UCG

Aonad na Geofisice Faidhmí, Coláiste na hOllscoile, Gaillimh, Éire.

EOS
Earth and
Oceanographic
Sciences Group

Applied Geophysics Unit,
University College Galway,
Galway,
Ireland.

Tel. Galway (091) 24411
Telex 50023 UCG EI
Fax (091) 25700

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# Reconnaissance Resistivity Mapping at Clara Bog, Co. Offaly Using the EM–VLF-R Technique.

*By*

*Deirdre Madden*

***Applied Geophysics Unit***
***University College***
***Galway***

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# Chapter 1

# Introduction

## 1.1 Background to Project

This report concerns a VLF-R survey which was carried out as part of the "Irish–Dutch Peatlands Project" on Clara bog. The "Irish-Dutch Peatlands Project" commenced in October 1989 and will continue until December 1992. The project comprises a study of the hydrology, geology and ecology of Clara bog. The research is being carried out by three Irish Ph.D students who are based in Sligo R.T.C. Environmental Science Dept., T.C.D. School of Botany and U.C.G. Geophysics Unit and Geology Dept.. Various three to four month projects are also carried out by students from the Netherlands.

The fundamental objective of the project is to discover how the hydrological system of a bog operates in order to maintain the bog's growth. This information can then be applied to schemes which aim to preserve our present raised bogs and to peatland areas of the Netherlands where the Dutch are trying to regrow their bogs.

The botanical and geological studies provide important aids to understanding the hydrology, in addition to their value as independent disciplines. Understanding the geology of the area is fundamental to understanding the controls which exist on water movement within the bog system. The regional geology tells us why bogs have developed in a particular place,and what controls are necessary to maintain their growth.

Clara bog, which was chosen for study by the Irish–Dutch Peatland Project, is one of the few remaining intact raised bogs in the Irish Midlands. Even though it has been subjected to some threats from peat harvesting along the margin, Clara bog is still relatively well preserved. The bog itself is unique in comparison to other raised bogs. The soak system on Clara bog is the only one of its kind in Western Europe, as similar ones have been destroyed due to extensive peat development programmes which have taken place since the last century. The soak system is believed to be related to the uniqueness of the geology in the region. This is because the water in the soak lake differs in chemical composition from that of the regular water flow within the peat.

## 1.2 Survey Objectives

This VLF–R survey forms a mini-project done as part of the geological research study on Clara bog. The objectives of the survey were, in part, to obtain an impression of the general geological configuration below the peat. An important element in the survey was a quest for a methodology which entailed a rapid reconnaissance of the bog to define the bedrock structure. The VLF-R technique afforded a method which was quick and efficient and yielded detailed information with coverage being obtained over the largest and most accessible area of the bog.

The geophysical coverage and information acquired from the VLF-R survey will allow rapid appraisal of shallow structures at or above the bedrock surface. Anomalous areas can be pin-pointed and geophysical techniques which are cumbersome and slow but provide accurate, more specific information can be concentrated at these locations.

The VLF-R method is both quick and productive and therefore a very valuable field technique. The instrument itself is lightweight, compact and very convenient to use. It is ideal for taking readings accurately and quickly.

The data set derived from the VLF-R survey has proved to be very informative, as this report will show. The time expenditure involved relative to the quality and value of information obtained is exceptionally favourable. As a means of reconnaissance surveying the VLF-R method is excellent. It reveals the location of anomalies and clearly defines areas worthy of further,more detailed study. The VLF-R method is recommended as an excellent initial reconnaissance survey on a given study area to quickly give an overall view of the area and define specific areas of interest to save on time and expenditure later in the field.

# Chapter 2

# Geophysical Technique Used

## 2.1 Theory

The VLF-R method uses a hand held radio receiver which can be tuned to receive signals from a number of low frequency transmitters around the world. For the purposes of this project a transmitter, GBR, at Rugby in England was used. This transmits at a frequency of 16kHz. The receiver measures two parameters; the resisitivity and the phase angle.

The instrument used, called a "Geonics EM16R direct reading ground resistivity meter", consists of a radio receiver with two potential electrodes attached to it. The receiver is laid on the ground between the two electrodes which are pushed into the ground. The electrodes are spaced 10m apart along a line pointing towards the transmitter (i.e. transverse to the profile line ).

The transmitter emits electromagnetic waves. The electric field (Ex) is transmitted horizontally outwards over the surface of the earth. The VLF-R instrument measures the phase difference between the electric field and the tangential magnetic field (Hy). The apparent resistivity of the ground is determined from the instrument controls, the basic expression used is :

$$\rho_a = \frac{1}{\mu\omega}(Ex/Hy)^2$$

where:
$\mu$ = magnetic permeability of medium
$\omega$ = angular frequency of signal
$\rho_a$ = apparent resistivity (ohm-m)

The magnetic field is measured by an integral coil in the instrument and the electric field is measured by the two ground electrodes spaced 10m apart. The instrument is orientated so that the coil is aligned to the magnetic field. This is done by rotating the instrument until the audio signal is nulled. Then the two electrodes are placed in the ground along the direction the instrument is facing, which is pointing towards the transmitter. The audio signal is then nulled by means of two controls. The phase angle and apparent resistivity are then read off from the graduations on the respective controls.

In this project a picture of the bedrock topography was constructed using resistivity and phase values. High resistivity and low phase values indicate that a resistive material, possibly bedrock, is near the surface.

# Chapter 3

# Data Aquisition

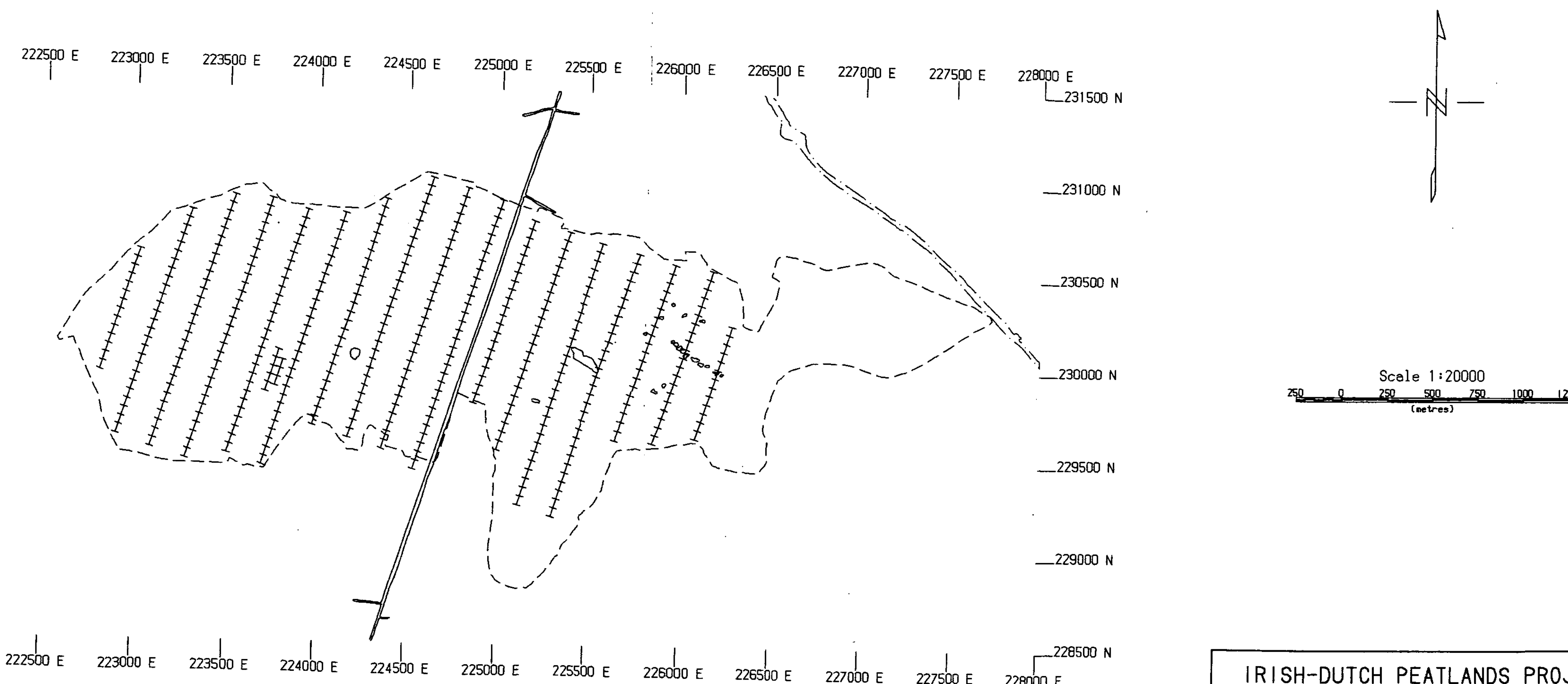
The VLF-R survey over the bog was conducted along a series of grid lines which were laid specifically for the project. The grid was installed by the Office of Public Works.

