

10.000/100

RIJKSWATERSTAAT COMMUNICATIONS

DIGITAL LARGE SCALE RESTITUTION  
AND MAP COMPILATION

by

J. G. VAN DER KRAAN

H. RIETVELD

M. TIENSTRA

W. J. H. IJZEREERF

Survey Department of the Rijkswaterstaat

Government Publishing Office – The Hague 1980

*All correspondence should be addressed to*

RIJKSWATERSTAAT

DIRECTIE WATERHUISHOUDING EN WATERBEWEGING

P.O.B. 20907

2500 EX THE HAGUE – THE NETHERLANDS

*The views in this article are the authors' own.*

ISBN 90 12 03281 4

## Contents

### Page

5		<b>Introduction</b>
7	<b>1</b>	<b>The development of digital mapping</b>
7	1.1	How a map is produced
8	1.2	The prehistory of digital mapping
9	1.3	The beginning of digital mapping
10	1.4	The chronological development
12	1.5	The trial period 1969-1970
17	1.6	The first operational period 1970-1972
20	1.7	The study period 1972-1974
25	1.8	Implementation period 1974-1976
28	<b>2</b>	<b>Introducing the HRD-1 Laser Display</b>
28	2.1	Digital map compilation before the purchase of the HRD-1 Laser Display system
29	2.2	Digital map compilation after the purchase of the HRD-1 Laser Display system
31	2.3	Software
31	2.3.1	Coding
32	2.3.2	Preprocessing of data
37	2.3.3	Processing of data
39	2.4	Operation of the HRD-1 Laser Display
40	2.5	Making the HRD-1 Laser Display operational
43	<b>3</b>	<b>Production and experiences in 1979</b>
44	<b>4</b>	<b>Man and digital mapping</b>
44	4.1	Expectations
44	4.2	Acceptance

45	4.3	Social aspects
47	4.4	The modification of the drafting work
49	4.5	The process of adaptation
50	5	<b>A glimpse into the future</b>
53		<b>Appendix 1 The HRD-1 Laser Display/Plotter</b>
57		<b>Bibliography</b>
		<b>Appendix 2 Laser Display hard copy</b>
		<b>Appendix 3 Digitally compiled map</b>

## Introduction

The Rijkswaterstaat, which comes under the Ministry of Transport and Public Works, is a government department of mainly civil-engineering orientation. Its responsibilities include flood control, water conservation, and the building, maintenance and management of waterways and roads.

For the effective performance of its work, the Rijkswaterstaat, which has a staff of about 12,000, consists of 25 Directorates with different duties.

One of them is the Meetkundige Dienst (Survey Department) with a staff of about 500, which is charged with the geodetic support of the Rijkswaterstaat. Part of this support is the preparation of large-scale maps for various purposes.

These are mainly prepared photogrammetrically, for which purpose the Survey Department currently has at its disposal about 35 stereoplotters.

At the end of the 'sixties the Survey Department had 12 stereoplotters which were worked on a two-shift system.

This capacity was insufficient to satisfy the demand for maps. One of the possibilities for increasing the production capacity appeared to be digital mapping. A system was introduced based on digital recording direct to paper tape at the photogrammetric instrument. Its subsequent gradual development is described in this publication, up to and including the introduction of an interactive graphical system. The HRD-1 Laser Display with its 70 × 100 cm screen forms an essential part of this system. In addition to a prescription of the hardware configuration, detailed information is given about the software and operational procedures.

The fact that the introduction and use of an automated system is not exclusively a technical and financial matter may be taken as well known.

It is important to consider also the consequences for the personnel, both individually and collectively. Experiences obtained in this field are reported in a separate chapter.

The method of digital map compilation that has been devised has the following characteristics:

- information is collected at about 20 photogrammetric plotting instruments simul-

- taneously and there is one central processing system for updating, etc.;
- the operators of the photogrammetric instruments digitize 'blind', i.e. they have no displays available to them that register the progress of the digitizing;
  - each photogrammetric instrument being used digitally has its own tape punch for recording the information;
  - when digitizing, each feature is provided with a code which denotes its drafting symbol rather than its function;
  - the digital information is fed off-line to the central processing system;
  - in the design of the system, the compilation of maps was the main aim and not the creation of a topographic data bank;
  - the design is such that information from other sources can be processed, such as that obtained in the field with electronic tacheometers, or from existing maps with the aid of digitizing tables.

# 1 The development of digital mapping

## 1.1 How a map is produced

Apart from the possibility of deriving one map from another, for a very long time the only way of making a map was by measuring in the field, i.e. determining the relative positions and shapes of objects by the measurement of angles and distances. Maps can still be constructed from measurements collected in this way. In modern terminology, it could be said that field measurements are a digital representation of the terrain from which an analogue product, the drawn map, is then derived.

If only one copy of a map is required, the fair drawing is the endproduct. If several copies are needed, the map must be transferred to a printing plate. In the past this was done by engraving on copper. Later, photographic methods were developed, by means of which the fairdrawn map was transferred to a stone or metal printing plate. Now it is usual to scribe on a polyester material from which, photographically, other products can be obtained that are suitable for further reproduction.

A new development in the collection of information for map compilation became possible with the discovery, in the last century, of photography and the development, mainly in the present century, of the aeroplane. Their combination led to the appearance of aerial photography, which began to provide usable pictures in the 'twenties. The idea of making maps with the aid of photographs had been conceived even earlier. Photographs taken from sites on the ground were used as long ago as the late 1890's for supplementing maps with reliable information about inaccessible mountain areas. The use of aerial photographs for the compilation of maps was therefore a logical next step.

However, the proper tools for this new procedure still had to be developed. These were an aircraft suitable for use as the camera platform, the camera and photographic materials, and also the photographic technique.

In addition, the geometric properties of aerial photographs had to be investigated and instruments had to be constructed with which maps could be drawn from the photographs.

In the 'thirties all these developments had progressed sufficiently for the technique to be put into practice, and by the 'fifties the method was well established. A new specialization had arisen: photogrammetry.

A process had now evolved that was totally analogue, apart from the few measurements in the field and the calculations relating the photograph to the ground. The aerial photograph is always an analogue representation of the terrain and a map can be derived from it by wholly graphical methods. This manuscript is then processed further, as outlined above for the maps constructed from field measurements (see figure 1).

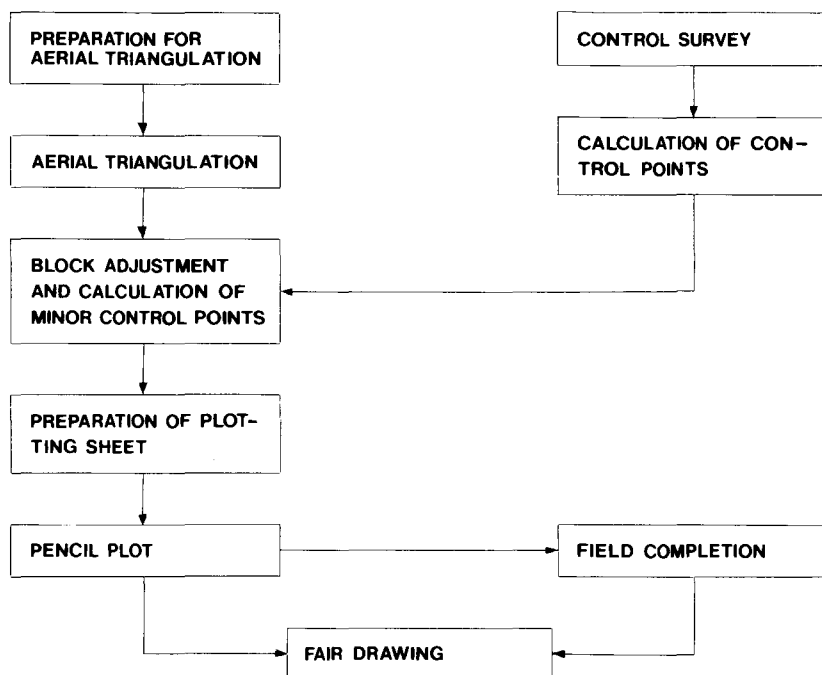


Figure 1. Procedure for conventional graphical plotting.

## 1.2 The prehistory of digital mapping

Thus, by about 1960 photogrammetry had found world-wide application, in particular for the mapping of inaccessible regions in the underdeveloped countries. It was precisely in these regions that it was most necessary to limit the amount of field work to the absolute minimum. However, reducing field work led inevitably to an increase in the amount of calculation work necessary to determine the interrelationships of the photographs. The Dutch survey profession, including the Survey Department of the Rijkswaterstaat, had already been confronted with these problems in the 'thirties when executing mapping for the Bataafsche Petroleum Maatschappij (now Shell) and later in the mapping of Dutch New Guinea. When the opportunity arose for the Survey



Department to use the Stantec ZEBRA computer at the International Training Centre for Aerial Survey (ITC), it was taken up gratefully in order to help to solve the considerable problems of photogrammetric calculation.

Another type of problem for which ZEBRA was an extremely welcome aid was the calculation of the hyperbolic lattices of radiolocation systems such as Decca and Hi-Fix, which were first used at the end of the 'fifties during engineering works along the Dutch coast. Originally, the calculations were performed on manual calculating machines and the points were then set out on the map sheets and linked by hand to form the hyperbolae. About 1960, the calculations were taken over by the computer, and later an automatic coordinatograph became available; later still, the Survey Department purchased its first simple automatic plotter, so that by about 1965 the whole process of the preparation of the so-called 'lattice sheets' had been automated.

In the meantime, simple registration units were purchased for the photogrammetric instruments, making it possible to print out automatically the coordinates of points measured in the aerial photographs. The purpose of these units was to eliminate errors of reading and writing down the coordinates. Soon afterwards they were provided with tape punches so that it became possible to record the coordinates on a computer compatible medium.

The computational procedures that were in fact developed for mapping inaccessible areas were of course found to save time and money even in the flat Dutch terrain, so that quite soon the computer ceased to be regarded as alien to the standard procedures of photogrammetry.

### **1.3 The beginning of digital mapping**

The climate had now become right for the next step to be made. Not only had the boom of the 'sixties caused doubts about the justification of existing labour-intensive procedures but the appearance of electronic aids made it possible to think of alternatives.

One unsatisfactory aspect of photogrammetric map compilation, for example, had always been that after the manuscript was prepared from the photographs it then had to be completely redrawn, since it is not easy to prepare a document of reproductive quality at the photogrammetric instruments. It is true that in the redrawing phase further information was added to the map, such as annotations, ornament and the filling in of details invisible in the photograph, but that does not alter the fact that a considerable amount of work was done twice.

In the boom period, moreover, it was very difficult to recruit sufficient and adequately

qualified personnel for the large amount of manual work involved in map compilation, and so it was obvious from the start that the remedy lay in labour-saving methods.

The concept of the originator of digital mapping, C.M.A. van den Hout, was that it had to be possible, instead of making a draft manuscript, to record all the mappable features by means of their coordinates on paper tape. From this paper tape, possibly after performing a few calculations, the drawing could be made directly in its final form with the aid of an automatic plotter. Apart from the saving of labour in drawing work, a number of other advantages were seen in this approach, such as:

- the digitized information could be stored in a databank;
- information in the databank could be used selectively according to type, position, and scale;
- measurements in the photograph could be done prior to field measurements and the calculation of minor control points;
- a preliminary map on an approximate scale could be rapidly produced;
- other information that was available in digital form could be added to the digital file;
- drawing tables would no longer need to be used at the photogrammetric instruments.

In the following chapters it will be shown to what extent the method has matched these expectations. It can be mentioned here and now that the greatest problem that arose in the whole development was to add information to the digital record, or to delete information from it.

In the beginning this was decidedly underestimated.

## **1.4 The chronological development**

### **1969-1970 TRIAL PERIOD**

Initially maps had to be drawn without annotations or conventional signs and with a single photogrammetric model as the largest unit. Towards the end of the trial period annotations and conventional signs could be generated and several models could be combined to form map sheets.

**EQUIPMENT:** Slow recording devices (Wild EK5) connected to the photogrammetric instruments, Stantec Zebra computer with CalComp 563 drum plotter and Electrologica X1 computer with CalComp 663 drum plotter.

### **AUGUST 1970**

Decision by the Director of the Survey Department to develop the digital mapping process into a production method.

### **1970-1972 FIRST OPERATIONAL PERIOD**

The procedure developed during the trial period was put into practice. Rapid recording

devices (Wild EK8) were purchased for four photogrammetric instruments. Many problems were encountered when drawing on stable-base materials on the CalComp 663 drum plotter. Therefore after a thorough investigation, a CalComp 745 flatbed plotter was purchased (see figure 2).



Figure 2. CalComp 745 flatbed plotter.

#### 1972-1974 STUDY PERIOD

During these years, intermittent studies were made of the steps to be attempted in the future. Two questions were central here: should the digital mapping procedure become the primary method of production for the Survey Department, and what software and equipment would be necessary in order to bring information from various sources together in manageable form. To the first question the answer 'yes, but gradually' was given. As to the second question, the conclusion was that the best choice would be the HRD-1 Laser Display instrument of the British firm Laser Scan Laboratories. Software should be developed to own specifications. Production continued as in the first operational period.

