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ORGANISATION EUROPÉENNE D'ÉTUDES
PHOTOGRAMMÉTRIQUES EXPÉRIMENTALES

EUROPEAN ORGANIZATION FOR EXPERIMENTAL
PHOTOGRAMMETRIC RESEARCH



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WILLI BECK:

**The Production of Topographic Maps at 1:10,000
by Photogrammetric Methods**

**L'établissement de cartes topographiques au 1/10 000
par voie photogrammétrique**

With statistical evaluations, reproductions, style sheet
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The Production of Topographic Maps at 1 : 10,000 by Photogrammetric Methods

By Willi Beck, Stuttgart

1. Introductory observations

1.1. Motives for the investigations

Topographic base maps at scale 1 : 10,000 and larger have a privileged position among all sorts of cartographic documents because of their twin function as a basis for research, planning and engineering on the one hand, and the production and revision of topographic maps at medium and small scales on the other. With the cartographic opening up of a country its elementary sphere of activity will soon put it at the head of the different map series, particularly in densely populated and fast developing areas. This fact — as well as the general lack of these maps and, to some extent, the lack of experience in all matters concerning economic production methods finalised the decision that the work of Committee D would be concentrated on this theme in the first place.

The choice of the scale 1 : 10,000 resulted from the consideration of keeping the cartographic work concerning production and revision of such a map series low, and at the same time keeping topographic performance at its best by the application of photogrammetric techniques. Because of the small map scale the number of map sheets is reduced (e. g. compared with the scale 1 : 5,000 to a quarter). In this way the amount of cartographic work is reduced, while the corresponding increase in survey work is technically and rationally captured by photogrammetry. With the same personnel considerably more can be produced at a smaller scale than a larger one. It must, however, be noted that the scale 1 : 10,000 roughly represents the limit in which map details can be indicated without some reduction, i. e. without generalisation and exaggeration. In other words, the amount of information of a map at this scale has not been reduced compared with larger scale maps. This fact is confirmed by the aerial photograph itself. At the scale 1 : 10,000 the aerial photograph is still topographically and cartographically interpretable and identifiable in detail without expensive optical aids. An orthophoto at this scale therefore can act as a map substitute.

A further argument which forms a basis for the treatment of this theme, is the tremendous progress of photogrammetry in the last decades. Particularly orthophotography, which allows to build in the aerial photograph directly into the map, irrespective of the topographic shape of the terrain, and opens up new prospects in topographic, cartographic, technical and scientific fields, which seem worthwhile to investigate.

1.2. Subjects to be studied

With the intention of fully examining the map production process the cartographic area involved should — contrary to many a custom — be of equal value to the photogrammetric problem. It was the intention to join effortlessly both branches of map production and to reveal their interrelations and interdependencies and collate both branches as well as possible. The aim was, however, only partly achieved. In some cases the cartographic results were far less than the photogrammetric ones and in other cases so much attention was paid to the topographic effort that the cartographic results became too small to permit of a good analysis. Weighing of the established results has hardly taken place. So the extent of the analyses has been limited to an acceptable degree, which still includes all essential facts.

At the beginning it was not planned to take into consideration, except for the given map and the usual map image of line maps orthophotographic maps, the orthophoto map also, and the sorts of maps which are between the two. At the moment that the first photogrammetric results and particularly the orthophotos were available, the committee decided to expand the photogrammetric and cartographic possibilities in these fields of map production. The most important part of the investigations should however be devoted to the production of a conventional map image.

The photogrammetric part of the test culminated in the comparison of the technical and economic achievements of stereophotogrammetric and orthophotographic method groups in the production of topographic maps at a scale of 1 : 10,000. The part of the work giving reliable information about the time- and cost-consumption of the individual methods was set up as the main aim. Under the effect of the large number of participating institutes, and hence the forthcoming possibilities of testing the diversity of technical equipment used and methods applied, as well as the desire to set the originally planned limits of the investigation higher, the work programme was soon greatly expanded. This plan could be realised all the sooner as its main features had been considered before the photogrammetric work started. The rate of success of the restitutions was concluded from the results of interpretation, from the accuracy of the situation- and height-measurements and from the time consumption.

Cartographic work is as a rule divided into the design of cartographic directions, the legend and sample maps as well as the development of technical regulations for practical map production. Before beginning the topographic work, in this case the interpretation, restitution and rectifying of the aerial photographs, the legend according to which the map image is built up, must be at hand. As consideration of this legend took up a considerable amount of time, and the practical work should begin as quickly as possible, first a provisional drawing instruction was compiled, sufficient for photogrammetric work. The final table of symbols as well as the map samples, were compiled so quickly however that even those were available in time for the photogrammetric work. It is to be noted that the guide lines for the cartographic work and the map samples, which have example [1] as a model must be considered as proposals. They can be modified according to the given conditions in the technical, topographic, cartographic, economic and scenic field, and as far as personnel is concerned. It would, therefore, be basically wrong to strive for uniform solutions.

