EXPERIENCE WITH THE PROGRAM SYSTEM KARIN

FOR THE MAPPING OF REMOTE SENSING INFORMATION

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ABSTRACT

A program system was jointly developed by NIWARS** and Rijkswaterstaat, the Netherlands, for the mapping of geographic detail from single or overlapping remote sensing images (Sidelooking Radar, Infrared, a.o.). The system consists, similar to the conventional systems for aerial triangulation, of programs for strip formation, strip and block adjustment and for the plotting of the information.

Examples of infrared and sidelooking radar projects are included to demonstrate the application of the system.

1. INTRODUCTION

This paper documents a program system designed to transform and subsequently draw digitized features from Sidelooking Radar (SLAR)- and Line Scanner-images in the map system.

The metric properties of these types of imagery are quite different from those of conventional aerial photograms, consequently new methods have to be developed for their transformation and restitution.

In the method presented the photogrammetric concept of a block is used: a block is here defined as a set of overlapping remote sensing images, which may consist of images from different sensors. In the computation, this block of images is related to the map coordinate system with the help of reference- and tie points*. Like in photogrammetry, the use of a block of remote sensing images - as compared with an individual image - has the advantage of yielding a higher accuracy of the transformation with less reference points. The program system which was developed has no limitations with respect to distribution of reference points and arrangement of images in the block. It enables the computation of only the X and Y map coordinates, the Z coordinates must either be known a-priori or the terrain assumed to be flat.

In the following sections of this paper the theory of the programme system is outlined and examples of its practical application are given.

2. THE THEORY OF THE PROGRAM SYSTEM

THE STATEMENT OF THE PROBLEM

It is necessary to determine transformation formulae from partly overlapping remote sensing images such that points appearing in any one of the images can be transformed into the map coordinate system.

* Reference points are those points, whose coordinates are known both in the image and in the map system, tie points are points appearing in two or more images.
**Netherlands Interdepartmental Working-community for the Application of Remote Sensing techniques.

The transformation formulae should be based on the available information, namely:
- a geometric model describing the basic imaging properties of the sensors used;
- a set of reference points whose coordinates are known in the map system and in one of the individual images;
- a set of tie points whose coordinates have been measured in two or more images.

THE SOLUTION OF THE PROBLEM

The solution of the above problem is performed in three stages. In stage 1, which we will call strip formation, the measured image coordinates are transformed into a local "strip" system, according to the basic geometric properties of the different images and making use of the known flight parameters. This preliminary transformation is performed independently for every image in the block, the X-axis of the local coordinate system coincides with the flight axis of the individual image and the coordinate origin is chosen at the beginning of the photo-flight. This local coordinate system is called the strip coordinate system of the particular image.

In stage 2 of the solution, the block adjustment, the task is to fit the individual strip systems to each other and into the map system, with the help of the tie and reference points (see figure 1). After this transformation the transformed coordinates of the reference points should be equal to the pregiven values in the map system and every tie point should have an unique set of map coordinates (X,Y). The transformation equations of the individual strip systems are chosen in such a way that they can compensate for those non-linear deformations of the strip systems, due to the incomplete knowledge of the flight parameters.

Once the transformation parameters are known, in stage 3 of the solution, all the image points and lines of interest, may first be transformed onto the map system, and then plotted. This stage is therefore called the mapping stage. It is also possible to rectify the individual remote sensing images as a whole electronically with help of the transformation parameters. The developments of these techniques are being investigated and will be reported in due time.

THE PROGRAM SYSTEM KARIN

Following the above lines of solution, a program system was designed to solve the problem mentioned in the previous section.

The program system consists of three modules, according to the three stages of solution, and it was named KARIN; its name is derived from the Dutch expression for "mapping of remote sensing information", namely "KArteren van Remote sensing INformation". The program system was written for a Philips-Electrologica X1 computer, and the automatic drawing is done on a Calcomp 663 drum-plotter.