#### **1974-1976 IMPLEMENTATION PERIOD**

More recording devices (of various makes) were purchased for the photogrammetric instruments, so that production could gradually be increased, but no substantial changes were yet made in the procedures.

Specifications for the software were further developed and programs were written for the Laser Display.

#### **1976-1979 SECOND OPERATIONAL PERIOD**

The HRD-1 Laser Display was brought into use and the procedures suitably adapted. This brought the development of digital map compilation into a more or less definitive phase.

### **1.5 The trial period 1969-1970**

The belief that photogrammetric mapping via a digital file might have advantages over the usual direct graphical procedure stemmed largely from acquaintance with the hardware. It was expected that the use of this hardware would make possible a reduction in the number of man-hours per unit of production. Furthermore an improvement in the flexibility of the mapping was anticipated. In the event, however, it proved necessary to develop from scratch both the procedures by which the photogrammetrist builds up the digital file and the software by which the map is derived from it.

In any map, the following graphical elements are present :

- lines, straight or curved;
- point symbols, with or without a prescribed orientation;
- symbols made up into lines;
- characters and words placed in a prescribed manner.

The Survey Department does not produce multi-colour maps and so the problem of colour separation does not arise.

In the first instance, the graphical elements were limited to straight lines and symbols in the form of regular polygons. The use of only straight lines was reasonably successful, it being quite possible to approximate a curve by a sequence of short straights. This procedure actually remained in use for several years, and in this connection it must be borne in mind that in large-scale technical maps such as the Survey Department produces, many of the lines are in fact straight. The symbols in the form of regular polygons were not so successful. It was found that only the triangle and the rectangle were readily distinguishable. The use of a larger number of sides resulted in more or less close approximations to a circle. The program was therefore changed to use standard Rijkswaterstaat symbols, coded as drafting subroutines.

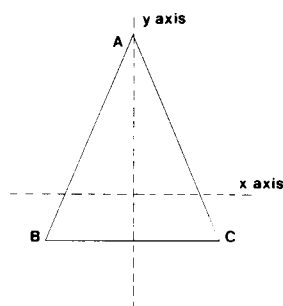
The technique for these subroutines is very simple: each symbol is defined in a local coordinate system and the movements that the pen has to perform in drawing the symbol are given step by step.

When digitizing, it is now necessary only that the code number of the desired symbol should be given together with the coordinates of the position where it is to be drawn.

The approach outlined here proved to be outstandingly satisfactory in practice.

The process is simple to handle for the person doing the digitizing and the arrangement is so flexible that symbols can be added very simple or the whole legend can be redesigned for another type of map.

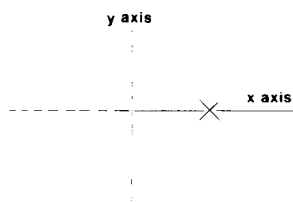
As well as point symbols which have a fixed orientation, there are those whose orientation must be specified by the operator. In these cases, the alignment is indicated by registering a second point appropriately displaced from the first.



symbol 1001; triangle

subroutine instruction	X	Y	comment
1001	0	0	(centre of gravity)
1	0	18	(go to A, pen up)
0	-7	-4	(go to B, pen down)
0	7	-4	(go to C, pen down)
0	0	18	(go to A, pen down)

The centre of gravity of the triangle will coincide with the registered coordinate. All coordinates are in millimetres.



symbol 2002; fence

subroutine instruction	X	Y	comment
2002	0	0	(reference point, indicating beginning of symbol)
0	110	0	(ref. point, indicating end of symbol)
1	0	0	(go to first ref. point pen up)
0	13	0	plot instructions as in first example, going from point to point, either with pen up or pen down.
1	14	1	
0	16	-1	
1	14	-1	
0	16	1	
1	17	0	
0	110	0	All coordinates are in millimetres

Figure 3. Subroutines for symbols.



The difficulties of drawing characters were less pronounced than those of plotting symbols. With the CalComp drum plotter there is available a standard CalComp character set, so that no subroutines had to be prepared for the characters themselves. Naturally, it was necessary to develop a procedure by means of which the characters, when assembled into words, could be drawn in the correct place. Just as with symbols, two situations arise in the case of text: some must always be written with the same orientation in relation to the side of the map, and some take their alignment from elements within the map. Another way of grouping is achieved by division into standard annotations, such as may be included in the legend, and non-standard ones such as place names and descriptions.

The standard annotations that are written in a fixed direction (parallel to the lower side of the map sheet) are on the whole treated in the same manner as point symbols: they are included in the standard legend, they are called up by means of a code number, and their position is defined by the coordinates of the centre of gravity of the text. Place names and the like which have to be written in a direction dependent on map detail (such as the name of a street parallel to the edge of the street) are treated differently. The operator has available a number of 'free' code numbers. If such an annotation is needed, one of these free code numbers is assigned and the position of the centre of gravity of the text is digitized. After this, the alignment is defined by digitizing two points on a line to which the annotation must be parallel. The 'translation' of the code number into the desired text takes place with the aid of a variable legend which must be compiled for each project.

The procedure for controlling the raising and lowering of the pen when drawing lines also dates from the initial period. The convention has been established that the last point of a line is recorded twice; in other words, the distance between the last two recorded points of a line is zero, and this information is interpreted by the plotter program as the command 'pen up'.

It is true that this simple arrangement involves extra recordings but, on the other hand, it limits the number of times that the code has to be entered.

In the digitizing of aerial photographs at stereoplotters account must also be taken of the fact that the photogrammetric mapping process has a number of peculiarities that affect its automation.

- Aerial photographs do not carry all the information that has to be included in the map. Naturally, they do not include place names, but, in addition, some features may be so small that they are invisible in the photograph.

Furthermore, some features may be invisible because they are masked by others. Conversely, not all the information carried in the photograph will be relevant to the mapping in hand.

The field situation may also have changed since the photographs were taken.

Consequently, it must be possible to add information to the digital file and to remove information from it during the digitizing/mapping process.

- The photogrammetrist has only a small field of view in his instrument. He sees a three-dimensional picture of the terrain, but the possibility of 'looking ahead' is very limited. Furthermore, during the digitizing process the photogrammetrist needs to interpret (what is this?), to select (should this be included in the map?) and to generalize (how must this appear on the map?), and to do all this at a scale different from that of the final map.
- The photograph itself cannot be marked to indicate what has already been digitized. It is of course quite possible to keep a separate record, but comparing would require the operator to be continually looking back and forth.
- Usually, a map sheet will contain information from several stereomodels. Visible discrepancies must be expected in the joining of lines that have been derived partly from one model and partly from the next. The correction of these errors provides another reason why it must be possible to amend the digital record.

The human problem of whether the photogrammetrist could in fact produce digital records that would be sufficiently complete and accurate has proved to be almost non-existent, much to everyone's astonishment.

Initially, the progress of digitizing was recorded by making a drawing on the plotting table of the photogrammetric instrument, which at the time was still attached. It was soon found, however, that the photogrammetrist hardly ever looked at this control plot. Admittedly, the geometry of the line work could be shown in this way, but it left no evidence as to whether the correct codes had been used, and point features were marked only by a dot (frequently difficult to find again).

Although in later years more advanced possibilities were considered, such as systems with display screens, it has become the practice that the photogrammetrist simply scans the stereomodel systematically from memory.

The number of omissions that occur with this mode of working is negligible.

Two computer programs were written for processing the digital information that became available on the paper tape. The first was a program which performed a syntax check on the data and the second was the true drafting program, by means of which the first map sheets were drawn at the beginning of 1970.

On the basis of the experience accumulated up to that time, it was decided in the middle of 1970 to adapt the digital method of mapping to productive use.



## 1.6 The first operational period 1970-1972

Although the digital method of mapping was still far from perfect, it was decided that any further development would be carried out concurrently with production. Four photogrammetric instruments were equipped with Wild EK 8 fast recording units. Paper tape was retained as the output medium. However, this was not quite a free decision. At that time the possibilities were limited in practice to paper tape, punched cards, and magnetic tape. On-line connection with a computer would in principle have been possible, but the technique had not then been fully developed. Tape cassettes were not yet reliable. Of the practical possibilities, punched cards were rejected as being too slow.

Long deliberations were held over the choice between paper tape and magnetic tape. Magnetic tape was finally rejected because of the relatively high capital investment it required (a magnetic tape unit would have had to be purchased for the computer as well). Furthermore, there was already considerable experience of working with paper tape, which was certainly an advantage.

The question of remaining with or abandoning paper tape was discussed repeatedly in later years. Essentially, the reasons for not changing have been the adequate reliability of the paper tape equipment and the fact that off-line working limits the consequences of breakdowns.

During this operational period, of course, development did not come to a stop. Program enhancements were related to expansion of the legend, improving the appearance of the symbols, simplification of the digitizing procedure, and so on. An important lesson was that it was found to be inadvisable to attempt to draw a whole map sheet at one time. Breakdowns of computer and drafting equipment and errors in the paper tapes that could be recognized only on the drawn map made it necessary to divide the process into shorter steps.

The types of error referred to here are those which cannot be detected by the computer, such as use of an incorrect but valid code number, the forgetting of the 'pen-up' command, and bad positioning of text.

Therefore initially a check plot was made of each sheet. It was soon found that because of computer malfunctions the drawing had to be repeatedly abandoned and re-started, so that many hours of drawing and computer time were lost. For these reasons a change was made to check-plotting individual models, the units that the photogrammetrist digitizes.

After checking and, if necessary, editing, the model dataset tapes were collected together and map sheets were drawn. This did not work satisfactory either, so that finally the following procedure was worked out and has remained in use for several years:

- digitize the stereomodels;
- make a syntax check of each model dataset;

- edit the paper tapes;
- prepare a check plot of each model;
- edit the paper tapes;
- make a syntax check on all the datasets related to the map sheet;
- edit the paper tapes;
- draw the map sheet;
- correct the drawing manually.

Much trouble had been experienced in the editing of the paper tapes, which was done mainly on a teletype. The use of a display screen for this purpose was considered but the idea was not adopted, partly because of the fluid state of the art at the time.

The situation was now, therefore, that corrections could be made only with great difficulty. Editing was thus limited to the absolute minimum, and only the really bad errors were corrected. It was virtually impossible to alter the digital record afterwards.

In conventional graphical mapping, information missing from the photogrammetric manuscript is added from field observations. This missing information is comprised mainly of place and road names, the identities of buildings, details invisible in the photograph (too small or masked by other objects), and changes in the terrain subsequent to photography (which can involve both additions and deletions).

For digital mapping, the practice was introduced of taking the photographs into the field, before mapping, and marking on them as much of the above-mentioned information as possible. Gathering non-metric information such as place-names is an easy task, while noting the changes in the terrain stops the photogrammetrist from digitizing details that have been disappeared in the interim.

In this way, an attempt was made to create digital records that were as complete as possible and free from unwanted information. However, it was (and is) impossible to prepare a map entirely without 'field completion', so there remained a need to edit either the digital record or the drawn map. For the time being, the second was chosen because of the impracticality of the first alternative.

The digitizing of information by classical field survey techniques was considered impractical because the process is very labour intensive. It was therefore necessary, after the map sheets had been plotted on the drafting machine, for a draftsman to make amendments by hand. This made an error-free digital record impossible.

(It was not until later, when the recording tacheometer appeared on the market, that the possibility was opened up of recording digitally in the field as well as in the office).

As to the registration equipment, this did not permit 'on the fly' recording in a time- or distance-dependent mode. The registration of each point required a separate command. In time, a virtue was made of this necessity. Point-by-point recording has several advantages for the operator:

- there need be no worry that a registration will be made at an inconvenient moment – for example when the reference mark is not positioned on the line being digitized;
- the spacing of the points can be locally adjusted according to the nature of the line being digitized.

In brief, the photogrammetrist need not be afraid that he will be controlled by the system. Moreover, for computer processing this state of affairs has the advantage that no data compaction need take place. Although in later years registration equipment was purchased with which it is in fact possible to record 'on the fly', little use is made of this facility.

Another more serious limitation that became evident during this period was caused by the drafting machine. In comparison with the manual drawings to which the Survey Department and its clients were accustomed, the quality of the CalComp 663 drawings was totally unsatisfactory because of the step size, the limited choice of pen and ink combinations and, especially, the restricted range of drawing materials that could be used.

The computer facilities of the Rijkswaterstaat were appreciably expanded in 1971 when the Data Processing Division was set up and equipped with a Philips P1400 computer. The Survey Department conducted an investigation into the various flat-bed plotters then available and with which scribing could be carried out. After an extensive comparative study, the choice fell on the CalComp 745 plotter.

The most important points for comparison were accuracy, speed of drawing, maintenance, and price. The choice was not influenced by software availability because at that time it was inadequate in every single case.

What did play a part was the fact that the CalComp 745 could be equipped with an optical writing system for drawings of very high quality. This system however was never bought.

The CalComp 745 plotter was installed in the spring of 1973.

In 1972, an internal report was drawn up concerning the digital method of mapping. The most important findings, recommendations, and conclusions of that report have been outlined above.

The general conclusion was that the method, although still by no means perfect, had lived up to expectations in all the most important areas and should therefore be developed further. At the beginning of 1973 a number of digitally produced maps and comparable ones that had been prepared graphically were analysed.