2. Photogrammetric part of the work

2.1. Test area (fig. 1)

The selection of this area was influenced by photogrammetric, topographic, cartographic and geographical aspects. As far as photogrammetry was concerned it was necessary that at all scales no more than two models ought to be worked out. This was a result of the desire of the cooperating centres to limit the photogrammetric work where possible. With the photo scales 1 : 18,000; 1 : 25,000; 1 : 30,000 and 1 : 37,000 this resulted in a test field with an area of approximately 15 sq. kilometers. The close scale sequence was chosen so that the effect of the scale of the aerial photographs on the results could be fully detected. Moreover, it had only very little effect on the costs of the flight.

The topographic conditions were concentrated on:

- as great a contrast as possible in relief forms,
- a dense pattern of hydrography,
- larger built up areas of different form and development,
- a highly developed traffic network,
- a great variation in land use, with a great amount of forest.

This variety in topography should enable us to compare in different ways the possibilities and achievements of the methods used. It was, however, impossible to find a terrain which fulfilled all these opposing characteristics. The demands therefore had to be greatly reduced and a compromise made.

From a cartographic point of view it was necessary to use recent and exact large scale maps (preferably topographic base maps) as basic documents for the quality test of the different restitutions. Cadastral maps or cadastral plans could be sufficient also if the appropriate contour lines were available or could be produced photogrammetrically or terrestrially. The accuracy of this basic information should be within the established norms.

Because of possible terrain work (surveying, reconnaissance and control work) it was geographically necessary that the area was situated in the neighbourhood of Stuttgart, the seat of the pilot centre for the investigations.

The area shown in the section of the German topographic map at 1 : 50,000, Sheet Nr. L 7318 Calw corresponded most closely to the requirements. It must be taken into consideration that this map is not completely up to date. It can, however, quite well serve as a general map.

2.2. Camera and flight data

The aerial photographs were taken on 20.4.1968 with an aerial camera Zeiss RMK, A 15/23 with a Pleogon wide-angle lens, $f = 153$ mm, field of view 104° . A summary of flight data is given in table 1:

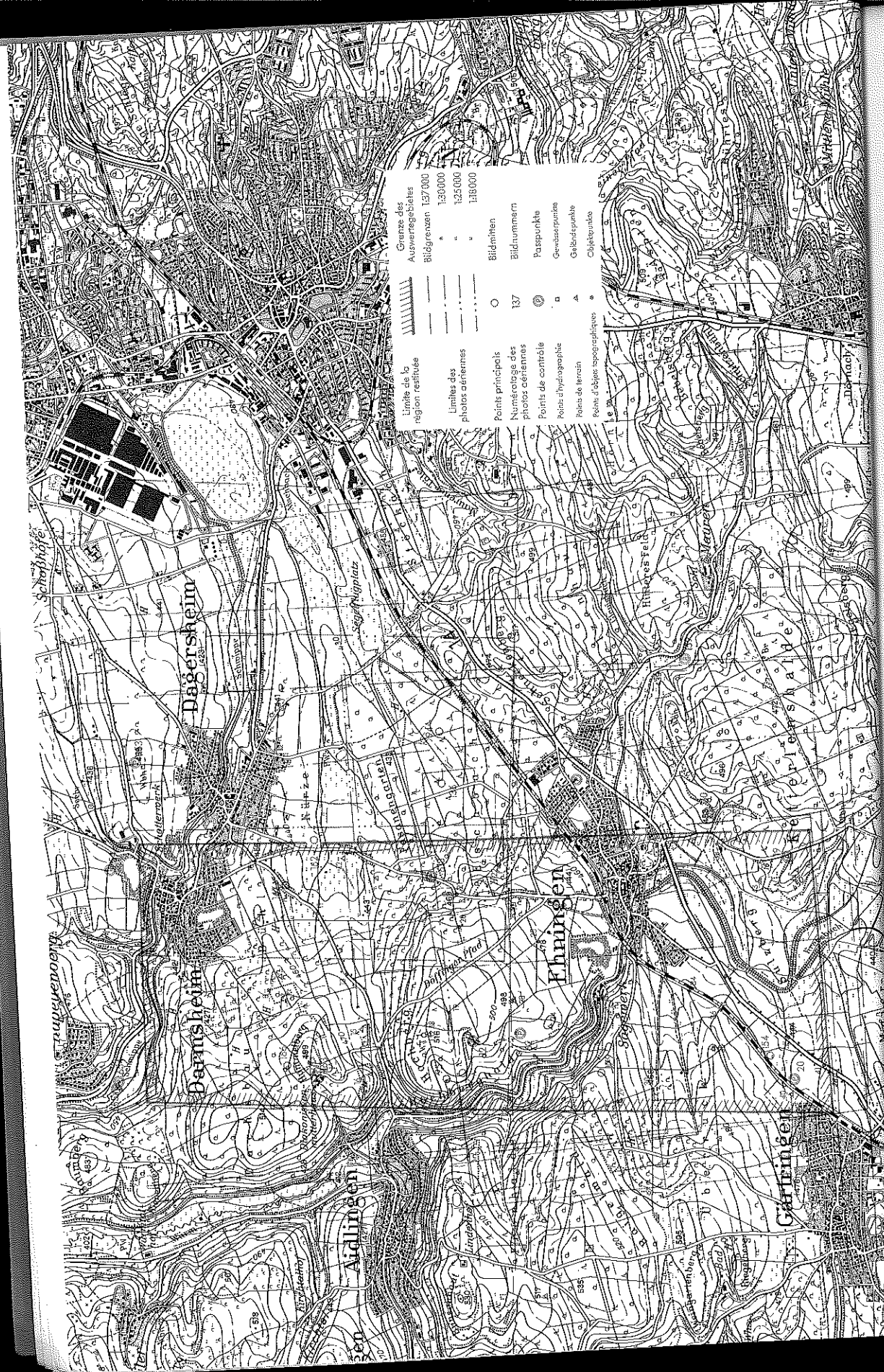


Table 1 — Summary of flight data

photo scales	flying altitude above ground (h_g)	picture overlap photographic coverage	strip & model
	1	2	3
1 : 37,000	5,700 m	longitudinal overlap 60%	1 + 1
1 : 30,000	4,600 m	lateral overlap 20%	1 + 1
1 : 25,000	3,800 m	Film negative	2 + 2
1 : 18,000	2,760 m		2 + 2

2.3. Basic data for the photogrammetric work

2.3.1. Aerial photographs

For each aerial photograph needed by the participating institutes, one positive on glass and 2 positives on paper were placed at their disposal. On one of the 2 contact prints the control points were indicated, as well as the points of which the heights were to be determined. These reproductions were combined into groups according to the photo scales. Their delivery followed the basic principle that in all cases only one set of aerial photographs of the same scale was at the participating institute. This arrangement was agreed upon so that independent results within the scale ranges were guaranteed.

2.3.2. Geodetic control data

For the determination of planimetric and altimetric control points a sufficiently dense (2 points/sq. km) and exact trigonometric and altimetric network was available. The coordinates of the control points needed by the participating centres for the photogrammetric work were at first determined by means of aerotriangulation conducted by the Institute for Photogrammetry from Stuttgart University. With the expansion of the examinations concerning the accuracy of the contour lines an extra 18 planimetric and 50 height-control points had to be determined by terrestrial survey.

2.3.3. Basic topographic documents

In place of the contour map at 1 : 2,500, which originated from a topographic ordnance map, and which no longer met modern demands, photogrammetric contour lines at 1 : 5,000 were produced from photographs at 1 : 12,000. This photogrammetric contouring was executed by the Institute for Photogrammetry of the University of Stuttgart. In connection with the surveying of the necessary control points, the Surveying Office of Baden-Württemberg determined a number of terrain profiles. These were used as proof of adequate accuracy of the photogrammetric contours at 1 : 5,000.

The 8 profiles (annex 9a) extended over a distance of approx. 5.3 km. Coordinates of the end points of these lines were determined either terrestrially or photogrammetrically. It was thus guaranteed that they could reliably be plotted in the contour line plot that had to be examined. The survey work required by this process could only be executed for some of the contour line plots. They were chosen so as to contain as much as possible of the terrain forms of the test area.

Along the profiles all points where the slope of the terrain changed were determined by tacheometric surveying. The density of the so measured profile points is indicated in annex 9a and the end points with transverse dashes. At the intersections of the contours and the profiles two heights result: the exact height (H_{Pr}) interpolated from two neighbouring profile points, and the nominal height ($H_{\delta L}$) of the corresponding contour line. From the differences:

$$d = H_{Pr} - H_{\delta L}$$

the standard deviation m_h was calculated according to:

$$m_h = \pm \sqrt{\frac{[d^2]}{n}} \quad (1)$$

The relationship between this standard deviation or m. sq. error and the terrain slope is expressed by:

$$m_h = \pm (a + b \cdot \tan \alpha) \quad (2)$$

The parameters a and b can be determined graphically and numerically by approximate and exact adjustment. Because of the smaller amount of work the semi-graphic process was applied here, which adequately fulfilled the demands. In the first instance the height differences were classified in the following classes of terrain slope:

Table 2 — Classes of terrain slope

0° — 1.5° 0.000 — 0.025	1.5° — 3° 0.026 — 0.051	3° — 4.5° 0.052 — 0.078	4.5° — 6° 0.079 — 0.104	degree tan α
6° — 9° 0.105 — 0.157	9° — 15° 0.158 — 0.267	15° — 25° 0.268 — 0.465	25° — 35° 0.466 — 0.700	degree tan α

For each group of points and each class

$$m_{hN} = \pm \sqrt{\frac{[d_N^2]}{n_N}}$$

was calculated.