The western margin of the road was chosen as the grid baseline. The origin of the grid was chosen to be at the intersection of the baseline with the northern margin of the bog (see Figure 3.1). The lines were layed every 100m parallel to the baseline. The respective lines were then marked with stakes at 100m intervals north to south along the lines.

The VLF-R survey was greatly facilitated by the establishment of the grid system by the Office of Public Works. Unfortunately some time delay was incurred when doing the VLF-R survey on the eastern side of the bog. The delay was caused by the fact that the grid has yet to be completed on this side. All the survey lines on the west used the OPW grid, whereas only two OPW lines were available on the east side of the bog. This resulted in temporary lines having to be surveyed on the bog simultaneously with the data acquisition. This inconvenience increased the duration of the survey on the east side by a factor of two.

The data were acquired at stations situated at 50m intervals. The survey used alternate OPW grid lines so the data were acquired along lines 200m apart starting at grid lines 100m east and 100m west respectively.

Some inconsistency of the Rugby transmitter (GBR) caused minor delays during the survey. The transmitter was switched off for approximately one hour on average every second day and on one occasion it stopped transmitting for a full day.




IRISH-DUTCH PEATLANDS PROJECT

**FIG.3.1 CLARA BOG**
EM16R Survey Lines and Major Map Features.

Line spacing 200m, station spacing 50m.
Map shows bog margin, lakes, central road and railway line to the north east.

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# Chapter 4

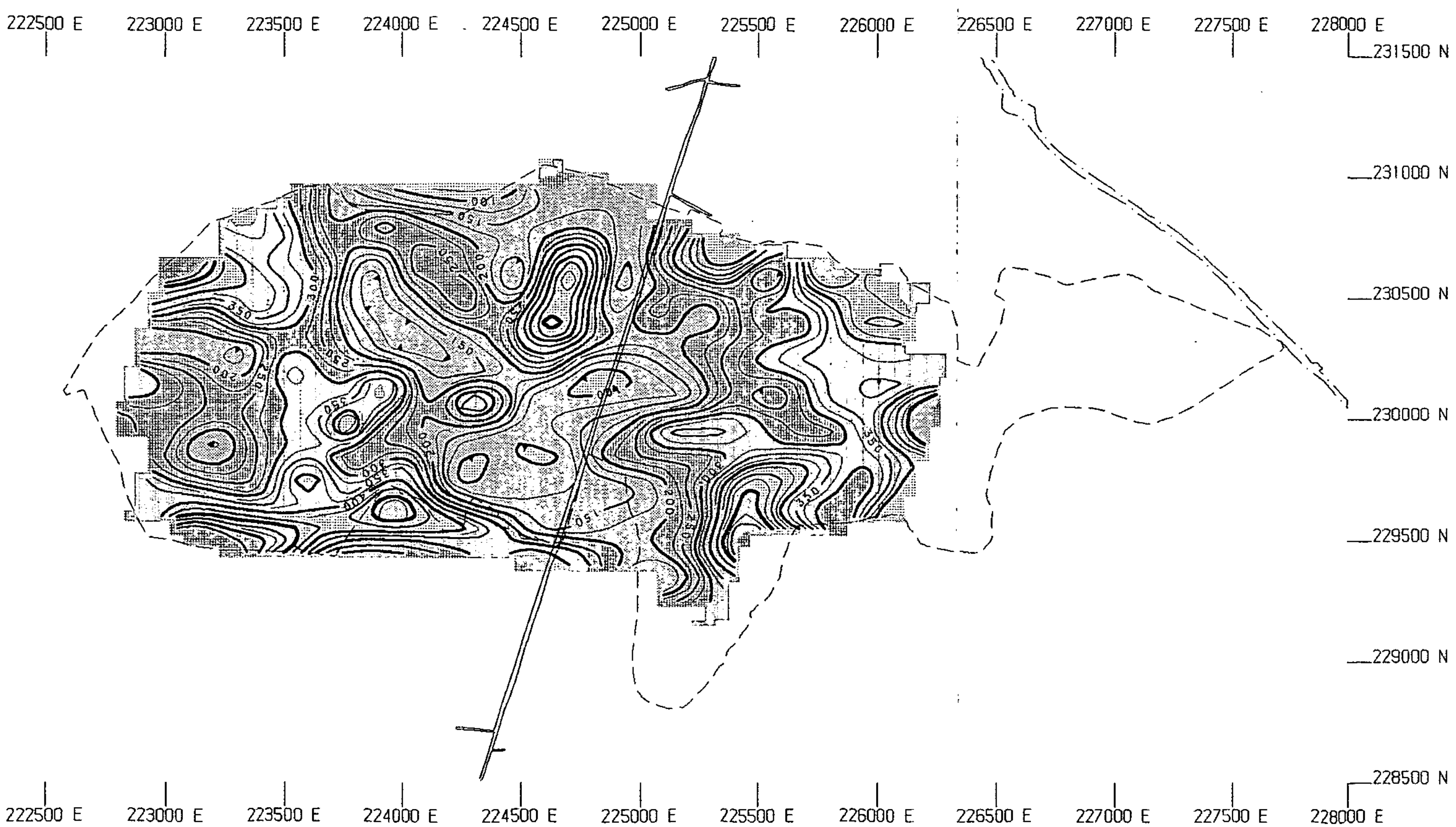
# Data Processing

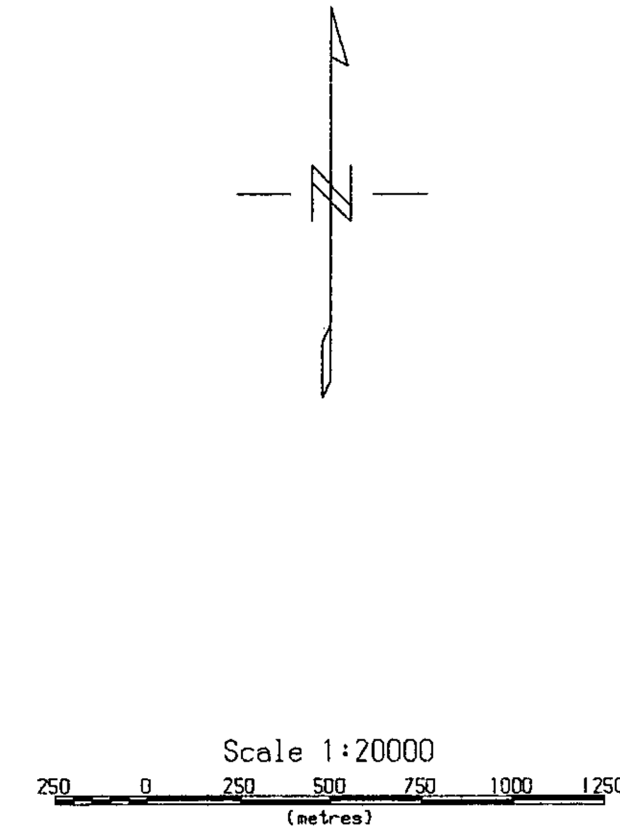
The field data was input on a nightly basis to a disk file using the IBM PS/2 computer in the field office in Clara. Processing of the data was carried out using the Geosoft computer package at the Applied Geophysics Unit, U.C.G..