The following is an extract from the analysis:

	digital	graphical
Number of sheets	145	149
Hectares	3250	3184
Hectares per sheet (average)	22	22
Man-hours field survey	8662	13850
Man-hours preparation and computing	1608	1707
Man-hours photogrammetric restitution	5503	5243
Man-hours fair drawing, etc.	5618	11205
Man-hours computer and drawing machine	435	—
Total number of man hours	21826	32005

From this comparison, a few conclusions were drawn:

Digital plotting did not save time in photogrammetric restitution; the hours necessary for fair drawing however were reduced by practically 50 % by the digital method. It should be remarked that with the digital method the results of the field completion were processed manually and that the quality of the maps drawn with the drum plotter was such that quite some 'touching up' was required.

A considerable number of hours was saved in the field. It was not quite clear to which cause this might be attributed. It is possible that the shorter turn-over time of the digital method gives the terrain less time to alter.

No really satisfactory explanation has ever been found for this phenomenon.

Since much more equipment was (and is) necessary for the digital method than the graphical, the difference in costs was appreciably smaller than the difference in man-hours. However, the digital method had not then acquired its definitive form, and so the costing figures will not be quoted here. Indeed, all the figures must be treated with great reserve. It is dangerous to assume that every difference can be ascribed to the digital method. There may have been other influences at work as well.

### 1.7 The study period 1972-1974

The conclusion from the internal report mentioned above was that the procedure needed to be improved further. The acquisition of the CalComp 745 plotter changed little in the procedure as such, although a very important consequence was that the aesthetic quality of the end-product improved considerably. In the event it proved impossible to avoid extensive programming work. The magnetic tape needed to control the CalComp 745 had to be prepared on the Philips P1400 of the Data Processing Division, for which purpose the information on the model dataset paper tapes had first to be transferred to this machine via a terminal.

Since the terminal at the Survey Department could not be equipped with a magnetic tape unit, the tapes produced by the P1400 had to be brought by car from the Data Processing Division at The Hague.

The various pre-processing checks and the preparation of model checkplots were still done on the Electrologica X1/CalComp 663 installation. Special attention was needed in the case of the X1. The machine dated from 1960 and the manufacturer's maintenance and spares service had been discontinued early in 1972.

In order to safeguard map production, therefore, it was necessary to find some kind of replacement for the X1. Furthermore, it was necessary to consider whether the digital method should be employed as widely as possible in the Survey Department map production or whether its use should be deliberately limited.

For the system to be acceptable, it was necessary to find a solution for the difficulties entailed in editing digital records.

To answer the question of the extent of application of the digital mapping method it is necessary to have a rough idea of the numbers and types of maps produced.

About 60 % of the productive time of the photogrammetric instruments is devoted to line mapping of roads and other civil-engineering works on a scale of 1:1000. These maps have no contours and they are produced in monochrome (see Appendix 3).

About 20 % of the time is devoted to other types of maps, mainly river and coastal maps at scales of 1:2000 to 1:5000, which do include height information and also a great deal of hydrographical data that cannot be deduced from aerial photographs. The remaining 20 % is employed on non-graphic applications (aerial triangulation, measurement of profiles, digital terrain models, etc.).

It was decided to work towards a completely digital production of the large category of road maps, etc.

The capacity calculations were based on an annual production of some 1000 map sheets comprising about 3000 photogrammetric models. In order to be able to edit the digital record of a graphic, it is necessary that the graphic be displayed so that the errors can be pointed out and the amendments specified. Systems developed for this purpose are therefore known as interactive graphic systems and consist in principle of a display device and a digitizer unit controlled by a computer. For such a system to function well, the interaction must be rapid.

The speed of the system directly affects mapping capacity. When the transition is made to maximum use of the digital method, the number of models to be processed will amount to about 3000 a year.

A year comprises about 250 working days. For breakdown and maintenance of equipment, one must reckon with a loss of about 20 days. The capacity then amounts to a maximum of about 230 productive instrument-days. This means that the checking and editing system has to be able to process  $3000/230$  i.e. approximately 13 models a day. However, each model has to pass through the system twice: the first time shortly after the completion of digitizing at the photogrammetric instrument and the second

time on completion of the additional field work and the assembling of the models into map sheets. The figure 13 should therefore be doubled to 26. Since checking and editing must take place interactively, only normal office hours are available for this purpose.

This means that with a single system the process of displaying, checking, and editing could last about 15-20 min. In practice, of course, peaks might happen and delays would occur but, on the other hand, maximum production would not be achieved immediately.

Nevertheless, it was felt that an effort should be made to find a system giving rapid response and making rapid processing possible. In fact, it is desirable that checking of models should take place as soon as possible after data capture, since everything is then still fresh in the observer's memory.

It was also considered whether to have the first check made by the photogrammetrist with the aid of an interactive display at the photogrammetric instrument. However, this was rejected, mainly because of the high cost. In fact, advanced plans were already in existence for increasing the number of instruments to some 30 or 35. In order to realize the envisaged digital production of maps, the majority of these instruments would have to be provided with recording equipment. At the prices prevailing at that time, the purchase of about 25 graphic display screens would have required an additional investment of about Hfl. 1,000,000, while the possibilities of such 'basic' systems were still fairly limited. This added to the good experience with blind digitizing created the situation that the choice fell on the simplest recording equipment with the photogrammetric instruments (of which a large number was necessary), so that room was left to invest in a somewhat more expensive control system of which, at least to begin with, only one was required.

It was contemplated again whether there was any reason to abandon recording on paper tape. Actually it would appear that it was more attractive to couple several instruments to a recording computer. The advantage of such an arrangement would be that the always noisy tape punches could be abandoned and that a number of computational checks and processes could be carried out, if necessary with the possibility of reporting errors to the photogrammetrist, so that the correction system would be relieved.

The disadvantages were that only a limited number (8 to 10) of instruments could be coupled to such a central recording system and that in the event of breakdowns a fairly large number of instruments would be put out of production simultaneously.

In addition, it was feared that the software that would be necessary for a central recording system would not be so easy to obtain, and would also again be a source of breakdowns and therefore of delays.

From the point of view of operational safety, in particular, it was therefore decided not

to go for a central recording system but to continue to record on paper tape at each instrument. Furthermore tape punches were cheaper than any other output device.

The most important requirements of an interactive checking and correcting system were as follows:

- graphic representation of digitized information must be possible to a resolution sufficient for cartographic purposes;
- it must be possible to delete, to move, or to add lines, symbols, and text and to process these amendments in the digital file;
- it must be possible to make a hard copy of the displayed picture;
- the speed of the system must be such that the planned production can be achieved;
- the display screen will have to be large enough for a model, or even better, a map sheet, to be displayed completely without loss of information.

In the period of the investigation suppliers began to bring complete systems onto the market. The systems were built around a controlling computer, usually a PDP 11/45, and included a graphic display tube, usually a Tektronix 4014.

Together with these there were of course, input and output devices such as tape readers and punches, operating keyboards, and backing store (magnetic tape, magnetic disc). In most cases, digitizing tables and a drawing machine were also included in the system. However, a great lack of software became apparent, only a single supplier could offer more than the necessary minimum.

In the instrumental respect, the most important limitation was the resolution of the display. The Tektronix 4014 has a  $38 \times 28$  cm screen with 4096 addressable points per axis. A representative photogrammetric model is  $20 \times 30$  cm and is measured in units of 0,01 mm. The number of addressable points is therefore  $20,000 \times 30,000$ . Although the accuracy of photogrammetric measurement is naturally smaller than the metric resolution, it will be clear that if its quality is to be judged, a model must be presented on the display screen of the Tektronix 4014 in sections.

For a map sheet composed of several models, this procedure is plainly very cumbersome.

Great interest then arose within the Survey Department in a new instrument that appeared on the market in 1973: the HRD-1 Laser Display of the British firm Laser Scan Laboratories, which has a  $70 \times 100$  cm screen with  $35,000 \times 50,000$  addressable points (see figure 5). It was of course necessary to investigate whether this instrument would also satisfy the demands set on its other functions.

This investigation was carried out during 1974. The conclusions were as follows:

- the drawing speed of the Laser Display is more than sufficient;

- the quality of the hard copy, a  $10 \times 14$  cm diazo film, is adequate but a difficulty is that the film has to be enlarged;
- interaction is possible to a sufficient degree and with adequate speed;
- practically no application software is yet available for the equipment;
- the price of Hfl. 800,000 is about Hfl. 250,000 higher than that of a system with a Tektronix 4014 display screen (including taxes, but without software).

After careful consideration, it was decided that the advantages of the Laser Display were worth the higher costs.

(A description of the Laser Display can be found in Appendix I).

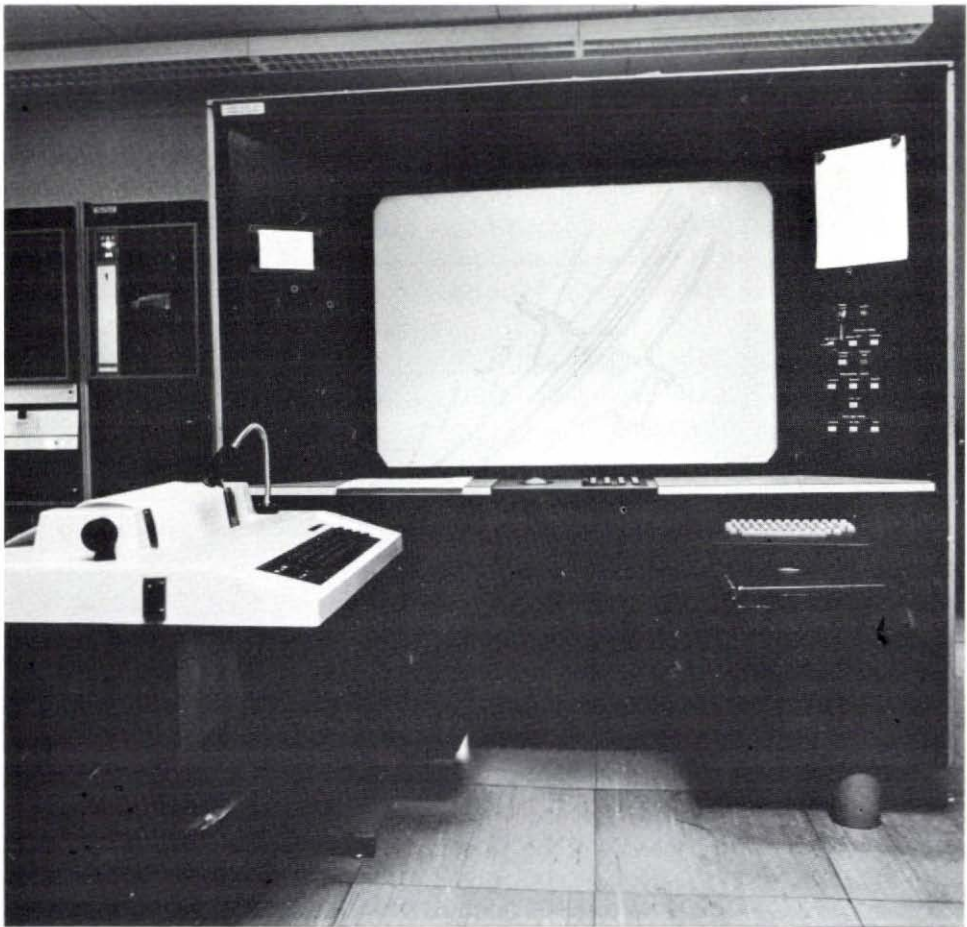


Figure 5. Laser Display



It was also considered whether the Laser Display could be controlled by the P1400 computer of the Data Processing Division of the Rijkswaterstaat, but this was found to be so complicated from the technical point of view that it offered no real solution, so that for the control computer a DEC PDP 11/45 was selected, which fitted the Rijkswaterstaat's requirements for standardization.

In order to prevent later difficulties with maintenance, the complete configuration was ordered from Laser Scan Laboratories:

- an HRD 1 Laser Display,
- a DEC PDP 11/45 minicomputer with 48 K-word memory,
- a LA36 DEC writer,
- a Facit 4070 tape puncher,
- a Trend tape reader,
- two Pertec magnetic tape units,
- a System Industries dual disc system (5 M-byte interchangeable and 5 M byte fixed).

Even before it was possible to put the Laser Display into use, it had been decided to expand the configuration by an additional input possibility, namely a Hewlett Packard 9825S desk calculator connected to the PDP 11/45 by means of a DR-11 C interface. The reasons for this expansion and the use that is being made of it will be discussed in chapter 2.2.

## **1.8 Implementation period 1974-1976**

In the preceding period a number of decisions were taken about digital mapping, the realization of which would require some time.

Although a technical choice was made for the equipment, the agreement to invest in the equipment still had to be obtained from the financial authorities concerned.

More or less simultaneously with the already described decisions about digital mapping, the decision was reached to change in photogrammetric mapping from a two-shift system to a single shift. To maintain the same production capacity, it was therefore necessary to double the number of photogrammetric instruments (from 16 to 32).

In the course of 1975 the Survey Department received the approval for the purchase of the Laser Display system described above together with 14 photogrammetric instruments, all with recording equipment. These purchases, which were distributed over

1975 and 1976, came to about Hfl. 3,000,000 including the necessary reconstruction of the computer room to accommodate the Laser Display.