By the equation

$$\tan_{MN} = \frac{[\tan_N]}{n_N} \quad (4)$$

also the average value of the inclination within one inclination class is determined. In a rectangular cartesian coordinate system the values $\tan_{MN}$ and m_{hN} are plotted as X- and Y-values (Examples: see fig. 9a to 9c, par. 2.6.4). From these graphics the parameters a and b of the adjusting straight lines can be derived approximately. The process was somewhat refined by mathematical determination of the coordinates of the centres of gravity of the point groups. They are calculated according to the following equations:

$$m_{hS} = \frac{[m_h \cdot n]}{[n]}; \quad \tan_S = \frac{[\tan \alpha]}{[n]} \quad (5)$$

For reference contour lines at 1 : 5,000 as derived photogrammetrically the following values were obtained:

$$m_h = \pm 0.34 \text{ m (from 125 profile points of intersection)} \quad (6)$$

and in consideration of the inclination conditions

$$m_h = \pm (0.27 + 0.6 \tan \alpha). \quad (7)$$

The limiting values [2], [3], [4], [5], which were recommended for the individual map scales m_h and with reference to the accuracy required by the German Basic Map (Deutsche Grundkarte 1 : 5,000)

$$m_h = \pm (0.5 + 5 \tan \alpha) \quad (8a)$$

was chosen as a standard of comparison. If this limiting value is compared to the above accuracy of reference contour lines at 1 : 5,000, it can be concluded that these photogrammetric contours can undoubtedly be used as a basis for the evaluation of the different terrain representations at 1 : 5,000.

The accuracy limits which are determined by m_h should be shown graphically in the reference contour map by bands. Their width (B_B) can be determined by the following equations:

$$m_{h\max} = \pm 2 m_h \quad (8b)$$

and

$$B_B = 4 m_h \cot \alpha. \quad (8c)$$

(3) The reference contour map with permissible variations in line position is given as annex 9a. If this reference image with the tolerances is transferred to the contour plots of the different institutes certain statements can be made about the accuracy of the individual contour restitutions. It is, however, difficult and laborious to find exactly the

results of these comparisons and to summarize them. For a better understanding of the relationship between height accuracy and parameters such as photo scale, production method, topography and terrain forms, further investigations, based on equations (1) and (3) had to be carried out. Furthermore all contour lines (photogrammetric as well as those derived from drop lines) were checked by the same method as applied to the reliability test of the reference contour map (semi-graphic method).

This threefold examination of the test results makes it possible to comment also on systematic errors. It will be seen which influences each process can expose, and whether one of the three methods of examination is able to represent all the effects sufficiently.

On the general rules [4]

$$M_{\text{photo}} \sim 200 \cdot \sqrt{M_{\text{map}}}$$

$$m_{\text{spot height}} = 0.1 \text{ to } 0.2 \text{ } ^0/_{00} \text{ of the flying altitude}$$

$$m_{\text{contour}} = 0.2 \text{ to } 0.3 \text{ } ^0/_{00} \text{ of the flying altitude}$$

the results were interrelated. For the orthophotographic process it was tried to determine another constant factor in equation (9a).