The data first had to be formatted correctly for input to the system. This format is called "XYZ format", X and Y refer to the co-ordinates of the Z values for a specified co-ordinate system. Originally, the co-ordinate system used was the Clara grid as laid by the OPW, but by using a digitiser, these grid values were converted to National Grid co-ordinates. The Z columns contain the values of apparent resistivity and phase obtained at the locations defined by the co-ordinates in the respective XY columns. In the data listing (See appendix A), columns 1 and 2 contain the X and Y values respectively in National Grid co-ordinates. Column 3 gives the station location on the Clara grid, column 4 gives the resistivity values in ohm meters and column 5 contains the phase angle readings in degrees. This formatting allows the processing of the resistivity and phase data separately.

In order to produce a contoured map the data must first be gridded. Gridding allows two-dimensional geophysical data to be represented by determining its value at points located equally far apart at the nodes of the grid. This basically involves the interpolation between the actual data points to a stage where a specified 'grid cell size' has been achieved. A grid cell size of 50m was used to produce the resistivity contour map in Figure 4.1 i.e. interpolation of points occurred east-west across the grid where observed data were 200m apart. Figure 4.2 shows contours on a grid cell size of 200m so only all observed data points were used. As a check on the suitability of using a 50m grid size the data were also gridded at 200m and the respective maps were in broad agreement, but some resolution was lost in the 200m grid. It was therefore decided that the 50m grid size was the most suitable and thus was used in all subsequent processing.

The grid, if contoured at this stage, gives a very jagged, angular appearance which may obscure some of the important features and trends. For this reason and basically to enhance the cosmetic appearance of the contours, the data was smoothed by applying a 9-point Hanning filter. The filter may be applied up five times but since it is basically just a smoothing operation it should be used conservatively as the procedure can remove small features which may be significant. Resistivity data were passed twice through the Hanning filter, whilst the phase data had one pass through the filter,(Figure 4.3).




IRISH-DUTCH PEATLANDS PROJECT

**FIG. 4.1 CLARA BOG**
Smoothed Resistivity Contour Map.

Data Collected Using Geonics EM16R, Transmitter GBR used.
Line spacing 200m, Station spacing 50m.
Data set Gridded at 50m, Resistivity Values in Ohm-m.

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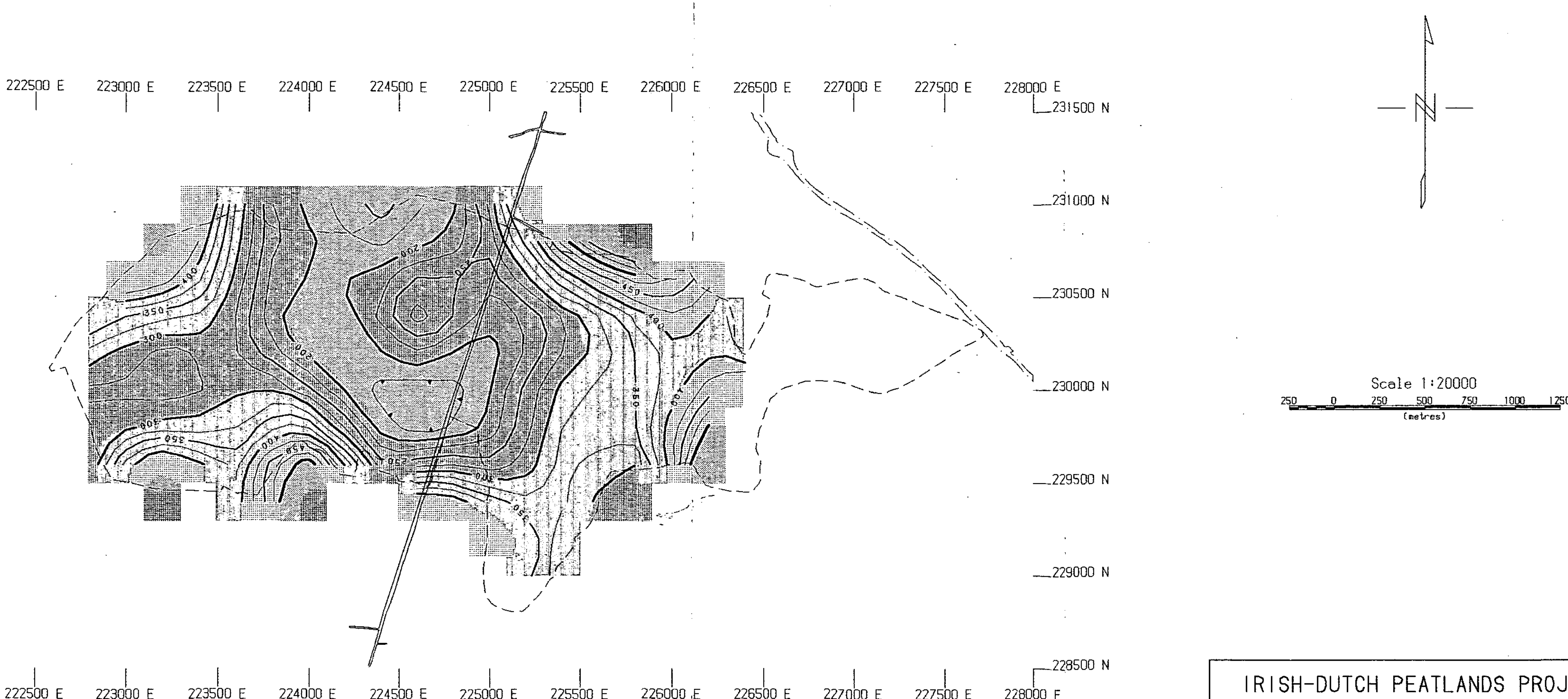


IRISH-DUTCH PEATLANDS PROJECT

## FIG. 4.2 CLARA BOG

Smoothed Resistivity Contour Map.

Data Collected Using Geonics EM16R, Transmitter GBR used.
Line spacing 200m, Station spacing 50m.
Data set Gridded at 200m, Resistivity Values in Ohm-m.

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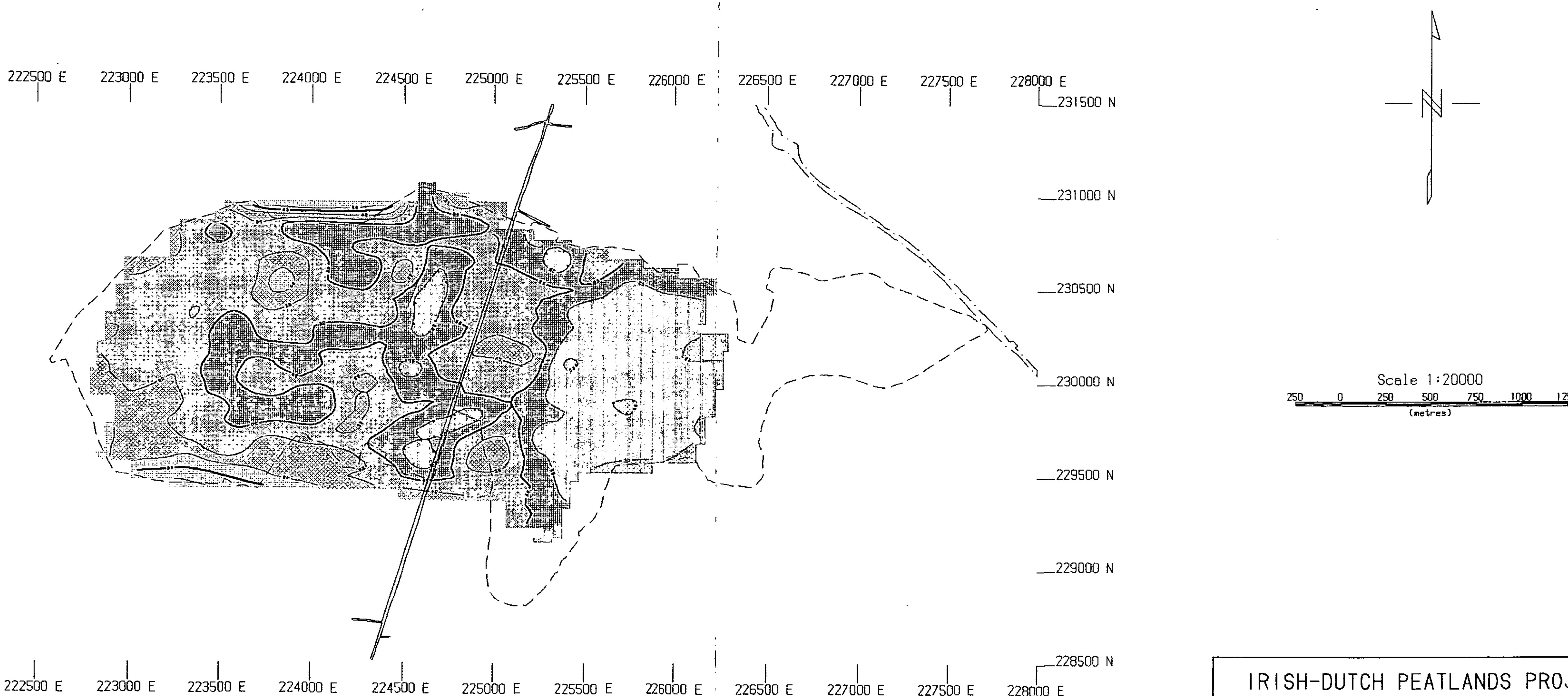