The flow of computation in the program system is shown in figure 2. For a more detailed description of the system reference is made to the literature (Kubik 1971, Bosman et al 1971).

3. NUMERICAL EXAMPLES

In the following examples the application of the program system to single images, or blocks of images, is illustrated and the obtained accuracy is quoted.

MAPPING FROM INDIVIDUAL SLAR IMAGES

Two SLAR images of regions in the Netherlands were processed with the program system. The areas were the Biesbos region and the region between the cities of Arnhem and Nijmegen. The SLAR images of these regions are at an approximate scale of 1:250000 (h = 150 m, paperprint) and 1:420000 (h = 4500 m, film) and are shown in the figures 3 and 4*. The measurements of the image coordinates were made using a Wild comparator STK-1, and the map coordinates of the reference points were obtained from 1:25000 scale topographic maps. Grids of reference points were chosen with a density of 1 / 10 km^2 (Biesbos) and 1 / 18 km^2 (Arnhem).
The accuracy of the transformation image - map was evaluated with the help of check points (points with known map coordinates, but not used as reference points during the computation). The obtained accuracy is listed in table 1. The coordinate accuracy, both in X and Y direction, is very high and is independent of the image scale. For an image scale of approximately 1:250000 and mapping at the same scale, the planimetric point accuracy σ_p of the transformed data is below 0.3 mm at map scale, which meets the specifications of the United Nations class A topographic maps at that scale.

Selected features were digitized from the image of the Arnhem - Nijmegen region, namely a part of the Maas-Waal canal, the lock system, and the railroad joining the two cities. The digitized features were plotted in the image coordinate system and are shown in figure 5.

* Images 3, 4, 9 and 10 are reproduced by kind permission of the Royal Radar Establishment (Great Malvern, England).

Figure 6 represents the same line features but now plotted in the map system after the transformation. A topographic map of the same area and at the same scale 1:200000, is included for purpose of comparison, cf. figure 7. The transformed lines of figure 6 show almost no detectable deviation from those of the map. This example illustrates the suitability of the system for small scale mapping.

THE TRANSFORMATION OF A SINGLE IRLS IMAGE

An IRLS "strip" at the nomial scale - along the flight line - of 1:27000 was used (film, flying-height (h) = 600 m). The region covered by the strip and the selected image points are shown in figure 8, the image is shown in figure 9.

The image coordinates were measured with a Zeiss mono comparator. The points used as reference points are indicated in figure 8 with the numbers: 1, 4, 8, 9, 18 and 30. All other measured points could be used as check points. The map coordinates of the reference and check points were obtained by photogrammetric triangulation of a photo-strip (wide angle scale 1:10000).

The standard deviation of the differences between the map coordinates of the check points as computed for the IRLS image and from the photogrammetric procedure are

σ_x = 0.30 mm at the scale of the IRLS image

σ_y = 0.50 mm at the scale of the IRLS image.

Although the example tested was too small to be statistically significant, it indicates the order of magnitude of the resulting coordinate errors by mapping digitized features from IRLS images. When analyzing these figures, the spatial resolution limitations of the scanner used (2 mill.rad instantaneous field of view) should be kept in mind.

THE SIMULTANEOUS TRANSFORMATION OF TWO SLAR IMAGES

Only two overlapping SLAR images were available, one at an approximate scale of 1:420000 (flying-height (h) = 12000 m, cf. figure 4) and the other to a scale of 1:300000 (h = 4500 m, cf. figure 10).

A number of image points was selected to be used either as reference and tie points or as check points. The image coordinates were measured with a Zeiss mono comparator, the map coordinates were measured with a high precision coordinatograph on a topographic map at scale 1:50000. The measuring accuracy of the instrument used was at least one order of magnitude higher than that of point identification.