2.3.4. Basic cartographic documents

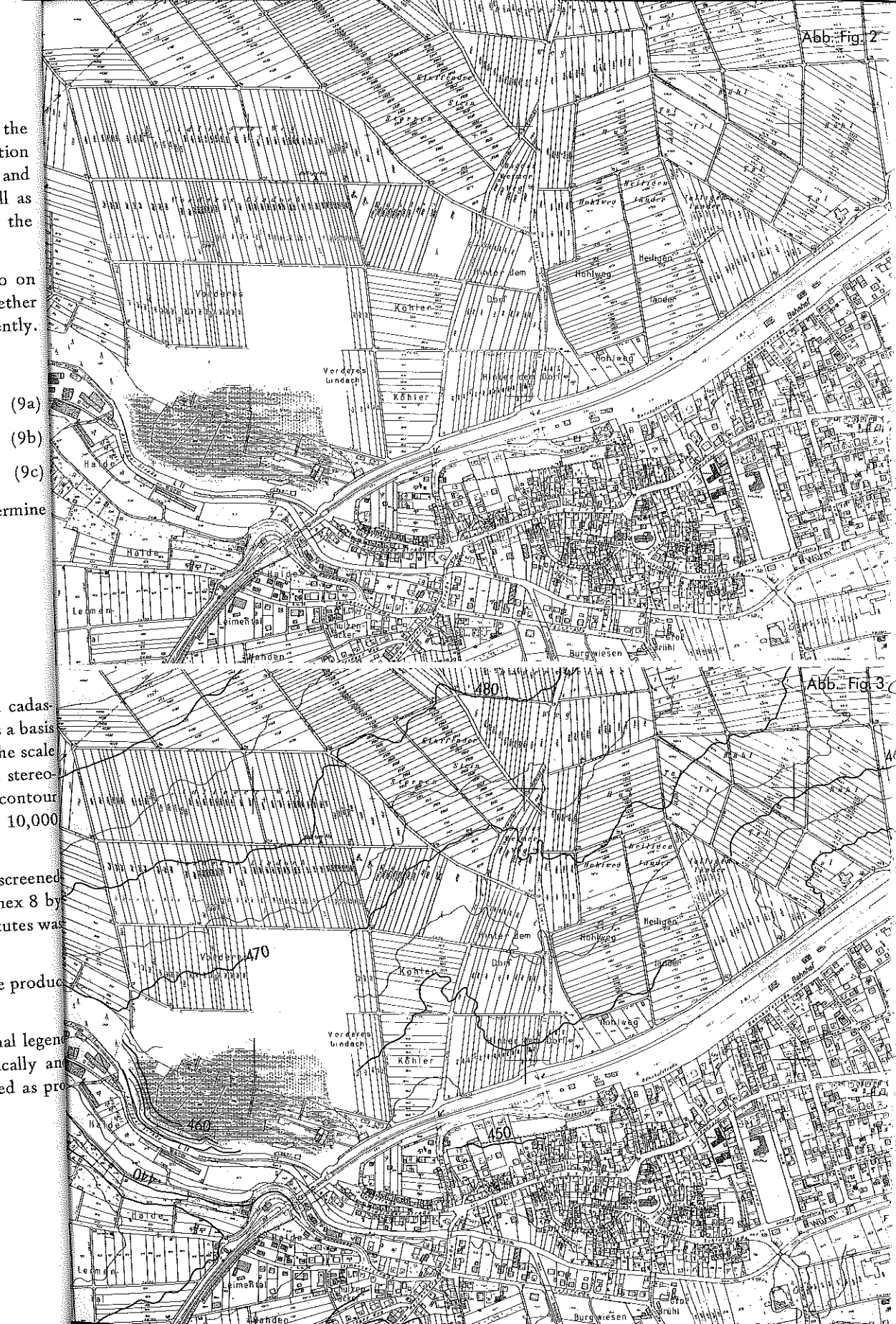
A cadastral map, the cadastral plan at 1 : 2,500, whose topographic and cadastral content represented the actual terrain situation at the time of flight, served as a basis for the analyses. This map was reduced in the limits of the area photographed to the scale of 1 : 10,000 and these reproductions were compiled (fig. 2). Together with the stereo-photogrammetric contour plotting at 1 : 5,000 (see par. 2.3.3 and annex 9a) the contour cadastral plan at 1 : 10,000 (see fig. 3) proved itself a topographic base map of 1 : 10,000 which was taken as the basis of different analyses.

Through the reduction of the cadastral plan at 1 : 2,500 the contrast of the screened built-up areas became insufficient. This lack of contrast was eliminated in annex 8 by covering the built-up areas. The comparison with the results of the different institutes was thus facilitated.

A complete legend (drawing instruction) with sample maps was essential for the production of a 1 : 10,000 line map.

As these tasks took too much time it was decided to prepare first a provisional legend with which the photogrammetric restitutions could be executed topographically and cartographically. The final legend with sample maps, which must be considered as proposals, were produced in due time.

The sample maps are mono- and multi-coloured (annex 16a to 16c and 17).



2.3.5. Other source material

Directives were given to the institutes as technical support. They contained indications regarding the dimensions and method of representation. In the directives the topographic details were divided into 5 object groups: buildings and settlements, traffic network, relief, water, and vegetation. Furthermore there were some form and time limitations.

The following list gives a summary of the participants of their working methods, and of the final delivered products.

