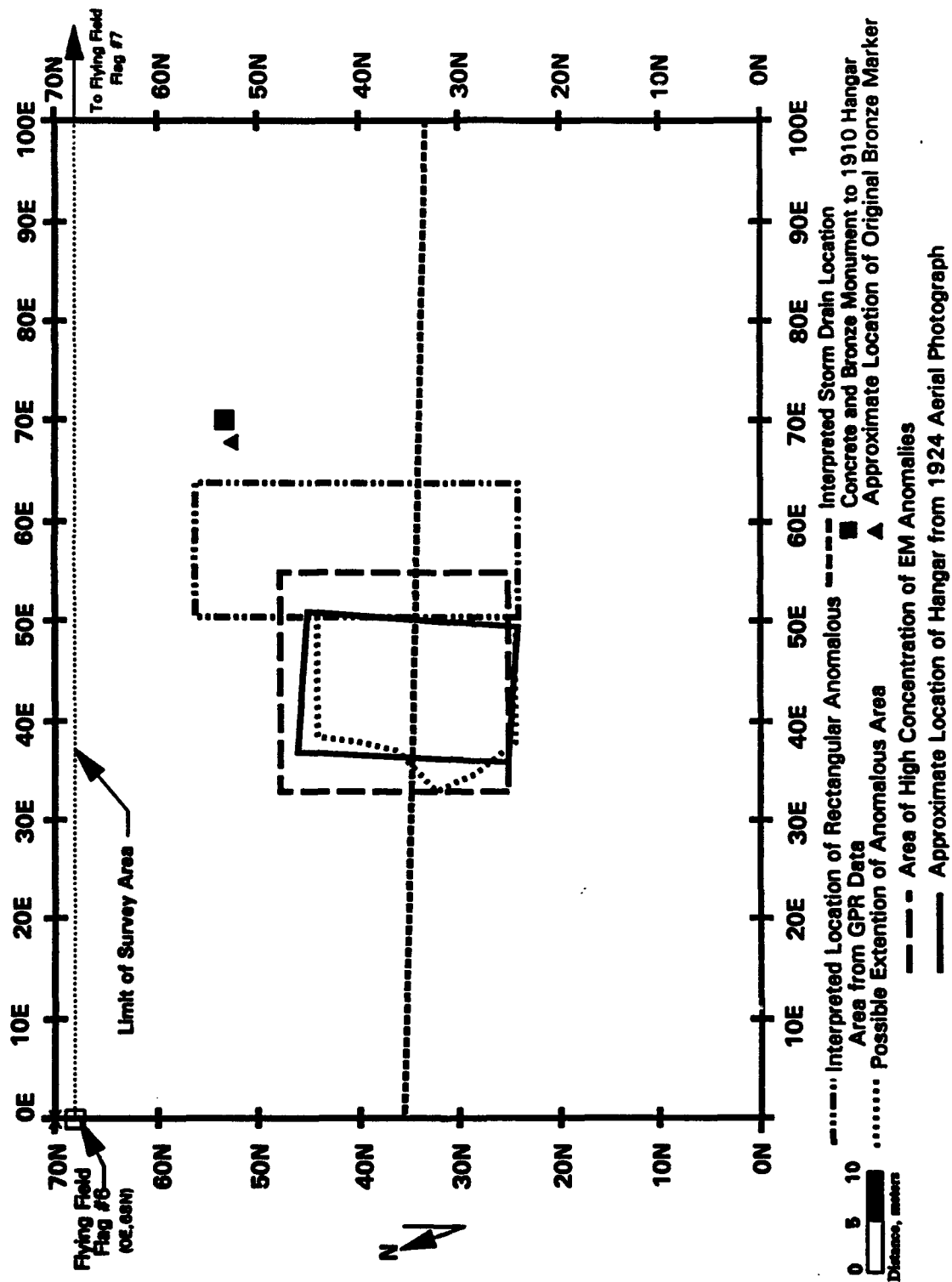


Figure 24. Comparison of interpreted rectangular anomalous areas with hangar location deduced from 1924 aerial photograph

The preceding is an example of a geophysical anomaly produced by a non-geologic and non-cultural feature. In the *shallow* subsurface, the only objects which typically produce localized magnetic anomalies will be cultural features and artifacts, such as iron-containing metals or fired bricks or rocks; thus all magnetic anomalies should be considered significant. Also, any location where more than one geophysical method indicates an anomaly must be considered significant.