In addition, during these years the specification for the software was drawn up and a beginning was made with system analysis and programming. Part of the software development was carried out – and very well too – by Laser Scan Laboratories. Since the part selected for this purpose would probably also be useful to other clients, Laser Scan Laboratories contributed to the development costs. The part of the software that was specific to the Rijkswaterstaat was written by the Survey Department and the Data Processing Division.

Until then any available photogrammetric instrument had been used for digital

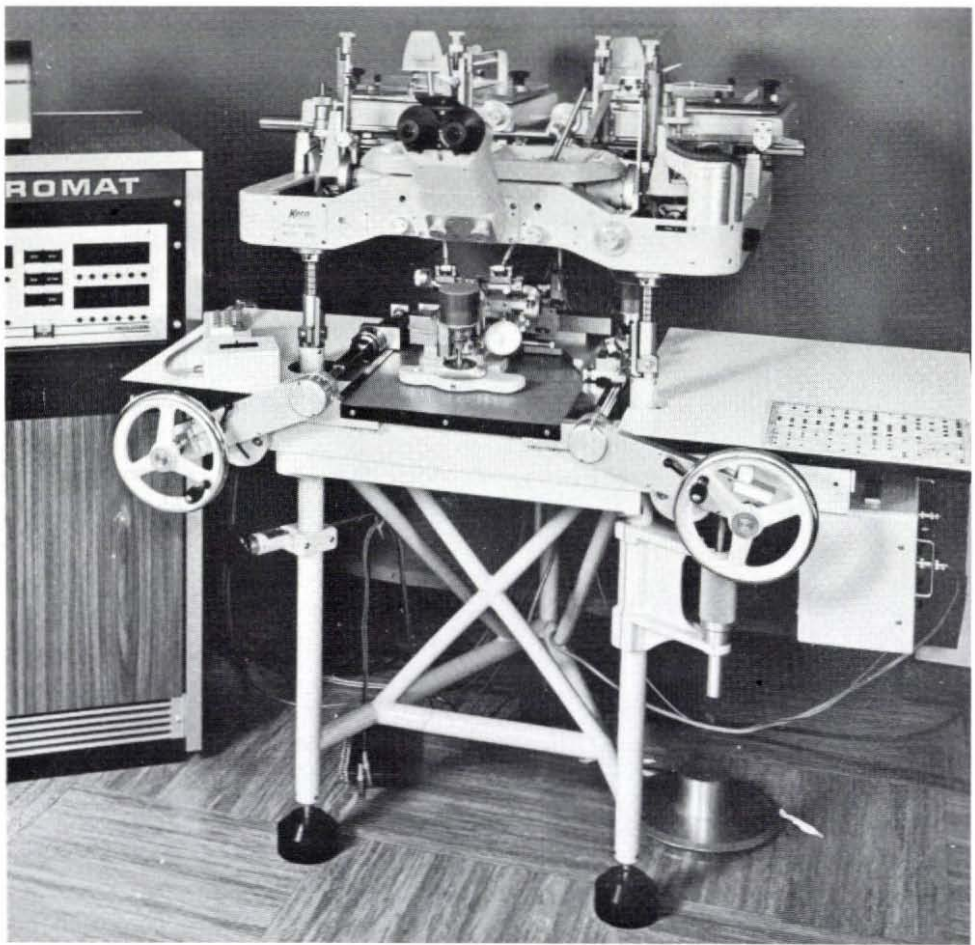


Figure 6. Kern PG2.

restitution. However as the enlargement from model to map was no longer done mechanically but digitally, there was reason to expect that topographic plotters, rather than precision plotters could very well be used for digital restitution. This was found to be true as far as the precision of restitution was concerned. However, it was found that the free-hand motion that most topographic plotters possess, made a rapid following of detail to be digitized extremely difficult. Also it was difficult to keep the floating mark on a point when changing the code-number. Eventually this led to the request for the construction of handwheeldrives for the instruments Kern PG2 and Galileo G6. (See fig. 6 and 7.) These adaptations of the instruments by the respective manufacturers completely fulfilled the expectations.

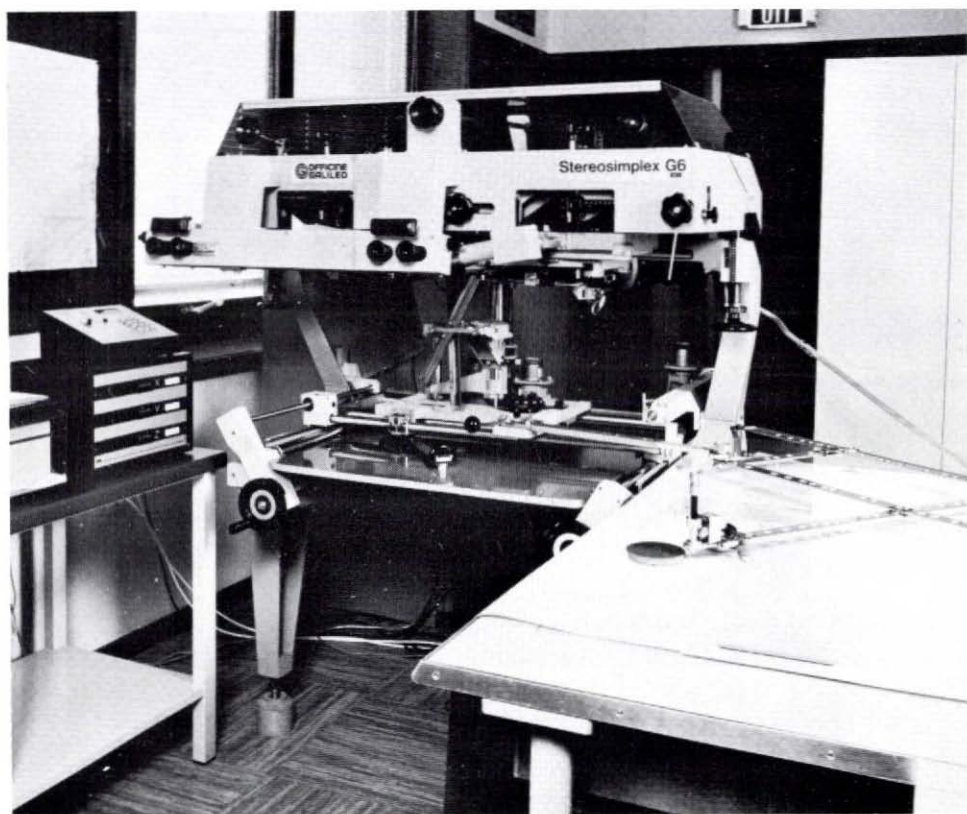
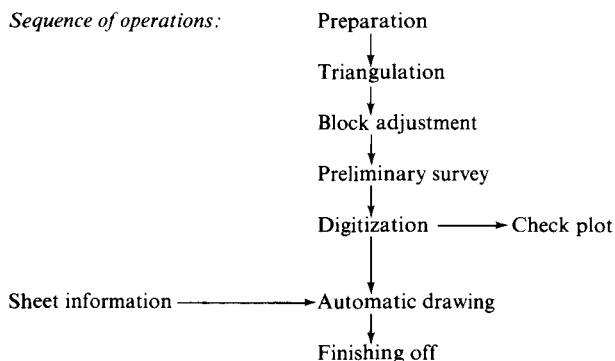


Figure 7. Galileo G6.

## 2 Introducing the HRD-1 Laser Display

### 2.1 Digital map compilation before the purchase of the HRD-1 Laser Display system

In 1975, the development described in the preceding paragraphs had resulted in the following procedure:



#### PRELIMINARY SURVEY

It was found from trials in 1972 that a preliminary survey could almost entirely replace post-plotting field completion provided that the date of the photography is adopted as the date of the map.

During the preliminary survey, which must be carried out as soon as possible after the flight, details difficult for the photogrammetrist to identify are given on enlarged photographs by the field surveyor.

Items that for one reason or another cannot be digitized from the photograph are measured and are included on the map in the processing phase.

#### DIGITIZATION

The photogrammetrist digitizes by means of paper tape recording units that output the map information in model coordinates with a numerical code.

During the digitization he has no check on completeness, and therefore the X1-Electrologica computer system with the CalComp 663 drum plotter coupled to it was used for the production of a check plot immediately after digitization (see figure 8).

Likewise, a syntax check on the coding used was carried out with the X1-software.

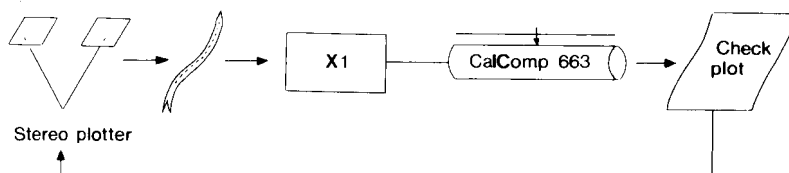


Figure 8. Digitizing phase.

Any errors had to be corrected manually in the paper tape.

If the digitized model was complete and free from syntax errors, the punched tape could be processed further (see figure 9).

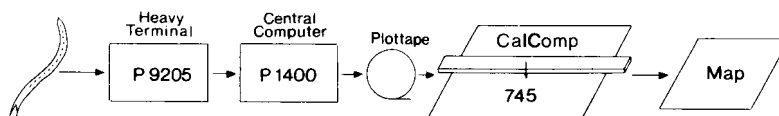


Figure 9. Processing phase.

The paper tapes were read into the central Rijkswaterstaat computer via the terminal. The models were then first transformed into the terrestrial coordinate system and then combined into map sheets.

After this, with the plotting program a magnetic tape was prepared with plotting instructions for the CalComp 745 flat-bed plotter.

## 2.2 Digital map compilation after the purchase of the HRD-1 Laser Display system

### HARDWARE CONFIGURATION

In the development of the system, the following tasks were assigned to the HRD-1 Laser Display system still to be purchased:

- Rapid preparation of check plots;
- Editing of map sheets;
- Plotting of definitive maps (on diazo film);
- Supplying a record that, via the central computer, possibly combined with additional information there present, can be processed into a plot-tape for the CalComp 745.

For this purpose the hardware shown in figure 10 was purchased.

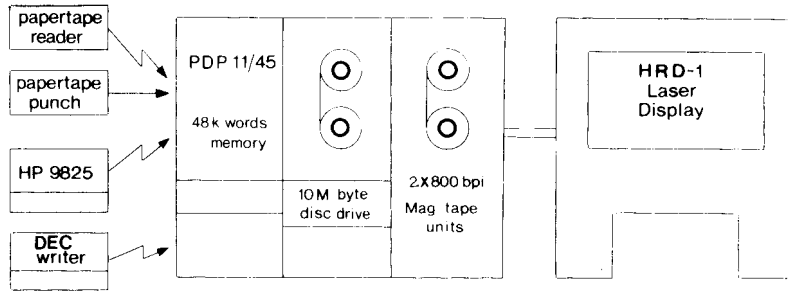


Figure 10. Hardware.

One of the greatest problems with the old system was that because of the limited hardware and software support of the X1 system the paper tapes had to be free from syntax errors before a drawing could be made.

Since the interactive system had to be able to process the information from about 20 stereoplotters, it was still necessary to work with information free from syntax errors.

Because of the great flow of production that the system was to process, the editing work had to be performed as economically as possible. Consequently, a pre-process phase was included in the procedure, which was performed by the photogrammetrist himself with special equipment.

Partly for the purpose of the simple operation of desk calculator systems, a system based on the Hewlett Packard HP9825S was chosen after a market investigation.

To prevent the stagnation of production in the collection of information, it was also necessary that in the event of breakdowns in the Laser Display configuration a reserve facility should be available for the preparation of check plots. For this purpose, by means of an interface the CalComp 663 drum plotter already available was coupled to the HP9825S system (see figure 11).

Another HP9825 was coupled to the control computer of the Laser Display, so that information could be transferred from the pre process station to the Laser Display with the aid of the tape cassettes of the two HP9825's.

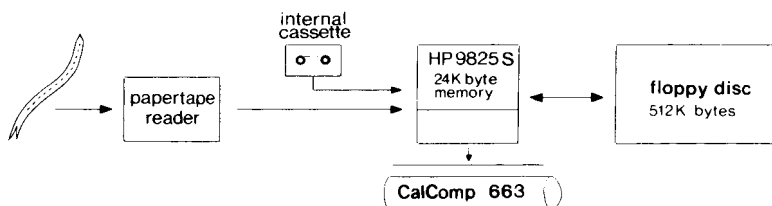


Figure 11. HP preprocessing station.