IRISH-DUTCH PEATLANDS PROJECT

FIG. 4.3 CLARA BOG

Smoothed Phase Contour Map.

Data Collected Using Geonics EM16R, Transmitter GBR used.
Line spacing 200m, Station spacing 50m.
Data set Gridded at 50m, Phase Values in degrees.

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# Chapter 5

# Qualitative Interpretation of Survey Data

The maps in Figures 4.1 and 4.2 show the apparent resistivity as measured over Clara bog. This resistivity data indicates closeness of bedrock to the surface in parts of the survey area. The high apparent resistivity areas indicate bedrock close to the surface. These areas are indicated by the red colouring, intensity of colour increasing with higher resistivity (Fig.4.1). The areas of low apparent resistivity, indicated by the light blue colour, show bedrock to be at greater depths below the peat and possibly covered by a thicker layer of overburden than the higher resistivity areas.

The areas of high resistivity are confined to the margin of the bog with the exception of one area in the north-centre and another area in the south-west of the bog. The significantly high resistivities of 400 ohm-m and 500 ohm-m at the margin compared with the 200 ohm-m and 300 ohm-m values occurring in the interior of the bog show that the general topographic configuration of the bedrock is a basin effect. The anomaly in the north-centre indicates the bedrock to be jutting up close to the surface here and this is also true in the south-east.

On the northern and extreme western margin of Clara West there are no significantly high resistivities. This is due to the fact that the contour lines here are interpolated and do not reflect observed data. The survey did not extend beyond the margin due to difficult terrain in the north and time limitation factors in the west.

The central region of the bog in Figure 4.2 shows the underlying bedrock topography to consist of a large depression with two lower depressions contained within it to the east and west. These two depressional features are each enclosed by the 200 ohm-m contour line in the contoured observed data using the 200m grid size (Fig.4.2), but are connected by this contour in the smoothed contour map (Fig.4.1). However both maps indicate a definite ridge, even though gently rising, separating the two low depressions. This ridge is connecting up the two anomalies occurring in the north-centre and south-west which show bedrock to be close to the surface.

The larger depression enclosing the central area of the bog is surrounded by the 300 ohm-m contour line in both Figure 4.1 and Figure 4.2. There is a narrow corridor bordered by the 300 ohm-m contour line extending out from this main depression to a wide depressional area in the south-east.

A contour map showing an image of the underlying bedrock constructed from the phase data is shown in Figure 4.3. The phase angle data contours are significantly less than 45 degrees (apart from interpolation in the north-west and south-west corners of the map). This signifies that the phase angle data shows the effect of a conductive layer overlying a more resistive layer. Since peat is a conductive material, the phase angle is picking up the underlying resistive bedrock. However the clay layer which was found beneath the peat at various borehole locations is obviously too thin in places and perhaps not present elsewhere, to be picked up from the phase angle data, which is below 45 degrees.

The information acquired from the phase angle data reinforces the knowledge of bedrock topography revealed by the resistivity data. The anomaly in the north-centre is confirmed by its enclosure by the 25 degrees phase angle contour line, indicating bedrock at significantly shallow depths in relation to the surrounding area. The south-west anomaly is connected up to this anomaly by the 30 degrees phase contour line thus reinforcing the impression of a ridge of shallower bedrock separating the two areas of deep bedrock to the west and east of the ridge. These two depressions are enclosed by the 30 degrees contour lines with the centres enclosed by the 35 degrees phase contour lines. The south-west depression of deep bedrock is also clear from the 35 degrees contour line.

The extremely shallow bedrock on the east margin of the the bog is shown up by the very low phase angle contour line of 20 degrees. The eastern half of Clara East has relatively shallow bedrock which corresponds remarkably with the phase contour line of 25 degrees since it occupies roughly the same position as the 250 ohm-m resistivity contour line.

The shallow bedrock beside the road to the south (Fig.4.3) is shown by the circular 25 degrees phase contour line. The more elongated enclosure by the 25 degrees phase contour is obviously distorted due to interpolation by the gridding algorithim on the eastern side of the road.

The general impression of the underlying bedrock which comes across from Figures 4.1, 4.2 and 4.3 is an area with a central depression of deep bedrock separated by a ridge of shallower bedrock running south-west to north-east. The shallower bedrock surrounding the depression is broad in extent, especially on the western and eastern sides.

From a correlation of the maps in Figures 3.1 and 4.1 it seems that the line of lakes on the eastern side lie in the direction of shoaling bedrock. The evidence for this is based on a resistivity high defined by readings along the most easterly survey line. Confirmation of this shoaling bedrock should be obtained by completing the grid of VLF/VLF-R measurements eastwards to the bog margin. If there is shoaling bedrock this could give rise to peat tearing due to stress as it grows upwards. This peat tearing could form a structural control along which a lake could result. However more detailed investigations need to be done before the exact origin of these lakes is known.

# Chapter 6

# Conclusions

From the maps produced using the resistivity and phase data it is shown that the underlying bedrock on Clara bog forms an overall basin effect. The basin is occupied by a ridge of shallow bedrock in the centre running in a north-east south-west direction. A wide margin of bedrock surrounds the basin on all sides apart from the north-west and south-west corners where the survey has to be extended.

The information obtained shows that the VLF-R survey has been extremely productive. The report shows that the VLF-R method is a very efficient technique for successfully determining relative depth of peat and illustrating the general configuration of bedrock. The complimentary results of the resistivity contour map and the phase angle contour map indicate definite areas of distinctiveness within the general configuration of the underlying bedrock. Both maps compare favourably in this respect.

The VLF-R technique is a very useful method as an initial reconnaissance survey. Once anomalies and areas of specific interest have been located with the VLF-R method, other techniques can then be used for more detailed examination of the locality, and drilling locations can be determined. The VLF-R method is quick, light-weight, easy to set up and simple to use.

# Chapter 7

# Recommendations

Since the VLF-R method was so successful in resolving the topography of bedrock, the technique should be used to extend the survey lines beyond the margin of the bog. This would result in a broader view of the bedrock in the region, enabling us to draw up a more conclusive hypothesis about the origins of the bog.

More intense use of the VLF-R method is suggested on areas which differ morphologically and topographically, enabling an understanding of the circumstances which accompany such features. This perhaps could be achieved by surveying the omitted 100m OPW grid lines in the vicinity of anomalies.

The areas where anomalies are shown to exist should be examined more closely using other geophysical techniques. Techniques such as vertical electric soundings should indicate distinct layers above the bedrock and successfully resolve depths of each layer.

Areas of relative inhomogeneity should be targeted as drilling sites. The information obtained from borehole logs would act as controls on the geophysical techniques used.

The VLF-R results should be integrated with other geophysical techniques already used in the area. This would build up a more complete picture of the nature of the bedrock and overburden layers. The different techniques could be calibrated against each other giving more accurate and detailed information about the region.