Table 3 — Summary of the distribution of tasks and their results

Nr.	institute	photograph scale model	working method date	photo- gramm. instruments	phot. product representation drawing base
1	2	3	4	5	6
1	Federal Gauging and Surveying Institute, Vienna	1 : 37,000 94/95 1 : 25,000 153/154 162/163	stereophot. June 1969	Wild A8	Pencil and ink drawing. Metalled paper — rough copies —
2	EIRA, Florence	1 : 30,000 136/137 1 : 18,000 166/167 178/179	stereophot. June 1969 March 1970	Stereo- simplex Galileo- M II C	pencil and coloured pencil and ink drawing. Metalled paper. Plastic drawing material
3	IfAG, Frankfurt a. M.	1 : 37,000 94/95 1 : 30,000 136/137 1 : 25,000 153/154 162/163 166/167 178/179	orthophot. April 1969 July 1969 Aug. 1969 Sept. 1969	Zeiss C8 with ortho- projector GZ1	Continuous tone film drop lines. Pencil and ink drawing. — rough copy and fair drawing.
4	Institute for Photogrammetry, University of Stuttgart	1 : 37,000 94/95 1 : 30,000 136/137 1 : 25,000 153/154 162/163 166/167 178/179	stereophot. and orthophot. until March 1971	Zeiss C8 as above ortho- projector GZ1	Continuous tone film. Drop lines. Pencil and coloured pencil drawing. Stabilene Metalled paper — rough copies —
5	ITC, Enschede	1 : 30,000 136/137 1 : 18,000 178/179 166/167	orthophot. June to Sept. 1969 Sept. 1970	Zeiss C8 with ortho- projector GZ1	Continuous tone film. Drop lines. Scribing on stabilene. Ink drawing transp. astralon. — rough copies — and fair drawing.
6	Topographic Service, Delft	1 : 30,000 136/137 1 : 18,000 166/167 178/179	stereophot. June to Sept. 1969 Sept. 1970	Wild A8	Pencil, coloured pencil and ink drawing. Opaque and transparent astralon. — rough copies —

2.4. Photo interpretation

2.4.1. Introductory note

The interpretation of objects in aerial photographs in connection with the production of a topographic map [6], [7] has a quantitative and qualitative component. The analysis of the quantitative problems must aim to determine how many of the objects in the aerial photograph were correctly recognised. The result can be determined by the comparison of the number of mapped objects with that of the corresponding objects in the basic map. The process is basically concerned with counting and comparing the number of objects in the test results and the base map for a certain area.

In addition to quantitative success, the qualitative result can be considered. In this case it is the individual object which is of importance. The number of objects correctly interpreted is no longer checked, but rather how accurately the objects are recorded according to position and shape. The interpretation is no longer directed at the totality of the object, but at its details. This recognition is expressed geometrically and is reserved for examining the planimetric accuracy of the objects (see par. 2.5).

Both methods of interpretation refer to the objective characteristics of topographic objects. Subjective e.g. functional, historical, administrative and political properties are also referred to in topographic maps. As these characteristics cannot as a rule be derived from the aerial photograph — or only indirectly — this leads to the general proposal to adapt the map image in a way which is more favourable to aerial photographs. These problems cannot be discussed here because of lack of time. It is, however, to be noted that as an evaluation factor of objects in topographic base maps at 1 : 10,000, they no longer have the importance they do at larger scales.

The graphical representation of the interpretation results makes it possible to discover the most important features. It is a laborious task to state all details. Therefore numerical extracts from these graphic representations have been produced with which the performance quotas of the participants can be more easily measured both individually and reciprocally.

In addition to the graphic and numerical representations of the quantitative investigation, fragments of the mapping results of the participating institutes were added to this report as annexes. This was not so much a matter of checking the statistical results as of showing that mere comparisons by eye of such maps, as so often takes place, render little service to reliable judgement. The laborious path of statistical analysis must be taken in order to enable one to weigh with a certain amount of accuracy the quality of the analyses against each other, and judge their dependence on the internal and external factors having an effect on them.

To ensure easy comparison of the reference image (cadastral plan 1 : 10,000, annex 8) with the different interpretation results (annex 1a to 7c), they have all been printed on transparent sheets. They are, moreover, grouped in colours. The fragments originating from aerial photographs at the same scale appear in the same colour.

Technical and financial difficulties were the reason why only parts of the mapping results could be selected. Annexes 1a to 7c refer to the planimetric details, the pictures of object groups settlements, traffic-network, water and land use. The sheet lines of the map fragment enclose an area in the south-west of the test area. It reflects a good mixture of all topographic details and their density. This section, which is typical for planimetry, is on the other hand not characteristic for relief forms in the experimental area. A different section had therefore to be chosen for them.

The Surveying Office of Baden-Württemberg as pilot centre evaluated the necessary statistics of fig. 4a to 10c for the analysis and carried out the reproduction of annexes 1a to 20.