The points 1, 2, 9, 30, 34, 46, 49, 52 were selected as reference points for image 1, and point 10 and 17 were selected as reference points for image 2. The points 13, 14, 34, 42 and 62 were used as tie points (see figure 7). These points were transformed into the strip coordinate system of the individual SLAR images. In the following stage the strip systems were simultaneously fitted into each other and into the map coordinate system. The mean discrepancies at the reference and tie points after these transformations are: σ_x = 0.25 mm for the X coordinate and σ_y = 0.02 mm for the Y coordinate (at the scale of the SLAR images). All other image points were then transformed. These coordinates were compared to the known "true" map coordinates, to find the accuracy of the transformation. The mean square errors of the differences (errors) were σ_x = 0.26 mm and σ_y = 0.08 mm at the scale of the image.

The relatively poor quality of the available images should be pointed out.

MAPPING FROM A BLOCK OF OVERLAPPING IRLS IMAGES

In order to assess the water flow pattern of the river Rhine into the North Sea, isothermic lines of the estuary region were mapped from a block of 7 IRLS images (scale along the flight path approximately 1:63000, h = 1500 m). The scanner used was a Singer Reconofax VI. The project area and the survey flight pattern are shown in figure 11.

A large number of reference points were used along the coastal region and all the tie points, which could be identified, were used for the transformation image - map. The image coordinates were measured on the photogrammetric instrument Wild A8, which was used as mono comparator, the map coordinates of the reference points were measured on a topographic map of scale 1:25000.

After block adjustment the grey tones were measured in a regular grid of image points on the individual images, these image points were transformed into the map system and the grey tones - with the help of reference values and using an appropriate transformation - were transformed into relative temperatures. Isolines were then interpolated in the map system, using the discrete temperature samples. A section of the resulting map is shown in figure 12. For a more detailed description of this project reference is made to the literature (Clerici et al 1972).

4. ACKNOWLEDGEMENTS

The authors would like to thank their colleagues, who have contributed to the general development of the program system, for their assistance in the system analysis, programming and data processing. In particular the work of Mr. M.Boerefijn, Mr. E.Ph.Brunet, Mr. T.Hirsch and Miss B.J.Vreugdenhil must be mentioned.

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Table 1. Results. Statistical investigation of point accuracy.

Area	Image scale	σ_r (mm at image scale) x	y	σ_c (mm at image scale) x	y	σ_p	No. of control points/ km^2	Z
Biesbos	1:250000	0.004	0.002	0.19	0.18	0.26	1/10	150
Biesbos (flat terrain)	1:250000	0.004	0.002	0.19	0.24	0.31	1/10	150
Arnhem-Nijmegen (ΔH max 70 m)	1:420000	0.016	0.004	0.19	0.11	0.22	1/18	4500

σ_r : standard deviation at the reference points, after digital rectification of the image.
σ_c : standard deviation at the check points, after digital rectification of the image.
Z : mean flying-height in meters.
ΔH max: maximum differences in height of terrain points.
σ_p : $\sqrt{\sigma_{cx}^2 - \sigma_{cy}^2}$

The table shows that the obtained point accuracy, in X and Y direction, is quite high and homogeneous, moreover it is independent of image scale and flying-height.

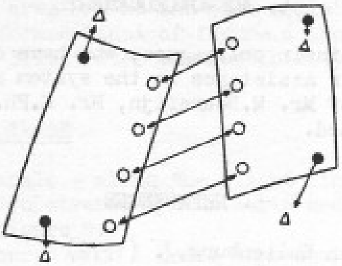

Figure 1. The fitting of strips onto each other (o) and onto control points (Δ).