# Chapter 8

# Acknowledgements

Deepest gratitude and thanks to Mary Smyth who allowed me to work with her on the Irish-Dutch Peatlands Project in the first place. Neither the fieldwork nor the report would have been completed without her diligence. Thanks to her also for making the stay in Clara and Galway so enjoyable.

Sincere thanks to Kevin Barton and Colin Brown. Their help, encouragement and enthusiasm were invaluable and greatly appreciated. Kevin Barton's wizardry with the computer and constant supervision and encouragement throughout made the project possible. The help afforded by Colin Brown in the data interpretation is greatly appreciated.

Thanks to Prof. A. Brock for allowing me the opportunity to learn so much from this experience and for making the facilities in the Applied Geophysics Unit available to me.

Thanks to Colm Murphy for sharing his expertise with the Latex wordprocessor and for contributing to the writing of the project by proof reading some of the original draft.

I wish to thank Prof. P.M. Bruck for first arranging for me to do this project.

Thanks to all those working on the project in Clara; Richard Henderson, Lara Kelly and Desiree Huismann and Henk Lensen. They made the stay in Clara enjoyable and very valuable. Good luck with the rest of the project!

# Appendix A

# Listing of field data

| | | | | |
|---|---|---|---|---|
| LINE 0100 | | | | |
| 225192 | 230796 | -50 | 280 | 24 |
| 225176.8 | 230749.1 | -100 | 280 | 24 |
| 225161.5 | 230702.2 | -150 | 300 | 28 |
| 225146.3 | 230655.4 | -200 | 400 | 28 |
| 225131.1 | 230608.5 | -250 | 260 | 29 |
| 225115.8 | 230561.6 | -300 | 160 | 34 |
| 225100.6 | 230514.7 | -350 | 200 | 35 |
| 225085.4 | 230467.8 | -400 | 350 | 30 |
| 225070.1 | 230420.9 | -450 | 200 | 30 |
| 225054.9 | 230374.1 | -500 | 200 | 32 |
| 225039.6 | 230327.2 | -550 | 220 | 32 |
| 225024.4 | 230280.3 | -600 | 120 | 32 |
| 225009.2 | 230233.4 | -650 | 160 | 38 |
| 224993.9 | 230186.5 | -700 | 080 | 40 |
| 224978.7 | 230139.6 | -750 | 080 | 34 |
| 224963.5 | 230092.8 | -800 | 140 | 32 |
| 224948.2 | 230045.9 | -850 | 120 | 30 |
| 224933 | 229999 | -900 | 180 | 30 |
| 224916.8 | 229951 | -950 | 180 | 32 |
| 224900.5 | 229903 | -1000 | 200 | 28 |
| 224884.3 | 229855 | -1050 | 300 | 22 |
| 224868 | 229807 | -1100 | 200 | 22 |
| LINE -0100 | | | | |
| 225014 | 230904 | 0 | 160 | 32 |
| 224998.6 | 230856.9 | -50 | 100 | 32 |
| 224983.2 | 230809.8 | -100 | 200 | 28 |
| 224967.8 | 230762.7 | -150 | 150 | 34 |
| 224952.4 | 230715.6 | -200 | 150 | 32 |
| 224937.1 | 230668.4 | -250 | 120 | 28 |
| 224921.7 | 230621.3 | -300 | 090 | 32 |
| 224906.3 | 230574.2 | -350 | 130 | 34 |
| 224890.9 | 230527.1 | -400 | 100 | 30 |
| 224875.5 | 230480 | -450 | 150 | 35 |
| 224860.1 | 230432.9 | -500 | 120 | 30 |
| 224844.7 | 230385.8 | -550 | 200 | 38 |
| 224829.3 | 230338.7 | -600 | 280 | 31 |
| 224813.9 | 230291.6 | -650 | 160 | 27 |
| 224798.6 | 230244.4 | -700 | 100 | 29 |
| 224783.2 | 230197.3 | -750 | 085 | 31 |
| 224767.8 | 230150.2 | -800 | 070 | 36 |
| 224752.4 | 230103.1 | -850 | 070 | 34 |
| 224737 | 230056 | -900 | 140 | 32 |
| 224721.8 | 230009.1 | -950 | 140 | 29 |
| 224706.5 | 229962.2 | -1000 | 160 | 28 |
| 224691.3 | 229915.2 | -1050 | 130 | 30 |
| 224676.1 | 229868.3 | -1100 | 080 | 32 |
| 224660.8 | 229821.4 | -1150 | 070 | 28 |
| 224645.6 | 229774.5 | -1200 | 130 | 20 |
| 224630.4 | 229727.5 | -1250 | 100 | 24 |
| 224615.2 | 229680.6 | -1300 | 130 | 27 |
| 224599.9 | 229633.7 | -1350 | * | * |
| 224584.7 | 229586.8 | -1400 | 150 | 20 |
| 224569.5 | 229539.8 | -1450 | 100 | 26 |
| 224554.2 | 229492.9 | -1500 | 150 | 28 |
| 224539 | 229446 | -1550 | 500 | 34 |
| LINE 0300 | | | | |
| 225388 | 230737 | -50 | 600 | 28 |
| 225372.8 | 230690.4 | -100 | 500 | 22 |
| 225357.5 | 230643.7 | -150 | 400 | 22 |

| | | | | |
|---|---|---|---|---|
| 225342.3 | 230597.1 | -200 | 400 | 24 |
| 225327.1 | 230550.4 | -250 | 300 | 28 |
| 225311.8 | 230503.8 | -300 | 160 | 34 |
| 225296.6 | 230457.1 | -350 | 180 | 28 |
| 225281.4 | 230410.5 | -400 | 160 | 30 |
| 225266.1 | 230363.8 | -450 | 140 | 30 |
| 225250.9 | 230317.2 | -500 | 300 | 30 |
| 225235.6 | 230270.5 | -550 | 200 | 28 |
| 225220.4 | 230223.9 | -600 | 180 | 30 |
| 225205.2 | 230177.2 | -650 | 200 | 40 |
| 225189.9 | 230130.6 | -700 | 120 | 36 |
| 225174.7 | 230083.9 | -750 | 080 | 34 |
| 225159.5 | 230037.3 | -800 | 100 | 36 |
| 225144.2 | 229990.6 | -850 | 400 | 30 |
| 225129 | 229944 | -900 | 500 | 30 |
| 225112.6 | 229895.5 | -950 | 240 | 30 |
| 225096.3 | 229847 | -1000 | 300 | 30 |
| 225079.9 | 229798.5 | -1050 | 190 | 33 |
| 225063.5 | 229750 | -1100 | 180 | 33 |
| 225047.1 | 229701.5 | -1150 | 140 | 37 |
| 225030.8 | 229653 | -1200 | 160 | 38 |
| 225014.4 | 229604.5 | -1250 | 160 | 40 |
| 224998 | 229556 | -1300 | 230 | 40 |
| LINE -0300 | | | | |
| 224823 | 230966 | 0 | 120 | 40 |
| 224807.8 | 230919.1 | -50 | 100 | 30 |
| 224792.6 | 230872.1 | -100 | 250 | 28 |
| 224777.3 | 230825.2 | -150 | 200 | 20 |
| 224762.1 | 230778.2 | -200 | 100 | 38 |
| 224746.9 | 230731.3 | -250 | 280 | 30 |
| 224731.7 | 230684.3 | -300 | 500 | 26 |
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| 224701.2 | 230590.4 | -400 | 500 | 24 |
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| 224655.6 | 230449.6 | -550 | 500 | 20 |
| 224640.3 | 230402.7 | -600 | 700 | 22 |
| 224625.1 | 230355.7 | -650 | 600 | 22 |
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| 224579.4 | 230214.9 | -800 | 300 | 24 |
| 224564.2 | 230167.9 | -850 | 150 | 34 |
| 224549 | 230121 | -900 | 100 | 24 |
| 224533.8 | 230073.8 | -950 | 100 | 14 |
| 224518.5 | 230026.5 | -1000 | 100 | 30 |
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| 224427 | 229743 | -1300 | 120 | 30 |
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| 225530.8 | 230538.4 | -200 | 140 | 30 |