2.4.2. Buildings and settlements (fig. 4a to 4d and annexes 1a to 7c)

The relation between interpretation result and working method, photo scale, size and density of the topographic objects, can be successfully exposed by appropriate application of statistics. Hence the structure of fig. 4a to 4d is accounted for. The numbers included at the head of each representation correspond to the quantity of buildings incorporated in the investigations. These quantities fluctuate because of the different mapping formats of the delivered results. This fluctuation does not influence the results however. Geometrical definitions were dispensed with for the three density groups of built-up areas (dense, dispersed, open) and the three size-groups of the buildings (large, normal, and small), according to which the interpreted buildings are grouped. It is a classification of the evidence, and through it the aim of finding interdependence between the topographic and photographic constellation, and the success of interpretation, is well achieved.

False interpretation — namely cases in which other topographic objects, because of their photographic similarity, were incorrectly mapped as buildings — have been recorded also. They give an indication of the truth and reliability of the interpretation.

A preliminary analysis, which was organised strictly according to all four scales proved that the results of the interpretation are not so strictly dependent on scale, that the distribution of the enumeration at the four picture scales is possible, and that in so doing the increase of the figures and cost is twice as advantageous. Moreover this work could not have been accomplished with the available personnel. The investigations were therefore limited to two scale groups: 1 : 30,000 + 1 : 37,000 and 1 : 18,000 + 1 : 25,000. In the orthophotographic process the scale of 1 : 25,000 is not produced. The restitutions of the institutes in fig. 4a to 4d refer to the following scales (valid also for fig. 5a to 7d).

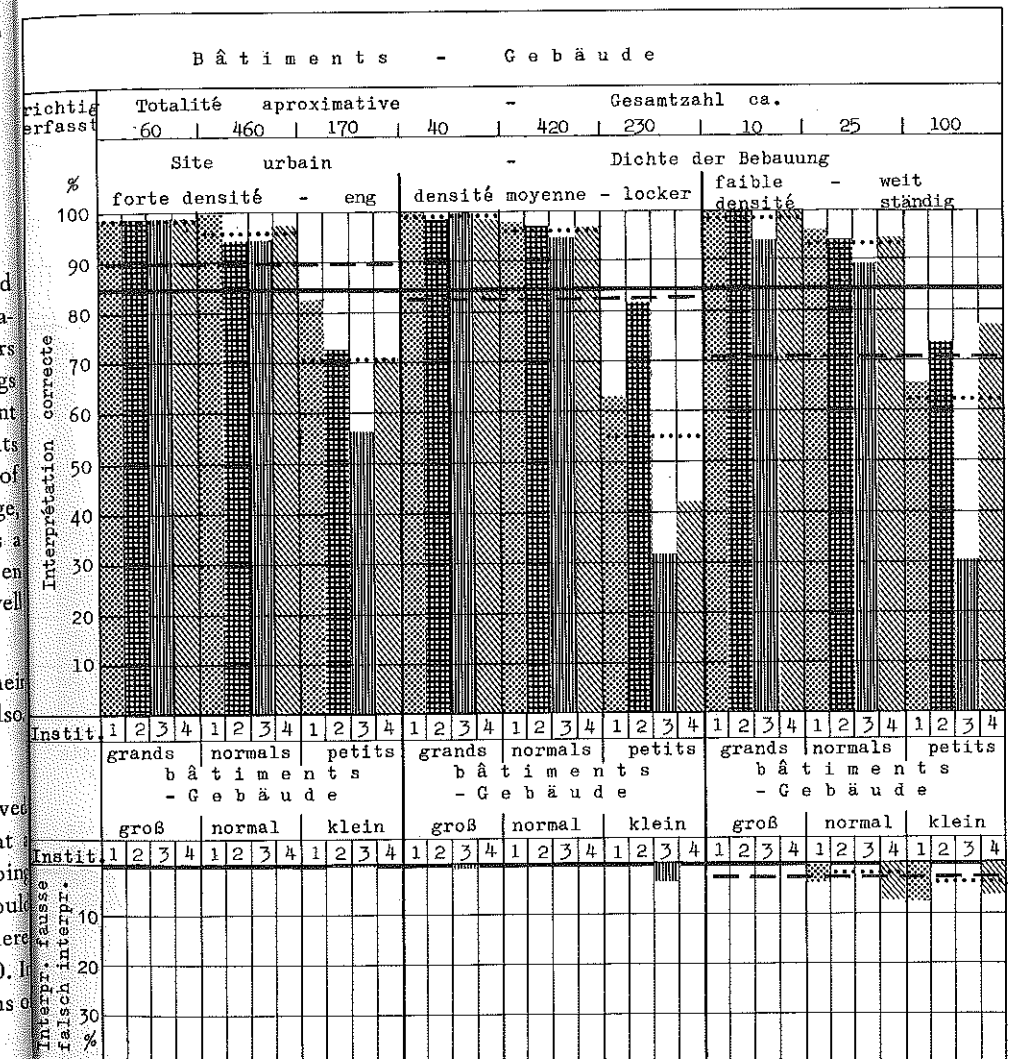
If the annexes 1a to 7c are placed upon annex 8 clear differences in the quality of the mapping results are visible. The differences between stereophotogrammetric and orthophotographic products are most striking. It is, however, difficult to evaluate these differences objectively. To do so, the fig. 4a to 4d and table 5 must be considered.