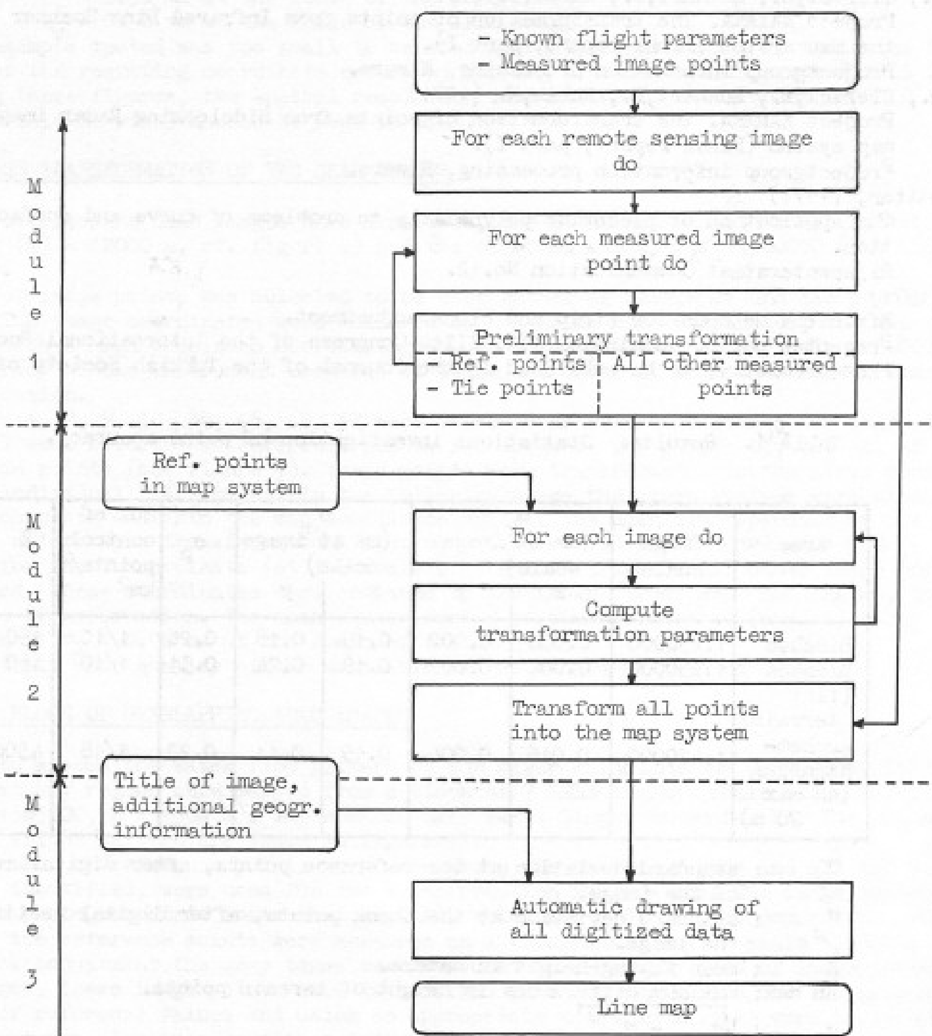

Figure 2. The flow of computation.