| | | | | |
|---|---|---|---|---|
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| 225500.7 | 230444.6 | -300 | 300 | 24 |
| 225485.6 | 230397.7 | -350 | 300 | 22 |
| 225470.6 | 230350.8 | -400 | 220 | 22 |
| 225455.5 | 230303.9 | -450 | 300 | 26 |
| 225440.5 | 230257.1 | -500 | 280 | 24 |
| 225425.4 | 230210.2 | -550 | 300 | 22 |
| 225410.4 | 230163.3 | -600 | 300 | 20 |
| 225395.3 | 230116.4 | -650 | 180 | 18 |
| 225380.2 | 230069.5 | -700 | 300 | 18 |
| 225365.2 | 230022.6 | -750 | 300 | 22 |
| 225350.1 | 229975.8 | -800 | 400 | 26 |
| 225335.1 | 229928.9 | -850 | 400 | 20 |
| 225320 | 229882 | -900 | 300 | 26 |
| 225304.5 | 229834.1 | -950 | 200 | 28 |
| 225289.1 | 229786.2 | -1000 | 220 | 24 |
| 225273.6 | 229738.2 | -1050 | 400 | 22 |
| 225258.2 | 229690.3 | -1100 | 300 | 22 |
| 225242.7 | 229642.4 | -1150 | 240 | 24 |
| 225227.2 | 229594.5 | -1200 | 240 | 28 |
| 225211.8 | 229546.5 | -1250 | 200 | 28 |
| 225196.3 | 229498.6 | -1300 | 260 | 28 |
| 225180.8 | 229450.7 | -1350 | 300 | 32 |
| 225165.4 | 229402.8 | -1400 | 160 | 30 |
| 225149.9 | 229354.8 | -1450 | 140 | 30 |
| 225134.5 | 229306.9 | -1500 | 060 | 32 |
| 225119 | 229259 | -1550 | 300 | 32 |
| LINE 0700 | | | | |
| 225770 | 230622 | -50 | 600 | 26 |
| 225754.3 | 230574.5 | -100 | 500 | 26 |
| 225738.6 | 230527.1 | -150 | 400 | 24 |
| 225722.9 | 230479.6 | -200 | 300 | 22 |
| 225707.2 | 230432.1 | -250 | 300 | 22 |
| 225691.5 | 230384.6 | -300 | 200 | 26 |
| 225675.8 | 230337.2 | -350 | 300 | 22 |
| 225660.1 | 230289.7 | -400 | 350 | 22 |
| 225644.4 | 230242.2 | -450 | 400 | 20 |
| 225628.6 | 230194.8 | -500 | 300 | 28 |
| 225612.9 | 230147.3 | -550 | 240 | 22 |
| 225597.2 | 230099.8 | -600 | 180 | 24 |
| 225581.5 | 230052.4 | -650 | 220 | 22 |
| 225565.8 | 230004.9 | -700 | 300 | 28 |
| 225550.1 | 229957.4 | -750 | 350 | 22 |
| 225534.4 | 229909.9 | -800 | 220 | 20 |
| 225518.7 | 229862.5 | -850 | 300 | 22 |
| 225503 | 229815 | -900 | 450 | 26 |
| 225487.8 | 229767.5 | -950 | 500 | 24 |
| 225472.5 | 229719.9 | -1000 | 500 | 24 |
| 225457.3 | 229672.4 | -1050 | 600 | 20 |
| 225442.1 | 229624.8 | -1100 | 500 | 24 |
| 225426.8 | 229577.3 | -1150 | 500 | 22 |
| 225411.6 | 229529.8 | -1200 | 700 | 22 |
| 225396.4 | 229482.2 | -1250 | 600 | 24 |
| 225381.2 | 229434.7 | -1300 | 600 | 22 |
| 225365.9 | 229387.2 | -1350 | 400 | 26 |
| 225350.7 | 229339.6 | -1400 | 300 | 26 |
| 225335.5 | 229292.1 | -1450 | 350 | 30 |
| 225320.2 | 229244.5 | -1500 | 300 | 24 |
| 225305 | 229197 | -1550 | 300 | 24 |
| LINE -0700 | | | | |

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|---|---|---|---|---|
| 224378 | 230902 | -200 | 100 | 40 |
| 224362.9 | 230854.6 | -250 | 150 | 28 |
| 224347.9 | 230807.1 | -300 | 100 | 24 |
| 224332.8 | 230759.7 | -350 | 200 | 34 |
| 224317.7 | 230712.3 | -400 | 240 | 34 |
| 224302.6 | 230664.9 | -450 | 200 | 26 |
| 224287.6 | 230617.4 | -500 | 170 | 26 |
| 224272.5 | 230570 | -550 | 300 | 22 |
| 224257.4 | 230522.6 | -600 | 300 | 32 |
| 224242.4 | 230475.1 | -650 | 300 | 30 |
| 224227.3 | 230427.7 | -700 | 240 | 32 |
| 224212.2 | 230380.3 | -750 | 190 | 32 |
| 224197.1 | 230332.9 | -800 | 120 | 32 |
| 224182.1 | 230285.4 | -850 | 100 | 28 |
| 224167 | 230238 | -900 | 140 | 22 |
| 224151.3 | 230190.9 | -950 | 120 | 30 |
| 224135.7 | 230143.8 | -1000 | 120 | 34 |
| 224120 | 230096.8 | -1050 | 140 | 30 |
| 224104.3 | 230049.7 | -1100 | 190 | 32 |
| 224088.7 | 230002.6 | -1150 | 190 | 31 |
| 224073 | 229955.5 | -1200 | 200 | 28 |
| 224057.3 | 229908.4 | -1250 | 180 | 28 |
| 224041.7 | 229861.3 | -1300 | 280 | 24 |
| 224026 | 229814.3 | -1350 | 400 | 26 |
| 224010.3 | 229767.2 | -1400 | 400 | 32 |
| 223994.7 | 229720.1 | -1450 | 400 | 32 |
| 223979 | 229673 | -1500 | 600 | 34 |
| LINE 0900 | | | | |
| 225966 | 230567 | -50 | 400 | 28 |
| 225950.3 | 230519.8 | -100 | 400 | 26 |
| 225934.6 | 230472.6 | -150 | 500 | 24 |
| 225918.9 | 230425.5 | -200 | 400 | 24 |
| 225903.2 | 230378.3 | -250 | 500 | 18 |
| 225887.5 | 230331.1 | -300 | 400 | 20 |
| 225871.8 | 230283.9 | -350 | 300 | 24 |
| 225856.1 | 230236.8 | -400 | 400 | 22 |
| 225840.4 | 230189.6 | -450 | 350 | 22 |
| 225824.6 | 230142.4 | -500 | 350 | 20 |
| 225808.9 | 230095.2 | -550 | 400 | 22 |
| 225793.2 | 230048.1 | -600 | 350 | 20 |
| 225777.5 | 230000.9 | -650 | 300 | 20 |
| 225761.8 | 229953.7 | -700 | 200 | 22 |
| 225746.1 | 229906.5 | -750 | 240 | 18 |
| 225730.4 | 229859.4 | -800 | 400 | 20 |
| 225714.7 | 229812.2 | -850 | 450 | 20 |
| 225699 | 229765 | -900 | 400 | 20 |
| 225683 | 229713.7 | -950 | 400 | 22 |
| 225667 | 229662.3 | -1000 | 400 | 22 |
| 225651 | 229611 | -1050 | 220 | 22 |
| LINE -0900 | | | | |
| 224149 | 230822 | -350 | 200 | 26 |
| 224133.1 | 230774.4 | -400 | 200 | 30 |
| 224117.2 | 230726.7 | -450 | 250 | 28 |
| 224101.3 | 230679.1 | -500 | 300 | 28 |
| 224085.4 | 230631.5 | -550 | 300 | 32 |
| 224069.5 | 230583.8 | -600 | 300 | 30 |
| 224053.5 | 230536.2 | -650 | 160 | 30 |
| 224037.6 | 230488.5 | -700 | 190 | 34 |
| 224021.7 | 230440.9 | -750 | 120 | 34 |
| 224005.8 | 230393.3 | -800 | 100 | 32 |