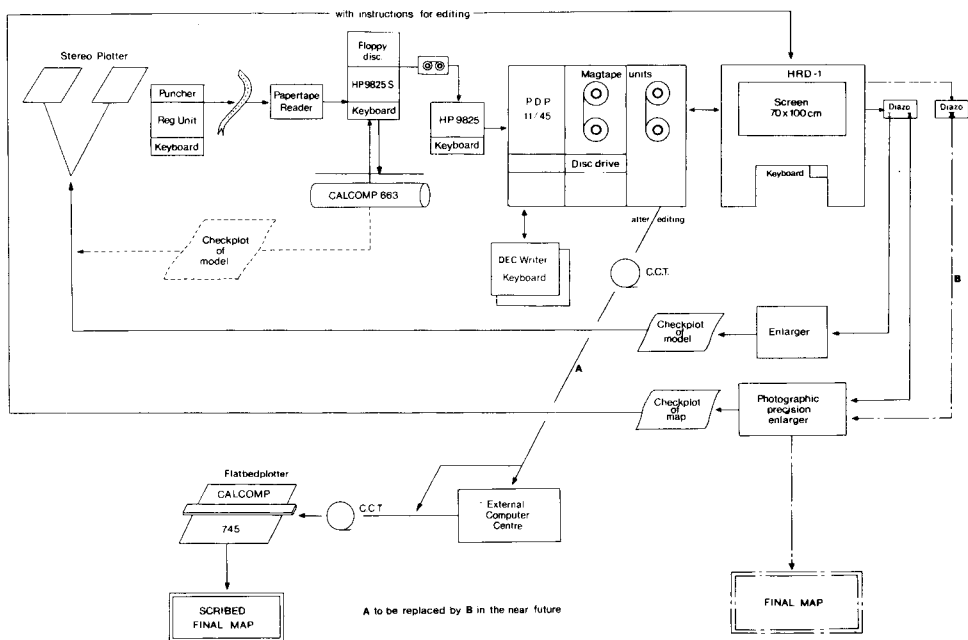


Figure 12. Diagram of procedure for restitution and map compilation.

Figure 12 gives a review of the whole hardware system and the production process.

## 2.3 Software

### 2.3.1 Coding

When digital mapping began, the available registration units could handle only numeric data.

Forced by this limitation, and with the idea that problems of automation should not be solved by complicated codings, a simple allnumeric coding procedure was chosen.

The aim has always been of digitizing a model as completely as possible. Thus, the texts occurring in a model were also digitized by the photogrammetrist.

The preliminary survey made it possible to include the positions of, for example, street names, types of surfacings, etc., in the record during digitization.

It is known from experience that the positioning of text, even when digitizing blind, raises no insuperable problem. The codes define only the graphical representation of a feature and usually give no indication of its function.

Over all, the coding procedure appears as in figure 13:

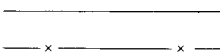
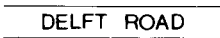


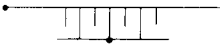
CODE	EXAMPLE	DESCRIPTION
0000-0019		Different linestyles inclusive smoothed lines.
0020-0090	Bridge House	Frequently occurring texts parallel to the map frame.
0100-0299		Variable texts parallel to the map frame.
0300-0399		Variable texts parallel to a digitized direction.
1001-1011		Centred single-point symbols (one recording).
2001-2012		Two-point symbols (two recordings).
3000-3003		Symbols and constructions. Slope symbol, circles, etc. (three recordings).

Figure 13. Coding.

The code 2000 is reserved for the measurement of a well-defined side of a building, which serves as basis for rectangularity corrections.

### 2.3.2 Preprocessing of data

Before the purchase of the HRD-1 Laser Display, eight stereoplotters were used in digital map compilation.

These instruments together had an average of three different projects in hand.

It was expected that after the realization of the interactive system about 20 stereoplotters would be involved in the digital map compilation process, and it would then be possible that the number of different projects that could be worked on simultaneously would increase to seven or eight.

This required that the administrative organization around the interactive system should be simple and efficient.

In blind digitizing, a rapid check plot facility, in combination with a check on completeness, is of great importance.

The correction of errors in the editing phase takes a long time and makes editing unnecessarily complicated.

Experience has shown that photogrammetrists have the urge to supply the most complete and 'error-free' model possible.



In the past this cost a fairly large amount of time, since the paper tapes were corrected by hand.

This form of correction had to be made impossible with the new system, but at the same time the photogrammetrists had to be able to supply a product that was satisfactory as far as he himself was concerned.

Line editors of minicomputers are in general slow and inefficient for the editing of large amounts of data, as they are designed primarily for software development.

Allowing each photogrammetrist to correct his own digital model by the minicomputer of the interactive system would make responsible control of the system impossible. Therefore a preprocess phase was introduced in which the photogrammetrist uses a desk calculator system to check, correct, and if necessary supplement the data that he has collected.

The paper tapes are first read into an HP9825S system, and control of the syntax is performed. Corrections are made as far as possible and the data are written on a floppy disc. When supplementary measurements have also been treated in this way, the data is passed to a tape cassette which is suitable for further processing on the HRD-1 Laser Display.

The digitized model comprises a number of independant elements – e.g. a text, a symbol, a line, etc.

Each element has a number in the element pointer file.

In order to provide the photogrammetrist with the possibility of rapid access to the digital information, the choice has fallen on the file structure that is shown in figure 14.

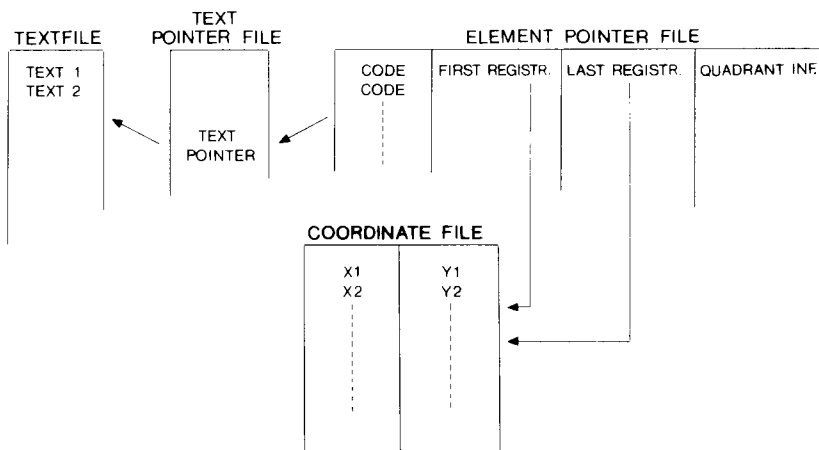


Figure 14. Filestructure.

The various files comprise :

– ELEMENT POINTER FILE

The element pointer file is a file built up sequentially with the following information per element :

- code of the element;
- position of the first recording of the element in the coordinate file;  
position of the last recording of the element in the coordinate file;
- information concerning the quadrant or quadrants of the model in which the element occurs.

Notwithstanding the sequential nature, the file is also record-oriented, with 8 elements per record.

If the number of an element is known, direct access is possible to the information relating to the element.

Element numbers can be found with the aid of the special coding or with the edit program.

– COORDINATE FILE

The recorded coordinates are stored in this file in records of 16 coordinate pairs.

Thus, from the element pointer file there is random access into this file.

The file has a capacity of 12,000 coordinate pairs per model.

– TEXT FILE

This is a record-oriented file with a capacity of 252 characters per record.

This file can remain relevant throughout the project, so that texts that occur in several models need be defined only once.

The text file has a capacity of 2520 characters per project.

– TEXT POINTER FILE

This is an array present continuously in the memory of the desk calculator.

For each text code it contains, in packed form :

- record number in the text file
- starting address of the text in the record
- length of the text.

Random access into the text file is possible with the aid of this array.

In addition to the above files, there are two files on the floppy disc, with the following contents:

– CONTROL POINT FILE

This file includes the results (if known) of the analytical block adjustment.

If the block adjustment is not yet ready, the model coordinates as determined with the triangulation instrument can be included here.

– STATISTICAL FILE

The file includes a number of statistical and administrative data on the project in hand and of the model processed at a given moment.

Each photogrammetrist moreover has a floppy disc upon which there are:

- Software
- Administrative information on the project with which he is concerned
- Digitized data for each model.

The software is divided into 4 different programs:

a TRANSFORMATION PROGRAM

Three different overdetermined similarity transformations can be performed by this program:

- From the model coordinate system to the terrestrial system, which is used whenever the block adjustment is ready.
- From the model coordinate system of the digitizing instrument to the model coordinate system of the triangulation instrument, which is used whenever the block adjustment is not yet ready.
- From the present model to the previous model.

In this case, the controlpoint measurements of the digitizing instrument are used for the block adjustment.

This transformation is also performed in combination with one of the other two.

The transformation program offers a significant check on the relative orientation.

b SYNTAX CONTROL PROGRAM

The digitized data are checked by this program for coding errors.

Data files of the valid recordings are created for each model on the floppy disc.

Invalid recordings are rejected and printed out with an element number, via the printer of the HP9825S. They can be redigitized and added to the file later.

Also, a limited reliability check is carried out on the recorded model coordinates.

As a numeric coding is being used while digitizing, the digitized textpositions are being supplied with alphanumeric text characters via the keyboard of the desk calculator.

The speed of processing is about 600 recordings per minute, and an average model runs to about 1600 recordings.

#### c CONVERSION PROGRAM

This program copies the data from the floppy disc to the internal cassette unit of the HP9825S.

During copying, the digitized codes are converted into the internal coding of the interactive system.

At the same time, buildings, for which this is required, are corrected for rectangularity.

Although the interactive system also provides a 'square' function, the choice fell on the above-mentioned procedure for reducing the editing work and because the photogrammetrist can best judge whether a building needs to be corrected or not.

The speed of working of this program is about 900 recordings per minute.

#### d EDITING PROGRAM

The editing program provides globally the following functions:

- Provision of statistical information on the model and project;
- Printing of parts of the file;
- Deletion of elements;
- Amendment or replacement of a string of characters;
- Change of codings;
  - Search for an element by means of its code;
  - Search for an element by means of its code and model coordinates.

It is not possible to introduce amendments into the model coordinates; digital values can be deleted only in total.

Coordinates can therefore only be changed by removing an element and redigitizing. Errors that were noticed at the time of digitization can be marked by recording the 'error code = 20' immediately after the error. The syntax control program then gives the element number of the element to be eliminated.

This facility allows a considerable reduction of the editing work on the interactive system.

The average time that this preprocess phase requires is about 15 min. per model.

#### CHECK PLOTS VIA THE CALCOMP 663 DRUM PLOTTER

If, because of maintenance or breakdown, the interactive system is not available for making check plots, these can be made via the HP9825S preprocess system to which the CalComp 663 drum plotter has been coupled.

The speed of calculation and the speed of data handling by the HP9825S is quite sufficient to control this type of drum plotter. Although a delay in production does arise by this method, because of the longer drawing time and the waiting time associated with it, the delay is acceptable for a reserve facility.

### 2.3.3 *Processing of data*

The main aim of the interactive operation is to be able to perfect a map sheet before it is drawn. A study of a number of representative projects has shown that about 80 % of the treatments in the finishing off process is non-numerical. The interactive program that was under development at Laser Scan Laboratories in 1975 largely satisfied the requirements that had to be set for such a program. Together with the manufacturers, the editor was adapted to the specific wishes of the Survey Department.

The speed of interaction, i.e. the response time of an action by the operator, had to be less than 8 sec, since otherwise the attention of the operator would begin to slacken. The editor comfortably satisfied this requirement.

Since the editor during drawing on the screen, makes up his own working file and works from it, it was not necessary to generate a file structure, specially designed for interactive working, during digitization.

For this reason, the file structure could remain simple, which was important for the application programs in the system.

The program package consists of the following parts (see figure 15):

#### SOLADI 02

A program for the conversion and checking of various forms of input to a standard data set.

The input possibilities are:

- HP9825 cassettes containing the digitized data from a stereoplotter.
- Magnetic tapes with plotting instructions for the CalComp 745 flat-bed plotter.

This latter possibility has been provided to check for correctness drawings that require a long drawing time on the flat-bed plotter, such as position lattices. The HRD-1 Laser Display draws about 100 times faster than the CalComp 745 plotter.

SOLADI 02 has as its second task the transformation of the digitized data to the national coordinate system.

#### SOLADI 03

A program for the interactive amendment of a standard data set, with the following possibilities:

- The preparation of a drawing;
- The deletion, addition, and amendment of line segments, texts, symbols and the like;
- Such amendment of the data that certain requirements are satisfied, such as rectangularity, parallelism, and circularity;
- Matching of common elements in adjacent models.

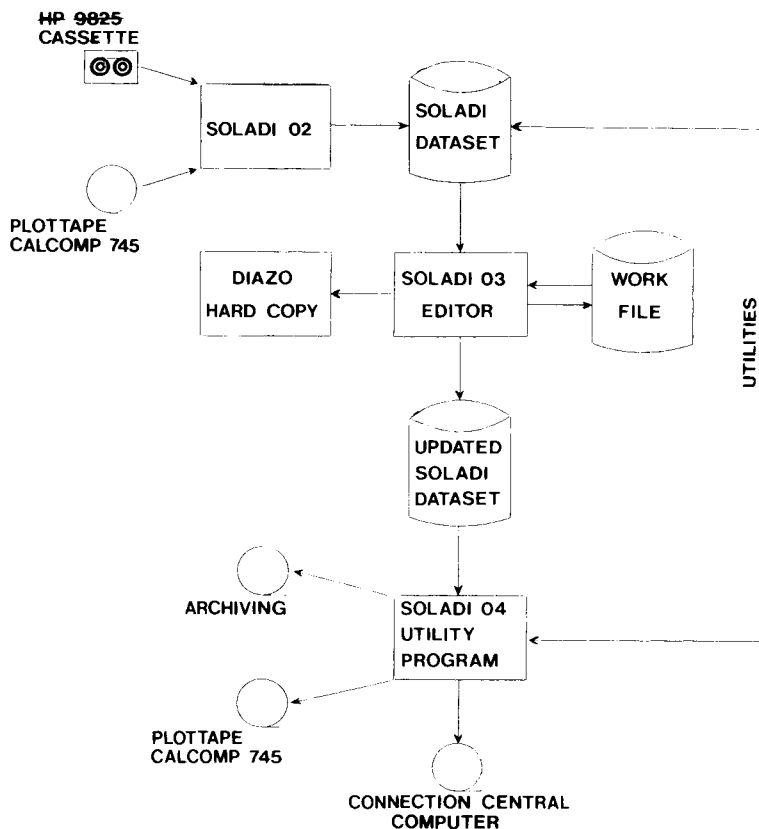


Figure 15. Development scheme of SOLADI\* software.