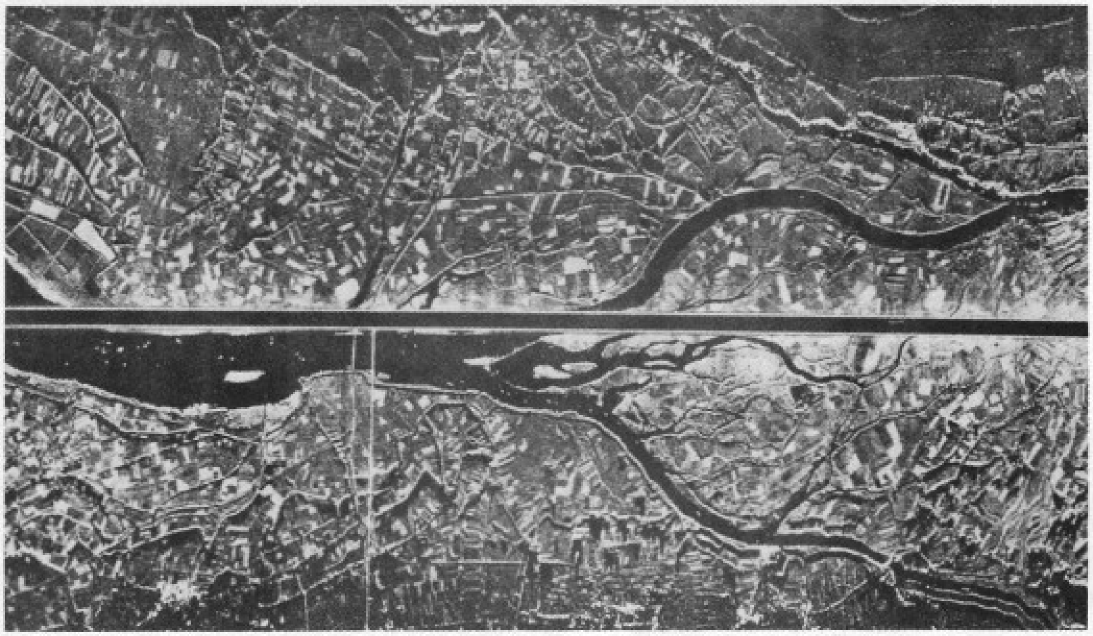

Figure 3. SLAR image region Biesbos, (original image-scale ~1:250000, paperprint).

Figure 4. SLAR image region Arnhem - Nijmegen (Scale ~1:420000, film).

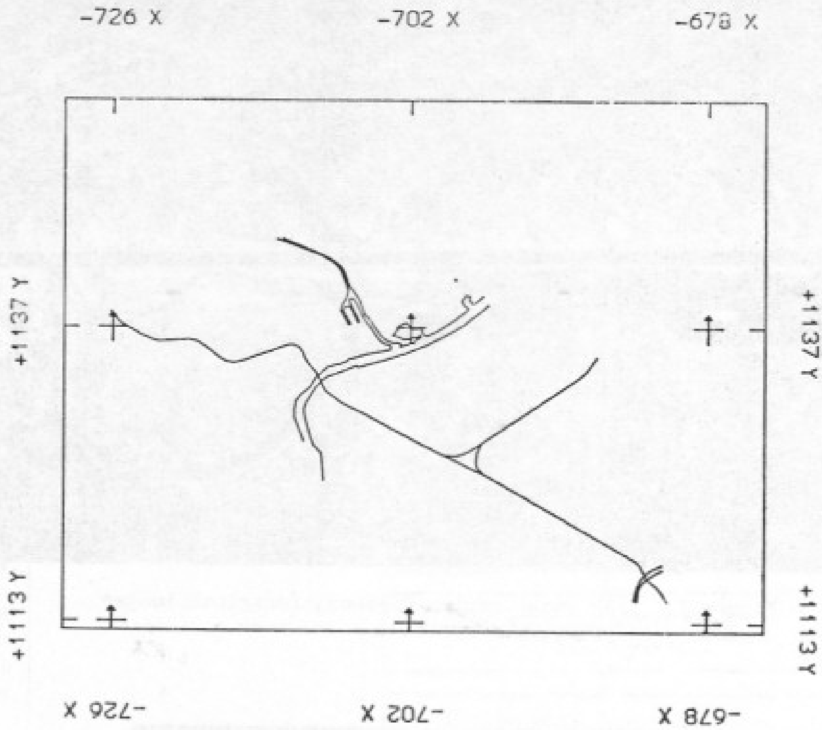

Figure 5. The digitized image data.