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|---|---|---|---|---|
| 223989.9 | 230345.6 | -850 | 100 | 30 |
| 223974 | 230298 | -900 | 090 | 30 |
| 223958.8 | 230251.2 | -950 | 140 | 32 |
| 223943.6 | 230204.3 | -1000 | 220 | 30 |
| 223928.3 | 230157.5 | -1050 | 600 | 28 |
| 223913.1 | 230110.7 | -1100 | 450 | 24 |
| 223897.9 | 230063.8 | -1150 | 400 | 30 |
| 223882.7 | 230017 | -1200 | 350 | 32 |
| 223867.4 | 229970.2 | -1250 | 300 | 30 |
| 223852.2 | 229923.3 | -1300 | 230 | 30 |
| 223837 | 229876.5 | -1350 | 180 | 28 |
| 223821.8 | 229829.7 | -1400 | 300 | 30 |
| 223806.6 | 229782.8 | -1450 | 200 | 28 |
| 223791.3 | 229736 | -1500 | 300 | 34 |
| 223776.1 | 229689.2 | -1550 | 400 | 38 |
| 223760.9 | 229642.3 | -1600 | 200 | 38 |
| 223745.7 | 229595.5 | -1650 | 600 | 42 |
| 223730.4 | 229548.7 | -1700 | 500 | 38 |
| 223715.2 | 229501.8 | -1750 | 300 | 40 |
| 223700 | 229455 | -1800 | 150 | 47 |
| LINE -0950 | | | | |
| 223815 | 230024 | -1200 | 600 | 32 |
| 223800 | 229977 | -1250 | 700 | 32 |
| 223785 | 229930 | -1300 | 500 | 30 |
| 223770 | 229883 | -1350 | 220 | 28 |
| LINE -1000 | | | | |
| 223792 | 230079 | -1150 | 240 | 32 |
| 223777 | 230033.6 | -1200 | 400 | 36 |
| 223762 | 229988.2 | -1250 | 600 | 31 |
| 223747 | 229942.8 | -1300 | 500 | 34 |
| 223732 | 229897.4 | -1350 | 400 | 26 |
| 223717 | 229852 | -1400 | 300 | 30 |
| LINE 1100 | | | | |
| 226166 | 230538 | 0 | 400 | 28 |
| 226150.4 | 230490.8 | -50 | 350 | 26 |
| 226134.8 | 230443.6 | -100 | 350 | 24 |
| 226119.2 | 230396.3 | -150 | 500 | 24 |
| 226103.6 | 230349.1 | -200 | 500 | 20 |
| 226087.9 | 230301.9 | -250 | 240 | 22 |
| 226072.3 | 230254.7 | -300 | 450 | 20 |
| 226056.7 | 230207.4 | -350 | 400 | 20 |
| 226041.1 | 230160.2 | -400 | 280 | 20 |
| 226025.5 | 230113 | -450 | 300 | 20 |
| 226009.9 | 230065.8 | -500 | 400 | 20 |
| 225994.3 | 230018.6 | -550 | 400 | 22 |
| 225978.7 | 229971.3 | -600 | 350 | 22 |
| 225963.1 | 229924.1 | -650 | 350 | 24 |
| 225947.4 | 229876.9 | -700 | 350 | 24 |
| 225931.8 | 229829.7 | -750 | 280 | 24 |
| 225916.2 | 229782.4 | -800 | 280 | 22 |
| 225900.6 | 229735.2 | -850 | 280 | 22 |
| 225885 | 229688 | -900 | 240 | 22 |
| 225868.5 | 229642.5 | -950 | 300 | 26 |
| 225852 | 229597 | -1000 | 260 | 20 |
| LINE -1100 | | | | |
| 223940 | 230836 | -400 | 270 | 25 |
| 223924.7 | 230789.1 | -450 | 300 | 29 |
| 223909.4 | 230742.2 | -500 | 280 | 30 |
| 223894.1 | 230695.3 | -550 | 150 | 36 |
| 223878.8 | 230648.4 | -600 | 100 | 40 |

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|---|---|---|---|---|
| 223863.5 | 230601.5 | -650 | 070 | 40 |
| 223848.2 | 230554.6 | -700 | 100 | 45 |
| 223832.9 | 230507.7 | -750 | 120 | 43 |
| 223817.6 | 230460.8 | -800 | 100 | 38 |
| 223802.3 | 230413.9 | -850 | 160 | 36 |
| 223787 | 230367 | -900 | 200 | 36 |
| 223771.6 | 230319.7 | -950 | 190 | 30 |
| 223756.2 | 230272.4 | -1000 | 190 | 32 |
| 223740.8 | 230225.2 | -1050 | 260 | 30 |
| 223725.4 | 230177.9 | -1100 | 290 | 28 |
| 223710.1 | 230130.6 | -1150 | 300 | 30 |
| 223694.7 | 230083.3 | -1200 | 350 | 32 |
| 223679.3 | 230036.1 | -1250 | 270 | 32 |
| 223663.9 | 229988.8 | -1300 | 400 | 30 |
| 223648.5 | 229941.5 | -1350 | 350 | 30 |
| 223633.1 | 229894.2 | -1400 | 240 | 28 |
| 223617.7 | 229846.9 | -1450 | 400 | 30 |
| 223602.3 | 229799.7 | -1500 | 400 | 28 |
| 223586.9 | 229752.4 | -1550 | 500 | 30 |
| 223571.6 | 229705.1 | -1600 | 400 | 32 |
| 223556.2 | 229657.8 | -1650 | 400 | 28 |
| 223540.8 | 229610.6 | -1700 | 250 | 32 |
| 223525.4 | 229563.3 | -1750 | 500 | 43 |
| 223510 | 229516 | -1800 | 700 | 44 |
| LINE 1300 | | | | |
| 226279 | 230239 | -250 | 300 | 20 |
| 226263.5 | 230191.8 | -300 | 280 | 18 |
| 226248.1 | 230144.7 | -350 | 350 | 18 |
| 226232.6 | 230097.5 | -400 | 500 | 22 |
| 226217.2 | 230050.4 | -450 | 750 | 24 |
| 226201.7 | 230003.2 | -500 | 500 | 24 |
| 226186.2 | 229956.1 | -550 | 600 | 24 |
| 226170.8 | 229908.9 | -600 | 600 | 22 |
| 226155.3 | 229861.8 | -650 | 300 | 20 |
| 226139.8 | 229814.6 | -700 | 400 | 20 |
| 226124.4 | 229767.5 | -750 | 450 | 18 |
| 226108.9 | 229720.3 | -800 | 400 | 22 |
| 226093.5 | 229673.2 | -850 | 400 | 20 |
| 226078 | 229626 | -900 | 500 | 18 |
| LINE -1300 | | | | |
| 223744 | 230898 | -400 | 180 | 32 |
| 223729.2 | 230851.3 | -450 | 180 | 36 |
| 223714.4 | 230804.6 | -500 | 170 | 35 |
| 223699.6 | 230757.9 | -550 | 220 | 32 |
| 223684.8 | 230711.2 | -600 | 200 | 33 |
| 223670 | 230664.5 | -650 | 270 | 34 |
| 223655.2 | 230617.8 | -700 | 350 | 34 |
| 223640.4 | 230571.1 | -750 | 300 | 30 |
| 223625.6 | 230524.4 | -800 | 300 | 32 |
| 223610.8 | 230477.7 | -850 | 300 | 34 |
| 223596 | 230431 | -900 | 300 | 34 |
| 223580.4 | 230383.7 | -950 | 300 | 28 |
| 223564.8 | 230336.4 | -1000 | 240 | 28 |
| 223549.2 | 230289.1 | -1050 | 300 | 26 |
| 223533.6 | 230241.8 | -1100 | 400 | 28 |
| 223518 | 230194.5 | -1150 | 300 | 28 |
| 223502.4 | 230147.2 | -1200 | 400 | 30 |
| 223486.8 | 230099.9 | -1250 | 250 | 26 |
| 223471.2 | 230052.6 | -1300 | 300 | 28 |
| 223455.6 | 230005.3 | -1350 | 300 | 30 |