The "dashed" rectangular area in Figures 23 and 24 was originally defined based on enclosing 9 localized electromagnetic anomalies. It is highly significant that the dashed area also encloses 5 magnetic anomalies, numerous localized GPR anomalies, and completely encloses the hangar location indicated by the aerial photograph ("solid" rectangular area). The "dot-dash" rectangular area in Figures 23 and 24, originally defined based on a distinctive GPR anomaly signature, encloses numerous localized GPR anomalies and 3 localized EM anomalies. The dot-dash area is immediately adjacent to the hangar location indicated by the aerial photograph.

Figure 25 is a site survey grid and current feature map with the 1990 CERL archaeological excavation plan superimposed. The shaded, circular area indicates the location of a high concentration of glass debris and other artifacts found by the CERL team. Also, the locations of buried wood and a 1910 penny found in excavated blocks are indicated. Most of the artifacts found by the CERL team are within the rectangular, significant GPR anomalous area.

Recommendations

Based on the integrated methods results, follow-up archaeological investigations (excavations) should be concentrated in the rectangular areas indicated in Figures 23-25. The highest priority excavation sites should be centered on locations where magnetic anomalies are located and where multiple geophysical anomalies are indicated. Magnetic anomaly locations are given in Table 1. Excavation at a magnetic anomaly location should extend *at least* to the depth indicated in Table 1 and outward from the location *at least* to a 1-m radius. The shaded boxes in Figure 26 indicate multiple geophysical anomaly areas. Some of the multiple geophysical anomaly areas in Figure 26 include some of the magnetic anomalies from Table 1. The significance of the remaining GPR and EM anomalies cannot be assessed; it is recommended that, at a minimum, remaining anomaly locations within and immediately adjacent to the rectangular areas in Figure 23 be investigated. Additional localized anomalies and anomalous areas should clearly have lower priority than the locations and areas discussed above.