#### SOLADI 04

A program that merges several data sets into a new standard data set and compiles and draws a map sheet.

The most important processes possible with this program are as follows:

- The combination of a number of datasets (models) into a single dataset which contains sufficient information for a map sheet;
- The selection of information from a number of combined models for a defined map sheet;
- The printing of statistical information concerning a SOLADI dataset;
- The rotation of the coordinates in a dataset so that the sides of a map sheet become parallel to those of the screen and the drawing surface can be utilized in the best possible manner.

\* SOLADI = Software Laser Display

There are three possible outputs from the SOLADI 04 program :

a Archive tape.

Since the interactive system has a limited disc capacity (10 M-bytes), datasets that have not yet reached the processing phase are stored on magnetic tape.

Likewise, magnetic tape is used to store the data for 6 months after the delivery date of the map sheet.

b Linkage with the central computer.

This linkage is effected via magnetic tape.

There, information from the interactive system can be combined with information already available, obtained from non-photogrammetric sources.

c Plot tape for the CalComp 745

If an edited map sheet requires no supplementary information, a plottape can be made immediately for the flat-bed plotter by this branch of the program.

## 2.4 Operation of the HRD-1 Laser Display

The HRD-1 Laser Display is the first equipment used in the Survey Department for interactive updating of cartographic information. Consequently, at the time of its purchase there was no experience with such equipment in such matters as the difficulty of operation, the requirements that had to be set for the operator, the time that an operator can work uninterruptedly with such a display without becoming too tired, and so on.

It was also not known how much time was necessary to process an average map by the HRD-1 Laser Display.

This time naturally depends on the possibilities offered by the software and on the speed of the equipment.

Another important factor is the completeness and correctness of the information and, consequently, the number of errors to be corrected and (cosmetic) corrections to be applied, and the organization of the work (which includes the distribution of tasks between those who digitize the aerial photographs, the draftsmen who finally make the map ready for delivery, and those who perform the data processing with the HRD-1 Laser Display).

Finally, the skill of the operator in working the HRD-1 Laser Display and his knowledge of equipment, software, photogrammetry and cartography play a part.

These questions boil down to whether the photogrammetrists who have digitized the information should themselves process it further by the HRD-1 Laser Display and derive the maps from it, or should that be done by cartographers who know what a map should look like. In other words, is the HRD-1 Laser Display operated by cartographers or photogrammetrists, or must a third possibility be taken into consideration,

separate HRD-1 Laser Display operators working under instructions from photogrammetrists and/or cartographers?

It was decided to make a final choice from the various possibilities only after an extensive practical trial with operators having different backgrounds.

This trial was carried out when the HRD-1 Laser Display had been installed and the equipment and the software had been tested. Three volunteers, after being trained in working with the computer and the HRD-1 Laser Display, actively participated in the test and in the drawing up of a production process.

The three volunteers had many years of experience in cartography, surveying calculations, and data processing, respectively. The trial was conducted by a person with a photogrammetric background.

After the trial period the experience was evaluated, and the following procedure was decided upon:

The cartographic department must be responsible for the final maps.

The information digitized by the photogrammetrist is submitted to the cartographic department in the form of still incomplete maps. On these maps editing instructions are recorded that relate to the connection of the several photogrammetric models, to increasing legibility and improving appearance, etc.

The operator of the HRD-1 Laser Display transfers all the required corrections to the digital record, makes a map, and submits it to the cartographer. The man behind the HRD-1 Laser Display therefore only operates the equipment and does not work on his own initiative, and the cartographer is essentially a map editor.

All this has the following consequences:

- cartographers and photogrammetrists need not be trained in the operation of the computer and the Laser Display;
- the HRD-1 Laser Display operator need not to have cartographic training;
- updating by means of the HRD-1 Laser Display can be done rapidly, since the operator does not need to analyse what must and what need not be amended. In this way, a maximum production can be achieved with the expensive apparatus;
- it is expected that the number of permanent operators can be limited to three people;
- only these three workers need remain up-to-date with the software, which is still under development.

## **2.5 Making the HRD-1 Laser Display operational**

The HRD-1 Laser Display system was delivered in January 1976.

After adaptation of the room, the system was installed in June of that year.

The first versions of the software were ready for a practical test in August.



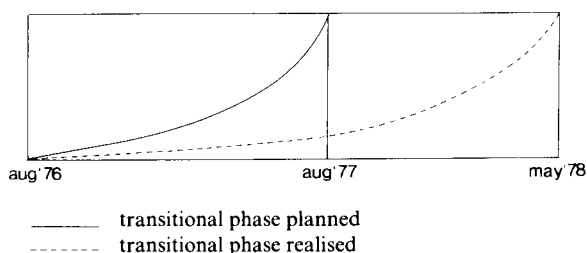


Figure 16. Progress development implementation of Laser Display.

The existing production line was still operational, but the X1 computer with which the syntax check and the check plots were made would remain so only up to August 1977. Consequently, it was decided that emphasis should first be placed on taking over the functions of the X1 by the new system.

In October 1976 the development of the software had advanced so far that the HP9825S system carried out the syntax check and the Laser Display system took care of the check plots.

After the satisfactory progress up to that moment with the introduction of the HRD-1 Laser Display system in the digital map compilation process, there was a period in which the development took place much less rapidly than had been foreseen in the development phase (see figure 16).

The most important reasons for this slowing down were as follows:

- Numerous hardware breakdowns of the HRD-1 Laser Display.  
This considerably delayed the testing and implementation of the software.
- The editing program still contained various faults which could be eliminated only slowly, since it was generally necessary to contact the manufacturers about these faults by telex.
- The operators' knowledge of the operating system was too slight.  
In addition to the usual training by manufacturers, long practical experience was found to be indispensable.
- The first versions of the software were insufficiently protected against operating errors.
- The knowledge of minicomputer systems possessed by the Survey Department programmers, who had had experience only on large mainframes, was too small.

The original design of the SOLADI dataset was found to be insufficient to contain all the information necessary for reliable map compilation.

The expansion of the possibilities of this dataset cost a disproportionately large amount of time. This was because three programs made by three different programmers, one of whom was in England, had to be modified time and time again.

In spite of the outstanding quality and the good service of the software division of Laser

Scan Laboratories, at least two weeks were required before a modification could be effected, mainly due to the sending of magnetic tape to and fro.

In August 1977, the planned date for the total change-over, the work was so far advanced that part of the production could be processed via the interactive system. This part of the production was used to train the operators further and to carry out more tests on the remainder of the production line, including the coupling via magnetic tape with the central computer.

During this period it became clear that the resolution of the coordinates in the dataset was insufficient to achieve the required accuracy on the map (0.15 mm). The various arithmetical treatments that had the consequence of an integer to floating point conversion (and vice versa) sometimes gave rounding-off errors of 0.3 mm on the map. Since the coordinates were defined in 16-bit integers and no Fortran IV-Plus compiler was available (which can work with 32-bit integers), other paths had to be taken.

In the first place, the truncation of values by the software was replaced by reliable rounding-off.

In addition, the coordinates were multiplied during transformation by a factor of 3. By these two measures it was possible to limit the loss of accuracy during the whole process to a few centimetres in the terrestrial system.

For reasons of standardization of the software within the Rijkswaterstaat, the graphics package of the central computer making a plottape for the CalComp 745 was converted into the graphics package Gino-F. This again involved a test phase and therefore more delay. When the production once more began to proceed, it was found that the whole administrative process round the editing took up about 30 % of the available system time.

The PDP 11/45 system was equipped with a 48K-word memory. The editing program used 32 K-words and, because of the refresh mode, had to be resident continuously in the memory.

Although the system makes use of the RSX-11M operating system, which offers multi-user facilities, no use could be made of these because the memory was too small.

The production capacity of the system was therefore about three sheets per day, which was not enough to satisfy the requirements.

It was therefore decided to expand the memory to 80K-words and to connect an extra terminal (DECwriter). This expansion was accomplished at the end of December 1978.

### 3 Production and experiences in 1979

In the beginning of 1980 an evaluation was made of the production of a number of map sheets. The sheets are considered to be 'average' sheets. The production figures were then compared with those of 'average' sheets in 1973. At that time the digital mapping process, although in a rudimentary state, was well established. Furthermore the operators were rather experienced in digital mapping.

The photogrammetric operators were experienced, too, in 1979, though by then the process was rather sophisticated.

The first column of figure 17 gives the results for graphical restitution in 1973, the second one for digital restitution in the same year.

The last column gives those for digital restitution in 1979.

man hours per sheet (planimetry only)	1973 graphical	1973 digital	1979 digital
photogrammetric restitution	35	38	29
fair drawing etc.	75	39	0
map editing	0	0	6
computer and drawing machine	0	3	1
Laser Display	—	—	1.5

Figure 17. Production figures.

These figures speak for themselves, it is only noted here that the decrease in restitution hours in 1979 is caused mainly by the new preprocessing methods.

One must keep in mind that the given figures are indicative, not absolute.

Plotting was done by experienced operators who needed only to be trained in using the new system, which they were very eager to do.

Less experienced operators will need more training. Furthermore it can be expected that once every one is used to the new system it will become routine work in which people are less interested so that productivity may drop. Whether this will be compensated by the increased experience the operators will have by then has to be awaited.

## **4 Man and digital mapping**

### **4.1 Expectations**

In October 1969 the Director of the Survey Department delivered a speech on digital mapping, in which he stated what was expected technically from digital compilation of photogrammetric maps:

- 1 Fair drawing can be completely avoided.
- 2 Information for the compilation of a map can be stored compactly on paper tape.
- 3 From these paper tapes a model or parts of it can be drawn at any desired scale.
- 4 It will make the flight plan and the layout of the sheets independent of one another.
- 5 The preparation of the models will become simple and be limited to the minor control points.
- 6 The layout of the sheets and the scale of the map can be chosen with complete freedom.
- 7 The model needs to be relatively oriented only once. Aerial triangulation and mapping are then done successively in that model.
- 8 Separate arrangement of the sheets is no longer necessary.
- 9 Only one observer is necessary for operating the instrument, and a drawing table is no longer necessary.
- 10 Damaged maps and/or tracings can easily be redrawn from the paper tape.
- 11 The cadastral information can be added to the paper tape.
- 12 An enormous saving of time through the exclusion of manual work is in prospect.

Surprisingly enough, in the ten years that followed scarcely any modifications have been made in relation to these expectations in the technical sense.

Only the 1969 idea of the development of a map databank proved to be too optimistic. Another striking fact is that hardly any attention was devoted to the social consequences of such far-reaching changes in the preparation of maps.

Nevertheless, a realization of the first and the last of these expectations must have enormous consequences.

### **4.2 Acceptance**

It will not come as a great surprise that from the beginning of the development of digital mapping there was a clear polarization of opinions among those who had to deal with

it. The great losers could only be the draftsmen, and in the opinion of the automation experts they would just have to put up with it. In this, they were practically alone. In addition to the arithmeticians, to whom automation was already a natural concept, and in addition to the photogrammetrists, who were keen on being able to produce maps completely independently without assistance and interference from cartographers, the field surveyors were also involved. The digitization of the mapping process involved little by way of direct changes for these last-mentioned workers, and they were therefore fairly indifferent to the process that in fact took place 'in the office'.

Unrest began and uneasiness arose. What one group did not know, another accepted as a certainty. For the one everything was clear, for the other everything was incomprehensible.

Everything then turned on the cardinal question of 'How and Why', and in the course of the years it was found that it is easier for management to answer the 'how' than the 'why' in a satisfactory way.

### **4.3 Social aspects**

In the automation process with respect to the social aspects one can go from large to small. It goes too far to discuss here the great social problems of automation. A government department fortunately needs not be concerned with one effect: no one is automated out of work. In the Survey Department automation enormously increased production and made much manual work superfluous. At the same time, much new work had arisen, which in the past could not be performed. In the limited context of a department such as the Survey Department there is little choice. Too much work for too few people unavoidably means automation.

The following employees are directly involved in the process of digital mapping:

- the field surveyors
- the arithmeticians and computing staff
- the photogrammetrists
- the cartographers.

What do these groups think about digital mapping?

#### **THE FIELD SURVEYORS**

The field parties took little notice of the digital process. The nature of their own work has not changed, though it is true that, particularly in the case of urgent commissions, there is some modification in the sequence of their activities.

The workers' interest almost invariably runs in proportion to the influence of the situation on their own work. During the years of development there have been no comments worth mentioning, in any direction at all, from the field organization. 'They'll have to sort it out in the office'.

Active interest arose only later, following the introduction of recording instruments such as the AGA 700 and the Reg Elta in the field, but this falls outside the scope of the present paper.