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|---|---|---|---|---|
| 223440 | 229958 | -1400 | 300 | 28 |
| 223424.4 | 229910.7 | -1450 | 270 | 32 |
| 223408.8 | 229863.4 | -1500 | 250 | 33 |
| 223393.2 | 229816.1 | -1550 | 280 | 32 |
| 223377.6 | 229768.8 | -1600 | 200 | 32 |
| 223362 | 229721.5 | -1650 | 280 | 36 |
| 223346.4 | 229674.2 | -1700 | 200 | 31 |
| 223330.8 | 229626.9 | -1750 | 400 | 42 |
| 223315.2 | 229579.6 | -1800 | 550 | 42 |
| 223299.6 | 229532.3 | -1850 | 600 | 45 |
| 223284 | 229485 | -1900 | 700 | 50 |
| LINE -1500 | | | | |
| 223540 | 230913 | -450 | 300 | 34 |
| 223524.7 | 230865.9 | -500 | 300 | 30 |
| 223509.3 | 230818.8 | -550 | 300 | 28 |
| 223494 | 230771.7 | -600 | 400 | 28 |
| 223478.7 | 230724.6 | -650 | 400 | 32 |
| 223463.3 | 230677.4 | -700 | 300 | 32 |
| 223448 | 230630.3 | -750 | 300 | 30 |
| 223432.7 | 230583.2 | -800 | 400 | 34 |
| 223417.3 | 230536.1 | -850 | 400 | 34 |
| 223402 | 230489 | -900 | 400 | 34 |
| 223386.4 | 230441.7 | -950 | 400 | 34 |
| 223370.8 | 230394.3 | -1000 | 400 | 36 |
| 223355.2 | 230347 | -1050 | 220 | 36 |
| 223339.6 | 230299.6 | -1100 | 120 | 34 |
| 223324 | 230252.3 | -1150 | 140 | 34 |
| 223308.4 | 230204.9 | -1200 | 180 | 34 |
| 223292.8 | 230157.5 | -1250 | 190 | 34 |
| 223277.2 | 230110.2 | -1300 | 200 | 36 |
| 223261.6 | 230062.8 | -1350 | 260 | 35 |
| 223246 | 230015.5 | -1400 | 270 | 35 |
| 223230.4 | 229968.2 | -1450 | 200 | 36 |
| 223214.8 | 229920.8 | -1500 | 120 | 38 |
| 223199.2 | 229873.5 | -1550 | 140 | 38 |
| 223183.6 | 229826.1 | -1600 | 200 | 34 |
| 223168 | 229778.8 | -1650 | 220 | 36 |
| 223152.4 | 229731.4 | -1700 | 220 | 36 |
| 223136.8 | 229684 | -1750 | 400 | 38 |
| 223121.2 | 229636.7 | -1800 | 400 | 36 |
| 223105.6 | 229589.3 | -1850 | 500 | 38 |
| 223090 | 229542 | -1900 | 800 | 44 |
| LINE -1700 | | | | |
| 223304 | 230831 | -600 | 450 | 34 |
| 223288.5 | 230784.3 | -650 | 350 | 34 |
| 223273 | 230737.7 | -700 | 350 | 36 |
| 223257.5 | 230691 | -750 | 300 | 36 |
| 223242 | 230644.3 | -800 | 500 | 34 |
| 223226.5 | 230597.7 | -850 | 500 | 34 |
| 223211 | 230551 | -900 | 400 | 34 |
| 223195.5 | 230503.9 | -950 | 350 | 34 |
| 223180.1 | 230456.8 | -1000 | 280 | 32 |
| 223164.7 | 230409.7 | -1050 | 180 | 32 |
| 223149.2 | 230362.6 | -1100 | 200 | 32 |
| 223133.8 | 230315.5 | -1150 | 200 | 34 |
| 223118.3 | 230268.4 | -1200 | 160 | 30 |
| 223102.8 | 230221.3 | -1250 | 220 | 32 |
| 223087.4 | 230174.2 | -1300 | 300 | 32 |
| 223072 | 230127.1 | -1350 | 300 | 34 |
| 223056.5 | 230080 | -1400 | 260 | 32 |

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|---|---|---|---|---|
| 223041 | 230032.9 | -1450 | 250 | 32 |
| 223025.6 | 229985.8 | -1500 | 300 | 36 |
| 223010.2 | 229938.7 | -1550 | 260 | 34 |
| 222994.7 | 229891.6 | -1600 | 280 | 36 |
| 222979.3 | 229844.5 | -1650 | 240 | 37 |
| 222963.8 | 229797.4 | -1700 | 240 | 38 |
| 222948.3 | 229750.3 | -1750 | 350 | 40 |
| 222932.9 | 229703.2 | -1800 | 400 | 40 |
| 222917.5 | 229656.1 | -1850 | 300 | 40 |
| 222902 | 229609 | -1900 | 300 | 40 |
| LINE -1900 | | | | |
| 223023 | 230611 | -900 | 700 | 36 |
| 223007.9 | 230563.9 | -950 | 500 | 34 |
| 222992.7 | 230516.9 | -1000 | 400 | 34 |
| 222977.6 | 230469.8 | -1050 | 500 | 36 |
| 222962.4 | 230422.7 | -1100 | 300 | 34 |
| 222947.3 | 230375.6 | -1150 | 140 | 28 |
| 222932.1 | 230328.6 | -1200 | 100 | 32 |
| 222917 | 230281.5 | -1250 | 120 | 41 |
| 222901.9 | 230234.4 | -1300 | 300 | 34 |
| 222886.7 | 230187.4 | -1350 | 350 | 32 |
| 222871.6 | 230140.3 | -1400 | 350 | 36 |
| 222856.4 | 230093.2 | -1450 | 300 | 36 |
| 222841.3 | 230046.1 | -1500 | 300 | 36 |
| 222826.1 | 229999.1 | -1550 | 180 | 38 |
| 222811 | 229952 | -1600 | 240 | 38 |
| LINE -0500 | | | | |
| 224634 | 231024 | 0 | 400 | 28 |
| 224618.6 | 230976.9 | -50 | 170 | 28 |
| 224603.1 | 230929.8 | -100 | 120 | 26 |
| 224587.7 | 230882.7 | -150 | 140 | 30 |
| 224572.2 | 230835.6 | -200 | 180 | 28 |
| 224556.8 | 230788.4 | -250 | 180 | 30 |
| 224541.3 | 230741.3 | -300 | 200 | 28 |
| 224525.9 | 230694.2 | -350 | 120 | 33 |
| 224510.4 | 230647.1 | -400 | 120 | 38 |
| 224495 | 230600 | -450 | 070 | 38 |
| 224479.6 | 230552.9 | -500 | 070 | 40 |
| 224464.1 | 230505.8 | -550 | 120 | 30 |
| 224448.7 | 230458.7 | -600 | 240 | 30 |
| 224433.2 | 230411.6 | -650 | 200 | 30 |
| 224417.8 | 230364.4 | -700 | 200 | 34 |
| 224402.3 | 230317.3 | -750 | 250 | 30 |
| 224386.9 | 230270.2 | -800 | 180 | 28 |
| 224371.4 | 230223.1 | -850 | 120 | 32 |
| 224356 | 230176 | -900 | 100 | 30 |
| 224340.7 | 230128.9 | -950 | 200 | 30 |
| 224325.3 | 230081.8 | -1000 | 600 | 34 |
| 224310 | 230034.8 | -1050 | 600 | 36 |
| 224294.7 | 229987.7 | -1100 | 100 | 40 |
| 224279.3 | 229940.6 | -1150 | 090 | 32 |
| 224264 | 229893.5 | -1200 | 130 | 38 |
| 224248.7 | 229846.4 | -1250 | 090 | 35 |
| 224233.3 | 229799.3 | -1300 | 070 | 36 |
| 224218 | 229752.3 | -1350 | 060 | 38 |
| 224202.7 | 229705.2 | -1400 | 080 | 32 |
| 224187.3 | 229658.1 | -1450 | 300 | 33 |
| 224172 | 229611 | -1500 | 400 | 38 |