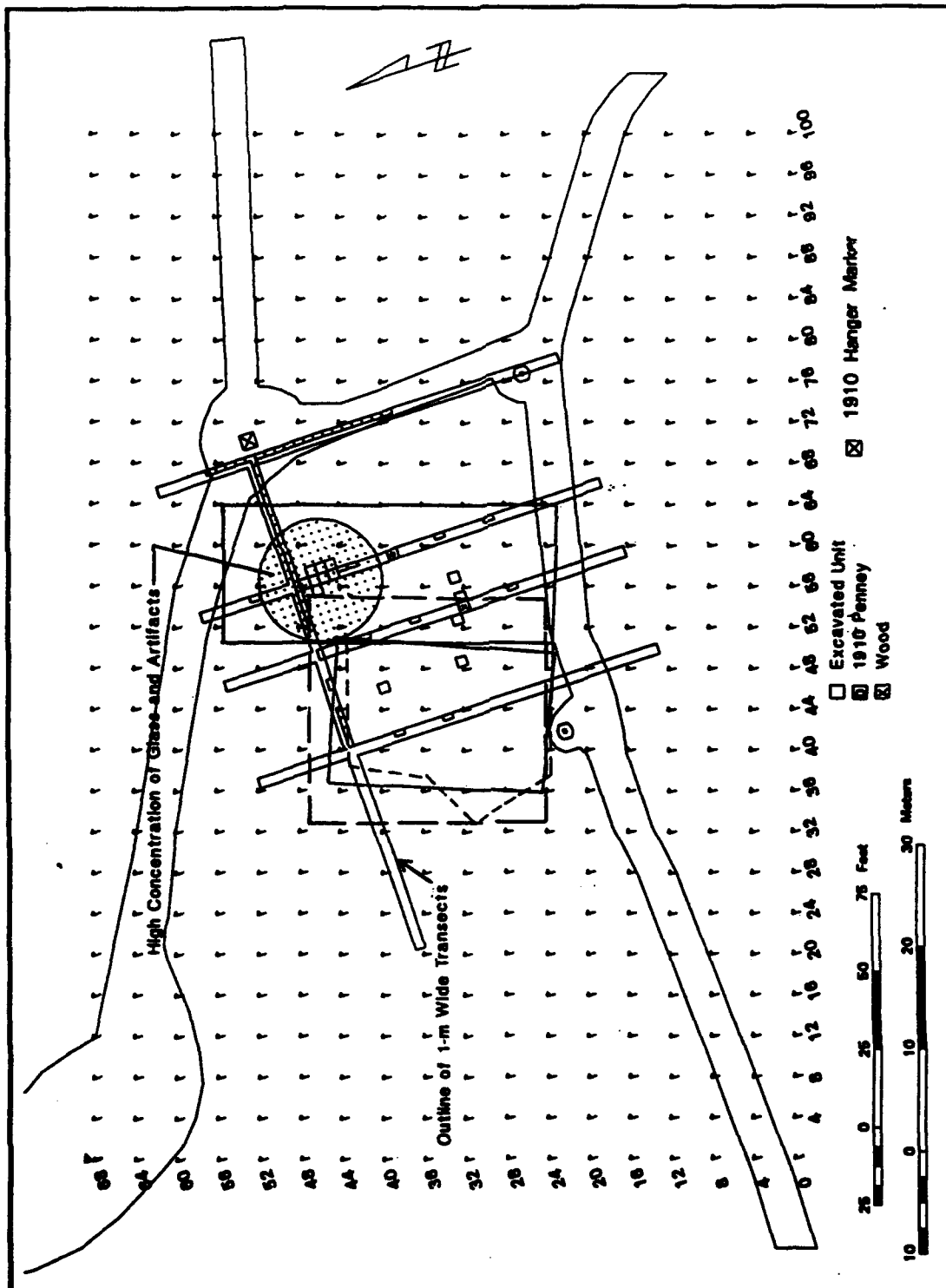


Figure 25. Superposition of archaeological excavation plan, site survey grid, geophysical anomalous areas, and hanger location from 1924 aerial photograph

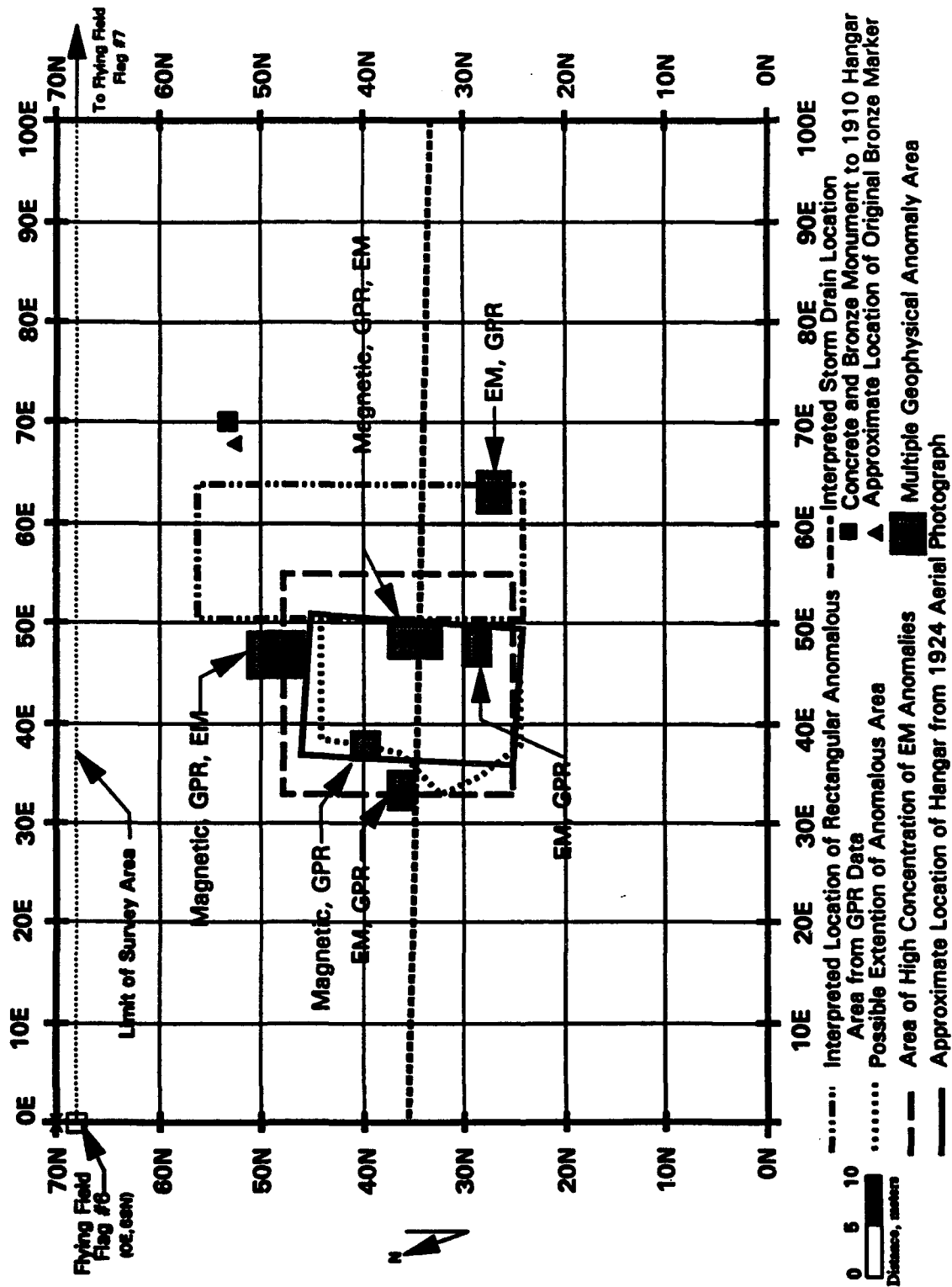


Figure 26. Locations of multiple geophysical anomaly areas

4 Assessment and Conclusions

This report presents the results of application of historical document search, early 1900's aerial photography, and surface geophysical surveying for locating and documenting any remaining in situ evidence of the Wright Brothers' 1910 hangar site at Wright Patterson Air Force Base near Dayton, Ohio. Specifically, determining the exact location of the hangar, identifying the nature of the hangar foundation, and locating any buried artifacts such as tools and aircraft parts were objectives of the work.