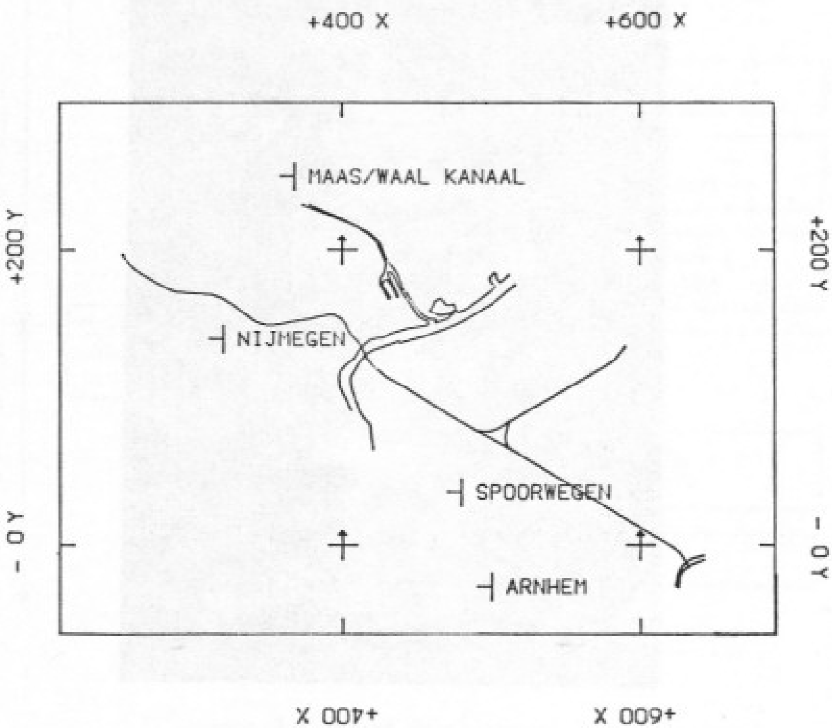

Figure 6. The resulting map.

Figure 7. Topographic map of the region Arnhem - Nijmegen, (scale 1:200000).

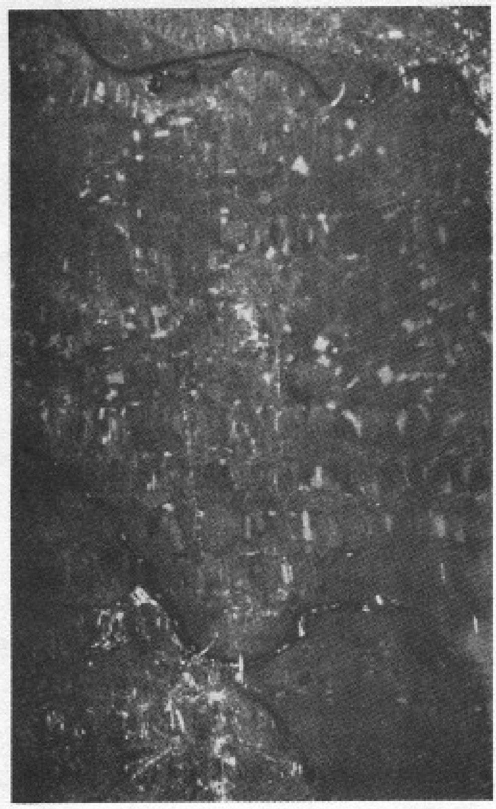

Figure 10. SLAR image region Arnhem-Nijmegen, (scale ~1:300000).