#### THE COMPUTING STAFF

The computing staff naturally threw themselves enthusiastically into the problem from the very beginning. The automation of geodetic calculations was something that they had confidence in for years already.

In a review of the computing section over the period around 1955 it is stated that the arithmeticians had to calculate innumerable points on Decca lanes with the desk calculating machine, starting from tables with information on standard hyperbolae. This was terrible work, of which one soon got tired. The review then stated: 'Our worry is at the most to some extent mollified by the thought of our unfortunate colleagues in the drawing section who have to plot thousands and thousands of points and then join them by meticulously flowing lines using lead-loaded splines.'

And when a few years later an experimental computer relieved the arithmeticians of the calculation work, it was again mentioned 'that unfortunately there was still no automatic drawing instrument that could draw curved lines, so that the draftsmen's misery continued.'

This misery came to an end in 1965 when the first computer-controlled drum plotter took over this work. The draftsmen were also happy about this, since they felt themselves relieved of heavy and monotonous labour.

The Survey Department has kept itself occupied with the automation of geodetic calculation work from the beginning. For years already there was practically no more 'manual calculation'. It is understandable that the arithmeticians should also raise no objection to automation in the mapping process. Playing with computers and displays was a pleasure to them.

#### THE PHOTOGRAMMETRISTS

Photogrammetry has assumed an important place in the Survey Department from the beginning.

Irresistible as its founder, Professor Schermerhorn, its participation in the production of maps by the Survey Department increased, and even years ago it made up a good 90% of the total.

Since the 'thirties the draftsmen and cartographers were called in by photogrammetrists to assist in the cartographic preparation and processing of the map. This took place in more or less harmonious cooperation, in which, however, each felt he should remain as much as possible within his own group. Within photogrammetry itself, the processes of mechanization and automation took place continuously. Via the improve-

ments in the stereo instruments and the addition of recording equipment, which was originally used only for aerial triangulation, the photogrammetrist grew slowly but surely towards the digital method of mapping. Drawing without a drawing table, that was the future.

The weather conditions in the Netherlands and the boom in the road and canalbuilding between 1950 and 1970 enormously promoted the use of photogrammetry in the Survey Department. Surveying teams in The Netherlands are still stopped by rain in the already short summer, and are therefore expensive and relatively unproductive. Photogrammetry brings the information home and depends on the weather only for the short time necessary to take the photographs.

Delivery of maps could not take place rapidly enough, and production increased to 40,000 instrument-hours per year. The dependence of photogrammetry on the drafting sections, which had both an assisting and a controlling task, annoyed the photogrammetrists to such an extent that they wanted to be free of it, and in this respect too the digital method was particularly attractive. Internally, the situation was that even the photogrammetrists who originally came from the drawing sections were enthusiastic about throwing the drawing away. The photogrammetrist who draws less rapidly and less well has naturally no objections to the digital method.

One clear loss is probably the lack of cartographic insight in the case of some photogrammetrists. In mapping they see only a small part of a stereo model and not the drawn lines of a final map. The fact that it is difficult to make a map in this way is sometimes clearly shown in the result.

Finally, as the last group involved in this process, the *cartographers* were clearly on the defensive from the beginning. Since the introduction of photogrammetry into the process of map-making they became the primary 'victims', and now they were themselves threatened in their capacity as draftsmen. There was therefore plenty of reasons to look closely and carefully at automation of the drafting work.

#### **4.4 The modification of the drafting work**

The automation of the drafting work in map production has come about over a long period and in so doing has passed through the following phases:

- scarcely detectable insidious beginning;
- quantitative reduction in the volume of drafting work;
- qualitative reduction in the drafting work;
- far-reaching elimination of the cartographer by the method of interactive processing.

#### THE SCARCELY DETECTABLE INSIDIOUS BEGINNING

It took decades for the draftsmen to come to a realization that photogrammetry could constitute a threat to their work.

In the initial years, from 1930 to 1960, the extent of photogrammetric production was so small, and the supply of work from the terrestrial operations was so large, that the small amount of photogrammetric work was hardly noticed.

#### REDUCTION OF WORK IN THE QUANTITATIVE SENSE

At the beginning of the 'sixties there was a rapid expansion of the photogrammetric capacity. Both the demand and the production following it rose so sharply that through lack of draftsmen many maps were issued as provisional sheets. They were frequently only copies of sheets drawn in pencil, and the quality was such that a right-thinking cartographer was justly ashamed.

Because of the prevailing situation, the map users were happy. The philosophy was 'better a provisional map than no map at all'. The omission of the finishing off of the sheets meant a considerable reduction of work for the drafting section, and was made necessary by the speed of delivery that the map users demanded.

In addition to these activities, there was an enormous reduction because of the automation of the drawing work of non-photogrammetric origin.

Between 1960 and 1970 gridding and plotting of control points was automated, and so was mapping in many variants of axes and legal boundaries. The manual work on profile and perspective drawings and on lattice sheets also disappeared.

#### REDUCTION OF WORK IN THE QUALITATIVE SENSE

Much of the drawing work was automated away, but in many cases some embellishing work remained for the draftsmen. Nowadays a cartographer almost never constructs and finishes a map himself. The work of embellishment no longer requires special drawing skill and the necessity for good training suffers. At an ever-increasing rate even field measurements are being recorded on paper or magnetic tape and are processed automatically wholly or in part. The cartographer may just have to adjust these mappings to the existing ones.

Between 1970 and 1973 such a pronounced qualitative reduction took place that many well-trained draftsmen asked themselves where this was going to end and insisted on retraining.

#### ELIMINATION OF THE MANUAL DRAWING WORK

Digital mapping complete with finishing by means of an interactive system eliminates practically all drawing work in the production of maps. The direct consequences of this phenomenon for the drafting section are as follows:

- a reduction in the number of personnel;
- an end to training directed at hand-drawing;



- additional training and work directed elsewhere for those who remain;
- retraining and transfer to other sections.

#### **4.5 The process of adaptation**

As mentioned previously, in the initial years of digital mapping hardly any account was taken of the social consequences of such a far-reaching change in one of the primary production processes of the Survey Department.

The discussion of the social consequences started only at a later stage, and was very vigorous because of the incomplete preparation.

The worry that all draftsmen would become redundant led to much unrest. Although, particularly because of the slow rate at which the change-over took place, it was eventually possible to find satisfactory solutions for all those concerned, an earlier recognition of the social consequences of automation could have prevented a number of problems.

A complex of measures was developed to make the change in the production process possible and acceptable.

Both from psychological and other aspects, the decision taken in 1977 to combine the photogrammetry and cartography sections into a single one proved to be very important, as it created the possibility for further gradual amalgamation.

In addition, it was clear to everybody that not all cartographic work would be automated in the short term. In particular, the many small but always varying activities involved in the revision of maps not drawn automatically would continue to be done manually for a considerable time to come. Moreover, activities performed in direct cooperation with other organisations generally lend themselves poorly to automation.

Finally, as explained in the chapter on the operation of the HRD-I Laser Display, an important task was left to the cartographers in the editing of the maps prepared by digital mapping.

Nevertheless, all this naturally has many consequences for personnel management, both with respect to the existing personnel and with a view to the future. The younger cartographers, in particular, make use of the possibility of being retrained as photogrammetrists and new recruits are tested for their capacity for seeing stereoscopically; in the subsequent in-service training much less emphasis is placed on drawing skill than used to be the case. It is expected that in time the separate disciplines of 'photogrammetry' and 'cartography' will be fused into what can perhaps be called 'map compilation'.

## **5 A glimpse into the future**

### **FUTURE DEVELOPMENTS**

It is expected that the method of digital map compilation will have to be continuously improved and expanded in the future. The method will also be capable of broader application.

Some of the more predictable developments are considered below.

### **ELIMINATION OF PROBLEMS WITH THE HARDWARE**

As stated in section 1.7, the system purchased is made up of parts from different manufacturers.

In the event of breakdowns, it is not always directly demonstrable in what part of the system the fault resides. Consequently, the remedying of breakdowns sometimes takes a fairly long time, particularly when maintenance engineers from the different manufacturers are involved.

The problems tend to decrease with a system consisting of parts from fewer different manufacturers.

It must therefore be borne in mind to what extent, in the replacement of parts of the system, it is necessary and possible to change over to parts made by other manufacturers.

### **INCREASING THE POSSIBILITIES OF SOFTWARE**

In the programming of the HRD-1 Laser Display a fairly limited number of editing functions was initially put up with or chosen deliberately. It must be considered whether the processing that the automatically drawn maps still have to undergo before they can be supplied as complete and correct can also be automated.

What is important here is how frequently the processes occur, and how complicated they are.

If it is worth the trouble and the cost, new editing functions can be added to the software.

The method of recording the final map on a diazo film and enlarging it to the desired scale does not yet result in the desired accuracy of the endproduct. This problem must be solved in cooperation with Laser Scan Laboratories.

### **APPLICATION OF THE METHOD OF DIGITAL MAPPING TO OTHER TYPES OF MAPS**

A study must be carried out to see whether the correct software, possibly with the

expansion of its facilities, can be used successfully and efficiently for the preparation of other types of maps currently prepared by the Survey Department. River maps with scales of 1:2000 and 1:5000 must be considered among others.

Problems could arise with the map contents (more complicated symbols) and scales (higher information density).

The river maps are revised periodically. In the considerations relating to digital preparation, particularly of this kind of maps, attention must also be paid to whether it may be desirable or necessary to make a databank and to maintain map information. If this last question is answered in the affirmative, it must be investigated whether the SOLADI file structure is suitable for this purpose.

#### EXPANSION OF SOFTWARE WITH POSSIBILITIES FOR PROCESSING INFORMATION FROM OTHER SOURCES.

At a certain stage of processing the information, it is no longer detectable that it has been obtained photogrammetrically.

When information from another source can be supplied in the form of a SOLADI dataset, the present software can be used directly for editing and drawing.

- The Survey Department has several electronic tacheometers with recording equipment. Measurements are made in the field with these for the purpose of preparing plans, and also for contour maps and profile drawing. A special preprocessor must be written for each type of tacheometer.
- The Survey Department possesses a digitizer table. With this it is possible to record existing maps in digital form. The introduction of records into the HRD-1 Laser Display, again via an adapted preprocessor, is possible.

The common feature of the three methods of collecting information that have been mentioned (photogrammetry, electronic tacheometer and digitizer table) is that a large area to be digitized is divided into small areas (in the three methods, respectively, photogrammetric models, recordings for each tacheometer station and digitized map sheets), and these 'models' can be processed into a single unit in the HRD-1 Laser Display with the aid of the editor.

#### COLLECTION OF THREE DIMENSIONAL INFORMATION FROM THE PHOTOGRAMMETRIC RECORDINGS

The Survey Department not only prepares maps but also provides the other Directorates of the Rijkswaterstaat with height information for the planning of motorways, for the calculation of estimated or executed earthworks, etc.

The height information concerned (a digital terrain model, DTM) can be deduced from photogrammetric recordings.

It is expected that in future there will be frequent requests both for map making and for the formation of a DTM.

A study must be made on whether the collection of information for a DTM can be done simultaneously with the collection of information for the purposes of digital map compilation.

#### ROAD DATABANK

Much information has been collected and stored at the Rijkswaterstaat on the construction, management, and maintenance of National Highways. A study is in progress whether information should be stored in a road databank. If information obtained in map compilation is considered for permanent storage (and periodic updating) this could affect the procedure for digital mapping.

## **Appendix 1    The HRD-1 Laser Display / Plotter**

(courtesy Laser Scan Laboratories)

### **1.1    Introduction**

The HRD-1 is a high resolution film recording and image display system. It not only provides a very high resolution display facility by using a photochromic (non-permanent) intermediate image, but, by writing onto diazo film directly, also provides ultra high quality hard copy.

The optical hardware of the HRD-1 is best understood if it is broken into five main parts. These are (see figure 18):

- a The light source
- b The writing system – which can expose, at high speed, a programmable pattern on the film medium with very good accuracy and resolution.
- c Diazo film – making the device a plotter for the production of very high quality hard copy.
- d Photochromic film and associated large screen storage display – making possible the presentation of large quantities of detailed information for direct viewing on the screen.
- e Refresh Mode – provided by direct writing onto the viewing screen and giving a dynamic image superimposed on the stored picture.

### **1.2    The Light Source**

An Argon ion laser is used to provide a writing beam, finely focussed at the film plane. Its intensity is high enough to cause either colouration of the photochromic film or bleaching of the diazo film, neither of which require conventional wet processing.

### **1.3    The Writing System**

The main laser is followed by a MODULATOR, the first of four components which constitute the writing system. In sequence, the remaining three are:

a SECONDARY DEFLECTION SYSTEM for very high speed spot positioning, a high quality imaging lens with DYNAMIC FOCUS capability, and the main DEFLECTION SYSTEM, which consists of two interferometrically controlled mir-

rors rotating about precisely defined, orthogonal axes. An auxiliary laser supplies coherent light for the interferometers.

The key to the accuracy and high resolution of the HRD-1 is embodied in the interferometric controls by which the two mirrors (MAIN DEFLECTORS) are positioned. This technique, though well known for the measurement of relative positions, has here been adapted to measure relative angles with a precision of 0.2 second of arc. With an optical lever from the MAIN DEFLECTORS of around 1 m, this corresponds to a distance of  $1 \mu$  or so at the film.