The following tabulation assesses the results of this work:

- a. A 100 m by 68 m site survey grid was established that encompasses the apparent location of the 1910 hangar;
- b. Existing features at the site are referenced to the site survey grid system;
- c. A 1924 aerial photograph that shows the 1910 hangar was scanned and referenced to the site survey grid system; the area of the hangar image is approximately 14 x 23 m (46 x 75 ft);
- d. The plan map of CERL (U.S. Army Engineer Construction Engineering Research Laboratory) archaeological excavations at the site are referenced to the site survey grid system;
- e. An approximately rectangular area is defined, based on a distinctive GPR (ground penetrating radar) signature noted on several GPR survey lines; the area is 13.5 x 32 m (44 x 105 ft) and is immediately adjacent to the aerial image of the hangar;
- f. An approximately rectangular area is defined that encompasses a large number of EM (electromagnetic) conductivity anomalies; this rectangular area completely encompasses the aerial image of the 1910 hangar and overlaps slightly the rectangular GPR anomalous area discussed in 'e.'; the area is 22 x 23 m (72 x 75 ft);

- g. *Subsequent* to referencing the aerial photograph to the site survey grid system, a detailed examination of the GPR records identified an anomalous area approximately collocated with the aerial hangar image;
- h. A large number of localized GPR, magnetic, and EM conductivity anomalies are located within the rectangular areas discussed above;
- i. Six anomalous areas are defined that are indicated by more than one geophysical anomaly;
- j. Additional localized and areal geophysical anomalies are identified throughout the site survey area;
- k. A concrete storm drain, crossing the survey site, is detected and mapped by the geophysical surveys.

It is concluded that the results of the work documented in this report indicate geophysical anomalous areas that are consistent with the location of the 1910 Wright Brothers' hangar as recorded by period aerial photography. An additional geophysical anomalous area is located immediately adjacent to the hangar location. This additional anomalous area encloses the locations of discovery of the majority of surface and very shallow buried cultural debris and artifacts by the CERL archaeological team. The significance of the additional anomalous area adjacent to the hangar location is not immediately apparent. A possible explanation is given in Babson (1991); it is suggested that the high concentration of cultural debris and artifacts "may represent displacement of materials from the 1910 hangar by bulldozer or other heavy equipment when it was torn down." It is also possible that debris from destruction of the hangar may have been buried or burned adjacent to its original location. Burial of the debris in a trench could explain the details of the "significant anomalous area" (Figure 20). Numerous localized geophysical anomalies are identified that may represent buried artifacts from the use of the site by the Wright Brothers. A prioritized approach to investigation of the anomalous areas and localized anomalies is presented in this report. The extent to which lower priority anomalies are investigated should and will clearly depend on the results of the investigations of the highest priority locations and areas.

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13. ABSTRACT (Maximum 200 words)

An archaeological geophysics investigation was conducted at the site of the 1910 hangar constructed by the Wright Brothers on Huffman Prairie, Wright-Patterson Air Force Base, near Dayton, Ohio. The hangar was destroyed as part of base renovation during the buildup to World War II, and its exact location is unknown. The purpose of the investigation is to confirm the exact location of the hangar and to locate any buried artifacts from the Wright Brothers occupation of the site. Ground penetrating radar (GPR), electromagnetic, and magnetic surveys were conducted over a 68- by 100-m area that is approximately centered on the suspected location of the hangar. Localized anomalies as well as areal anomalies are identified in the geophysical data. Rectangular anomalous areas are identified that are generally consisted with the suspected location of the hangar. A 1924 aerial photograph showing the hangar was digitally scanned and georeferenced to the site survey area. While two of the rectangular geophysical anomalous areas are consistent with the hangar location from the aerial photograph location, a rectangular area defined from GPR survey data is immediately adjacent to the aerial photograph location. It is postulated that base engineers may have bulldozed the hangar debris onto an area adjacent to its original location and either burned it there or buried it in a trench. A prioritized exploratory program is proposed for investigating the sources of the geophysical anomalies.

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