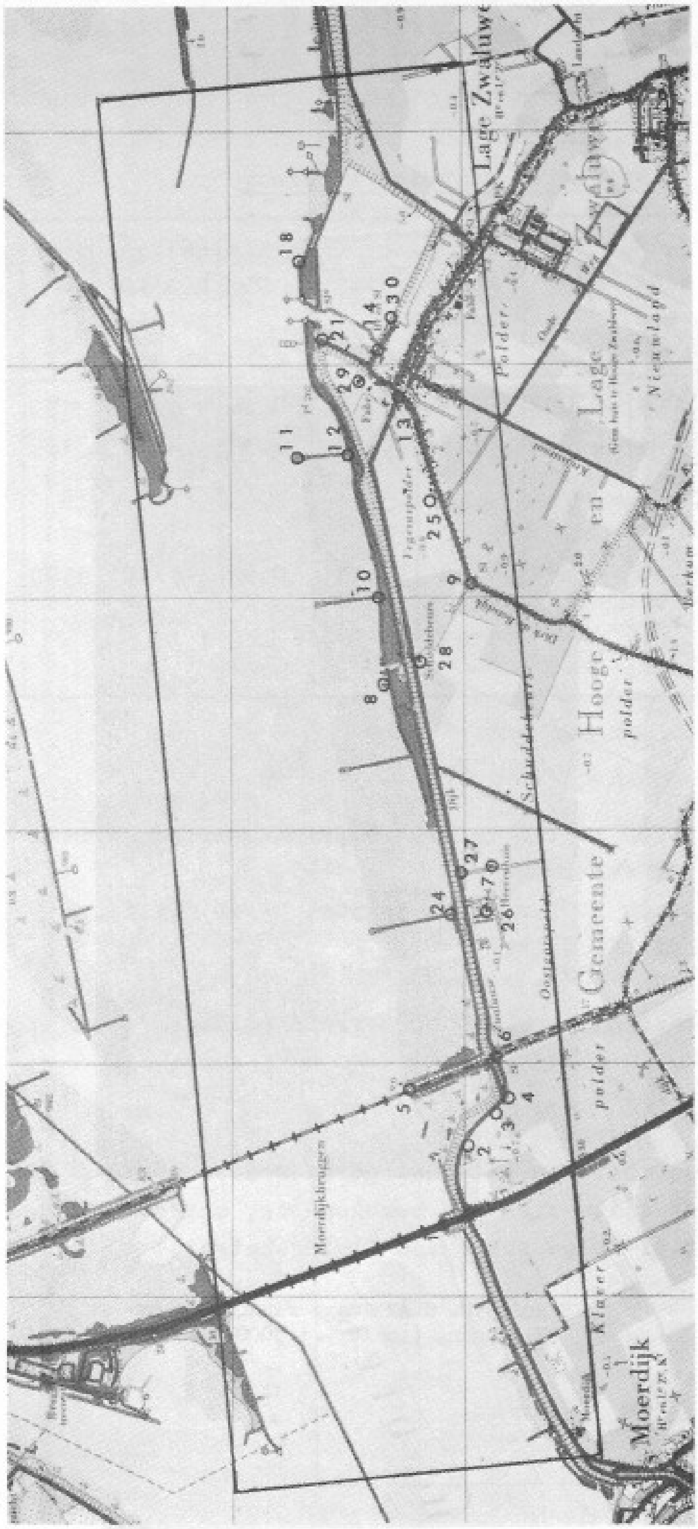

Figure 8. Coverage of IRLS image, (map scale 1:25000).

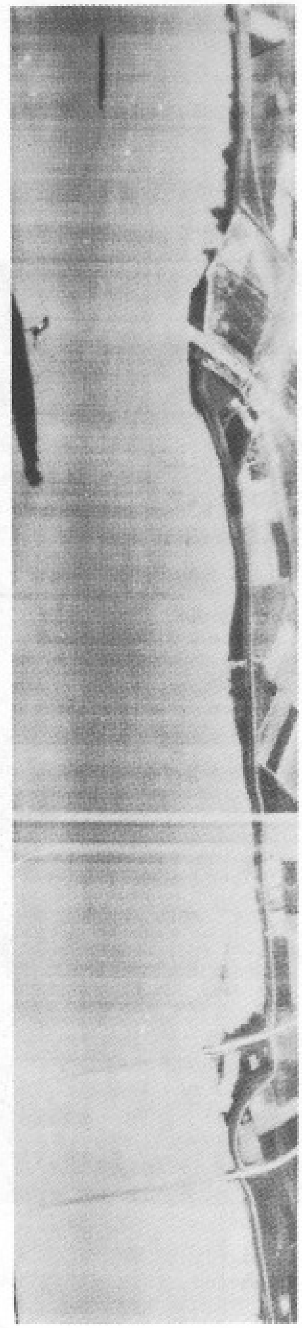

Figure 9. IRLS image, (scale ~1:27000).

Figure 11. The project area and the survey flight pattern, (map scale 1:100000).

Figure 12. Part of the project area and the resulting isothermic lines.