Since the film on which the recording is made is held flat, and the distance from the main deflectors to the point to be recorded is position dependent, the imaging lens is provided with a dynamic focus capability.

This correction is applied automatically by the controller. On the film a spot size of well under  $20 \mu$  can be obtained over the whole addressable area.

Whilst the position of the MAIN DEFLECTORS is very accurately known, for inertial reasons this may deviate from that required at any instant, particularly when fast detail, such as characters, is being drawn. A SECONDARY DEFLECTION SYSTEM capable of small scale but high speed operation compensates for such deviations. In order to record the desired pattern, the recording beam must, in addition to being programmed positionally, have its intensity carefully controlled. The first component in the light path is therefore an Acousto-optic MODULATOR which ensures that lines are drawn, regardless of speed, at a uniform, though programmable, intensity.

#### **1.4 Diazo film**

The most direct application of the HRD-1's laser writing system is in the production of high quality film hard copy (see appendix 2). As it can do this directly onto diazo film, a simple cassette holding up to 20 fiche sized film sheets is provided. Each new fiche is fed into the writing station by remote control and released when the recording is complete. The exposed film, which can be handled in daylight, is collected by the operator and developed by exposure to warm ammonia in a simple desk top machine. The polarity of the recorded image, (white lines on a dark background), and the extremely high resolution of diazo film makes the results ideal for reproduction or enlargement.

#### **1.5 Photochromic Film**

The movement of a single mirror causes the laser to write onto the photochromic film.

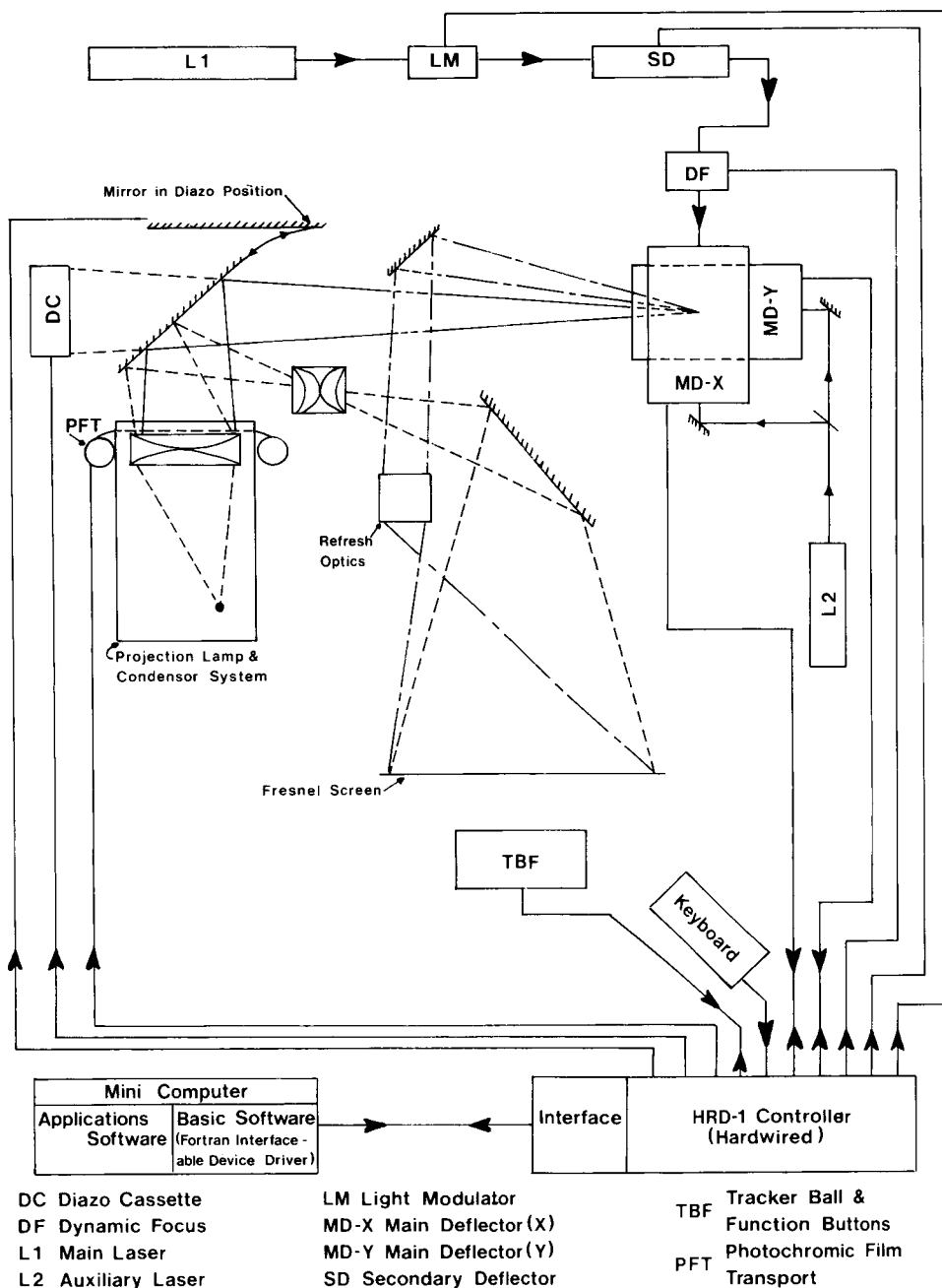


Figure 18. Schematic of HRD-1 Laser Display/Plotter System

The blue Argon laser darkens the orange film to a near black colour, and this image is continuously back projected in orange/yellow light onto a large (100 × 70 cm) screen. The photochromic film retains the image thus displayed for 15 min or so before it starts to fade significantly. However, for longer periods of viewing it may be overwritten without noticeable degradation owing to the high reproducibility of the HRD-1's writing system.

For a new picture within seconds, a film transport enables the selection of a fresh area of photochromic film. Conversely, old pictures, which are retained for a relatively long period when not subjected to viewing, may be recalled. Since picture reversal is a thermal effect and old recordings ultimately disappear, the roll of photochromic film is reusable.

### **1.6 Refresh Mode and Interaction**

16 function buttons and associated lights and a keyboard allow communication between the operator and the computer. Interaction with the displayed information is made possible by the HRD-1's refresh mode and by a tracker ball intended for use with a moving cursor or, in general, any other program dependent coordinate.

When used in the display mode, a small portion of the machine's coordinate space corresponds, via the refresh optics, to the whole of the display screen. Any image written in this area is thus superimposed on the stored image on the screen. By repeated writing in this area a dynamically variable refresh image in the blue light is obtained. Since the screen has no image retention, any pattern produced in this way must be refreshed several times per second. A one to one correspondence between the stored and the refreshed images makes it possible to interact precisely and effectively with the aid of the on line mini computer.



## Bibliography

- 1 C. M. A. van den Hout, Digital sketch-mapping on large scales, *Bildmessung und Luftbildwesen* 1 (1970), 85-90 (in German).
- 2 H. J. G. L. Aalders, Digital photogrammetric mapping, *Geodesia* (1972), 35-42 (in Dutch).
- 3 Digital Mapping Working Group, The development of digital mapping, May 1972. Meetkundige Dienst van de Rijkswaterstaat (in Dutch).
- 4 K. Kubik and M. Tienstra, Development of automated large scale mapping at the Survey Department of Rijkswaterstaat. *The Cartographic Journal*, (June 1974), 6-11.
- 5 M. Tienstra and J. G. van der Kraan, Some figures about automated large scale mapping, ICA Commission III, Technical Working Session, April 1975, Enschede, The Netherlands.
- 6 G. S. B. Street and P. A. Woodsford, The HRD-1 Laser Display System, ICA Commission III, Technical Working Session, April 1975, Enschede, The Netherlands.
- 7 H. Rietveld, Something about digital map making at the Survey Department of the Rijkswaterstaat. *NGT* (1975), 115-125 (in Dutch).
- 8 C. W. Corbet, The HRD-1 Laser Display/Plotter System, *NGT* (1977), 90-94 (in Dutch).
- 9 W. J. H. IJzereef, Digital mapping ... magic wand? *Geodesie* (1978), 7-15 (in Dutch).
- 10 J. G. van der Kraan, H. Rietveld, M. Tienstra, W. J. H. IJzereef, Digital Large Scale Restitution and Map Compilation. Paper presented to Commission IV, ISP Congress Hamburg, 1980.

In the series of Rijkswaterstaat Communications the following numbers have been published before :

- No. 1.\* *Tidal Computations in Shallow Water*  
Dr. J. J. Dronkers† and prof. dr. ir. J. C. Schönfeld  
*Report on Hydrostatic Leveling accross the Westerschelde*  
Ir. A. Waalewijn, 1959
- No. 2.\* *Computation of the Decca Pattern for the Netherlands Delta Works*  
Ir. H. Ph. van der Schaaf† and P. Vetterli, Ing. Dipl. E. T. H., 1960
- No. 3.\* *The Aging of Asphaltic Bitumen*  
Ir. A. J. P. van der Burgh, J. P. Bouwman and G. M. A. Steffelaar, 1962
- No. 4.\* *Mud Distribution and Land Reclamation in the Eastern Wadden Shallows*  
Dr. L. F. Kampst, 1962
- No. 5.\* *Modern Construction of Wing-Gates*  
Ir. J. C. le Nobel, 1964
- No. 6.\* *A Structure Plan for the Southern IJsselmeerpolders*  
Board of the Zuyder Zee Works, 1964
- No. 7.\* *The Use of Explosives for Clearing Ice*  
Ir. J. van der Kley, 1965
- No. 8.\* *The Design and Construction of the Van Brienenoord Bridge across the River Nieuwe Maas*  
Ir. W. J. van der Eb†, 1968
- No. 9.\* *Electronic Computation of Water Levels in Rivers during High Discharges*  
Section River Studies. Directie Bovenrivieren of Rijkswaterstaat, 1969
- No. 10.\* *The Canalization of the Lower Rhine*  
Ir. A. C. de Gaay and ir. P. Blokland†, 1970
- No. 11.\* *The Haringvliet Sluices*  
Ir. H. A. Ferguson, ir. P. Blokland† and ir. drs. H. Kuiper, 1970
- No. 12.\* *The Application of Piecewise Polynomials to Problems of Curve and Surface Approximation*  
Dr. Kurt Kubik, 1971
- No. 13.\* *Systems for Automatic Computation and Plotting of Position Fixing Patterns*  
Ir. H. Ph. van der Schaaf†, 1972
- No. 14.\* *The Realization and Function of the Nothern Basin of the Delta Project*  
Deltadienst of Rijkswaterstaat, 1973
- No. 15. \**Fysical-Engineering Model of Reinforced Concrete Frames in Compression*  
Ir. J. Blaauwendraad, 1973
- No. 16.\* *Navigation Locks for Push Tows*  
Ir. C. Kooman, 1973
- No. 17.\* *Pneumatic Barriers to reduce Salt Intrusion through Locks*  
Dr. ir. G. Abraham, ir. P. van der Burg and ir. P. de Vos, 1973

\* out of print

In the series of Rijkswaterstaat Communications the following numbers have been published before (continuation):

- No. 18.\* *Experiences with Mathematical Models used for Water Quality and Water Problems*  
Ir. J. Voogt and dr. ir. C. B. Vreugdenhil, 1974
- No. 19.\* *Sand Stabilization and Dune Building*  
Dr. M. J. Adriani and dr. J. H. J. Terwindt, 1974
- No. 20. *The Road-Picture as a Touchstone for the three dimensional Design of Roads*  
Ir. J. F. Springer and ir. K. E. Huizinga (also in German), 1975
- No. 21\* *Push Tows in Canals*  
Ir. J. Koster, 1975
- No. 22 *Lock Capacity and Traffic Resistance of Locks*  
Ir. C. Kooman and P. A. de Bruijn, 1975
- No. 23. *Computer Calculations of a Complex Steel Bridge verified by Model Investigations*  
Ir. Th. H. Kayser and ir. J. Brinkhorst, 1975
- No. 24. *The Kreekrak Locks on the Scheldt-Rhine Connection*  
Ir. P. A. Kolkman and ir. J. C. Slagter, 1976
- No. 25. *Motorway Tunnels built by the Immersed Tube Method*  
Ir. A. Glerum, ir. B. P. Rigter, ir. W. D. Eysink and W. F. Heins, 1976
- No. 26. *Salt Distribution in Estuaries*  
Rijkswaterstaat, Delft University of Technology, Delft Hydraulics Laboratory, 1976
- No. 27. *Asphalt Revetment of Dyke Slopes*  
Committee on the Compaction of Asphalt Revetments of Dyke Slopes, 1977
- No. 28. *Calculation Methods for Two-dimensional Groundwater Flow*  
Dr. ir. P. van der Veer, 1978
- No. 29. *Ten years of quality control in road construction in the Netherlands*  
Ir. C. van de Fliert and ir. H. Schram, 1979

---

\* out of print

\*KARTERING MEETKUNDIGE DIENST RIJKSWATERSTAAT.  
RW 1 GED:S15-AZELØ SCHAAL 1:1000 BLADNR. 284-59  
OPN.FOT. 19 MEI 1979 BIJZEN: GRENZEN