Interprétation de la planimétrie

Restitution stéréophotogrammétrique

Echelle d'image 1 / 30 000 - 1 / 37 000

Bâtiments
(Gebäude)



Centres de restitution : 1 = Bundesamt f. Eich- u. Verm. Wesen, Wien
2 = EIRA, Florenz
3 = Institut f. Photogrammetrie d. Univers. Stuttgart
4 = Topographische Dienst, Delft

Abb.-Fig.4b

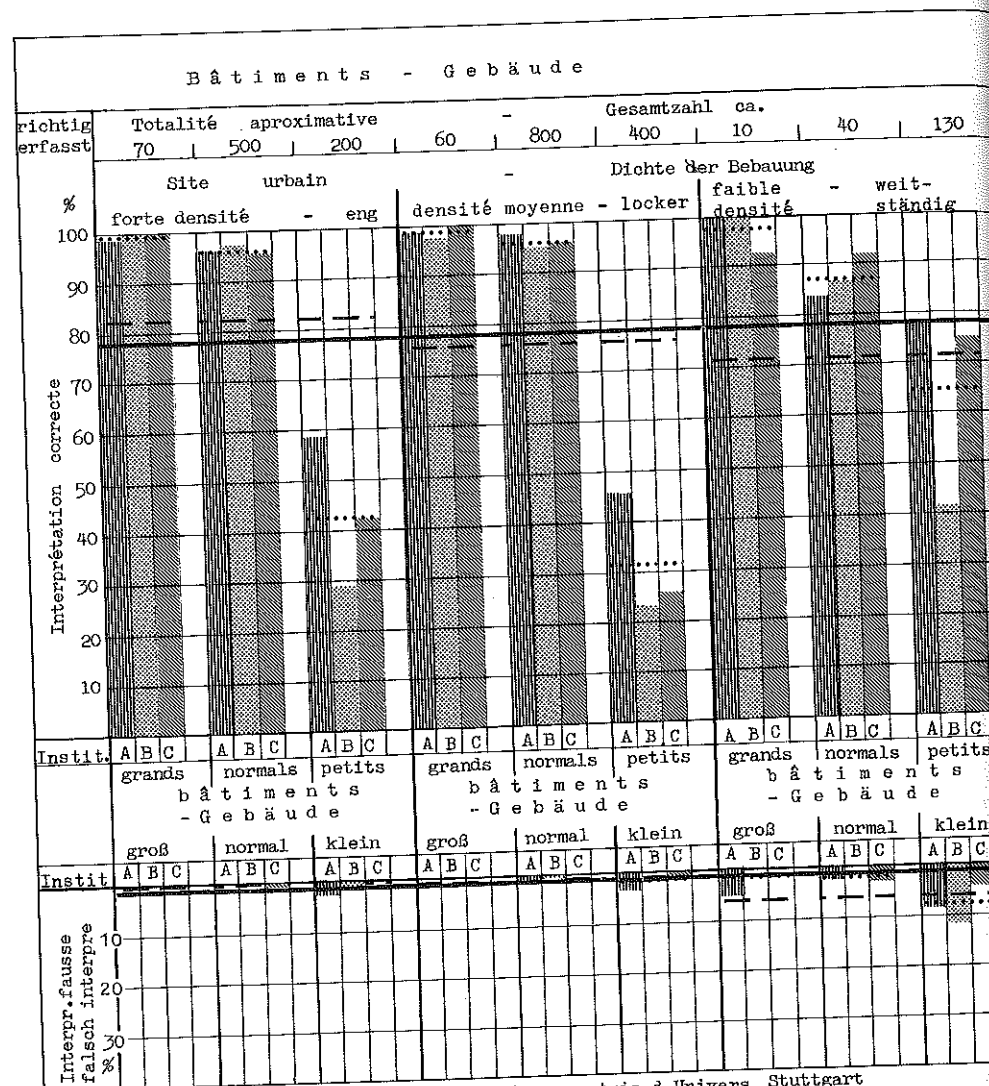
OEEPE / Comm. D

Champ d'Essai "Stuttgart"

Interprétation de la planimétrie

Restitution orthophotographique

Echelle d'image 1 / 30 000 - 1 / 37 000

Bâtiments
(Gebäude)

Centres de restitution: A = Institut f. Photogrammetrie d.Univers. Stuttgart
 B = IfAG, Frankfurt
 C = ITC, Enschede

Abb.-Fig.4c

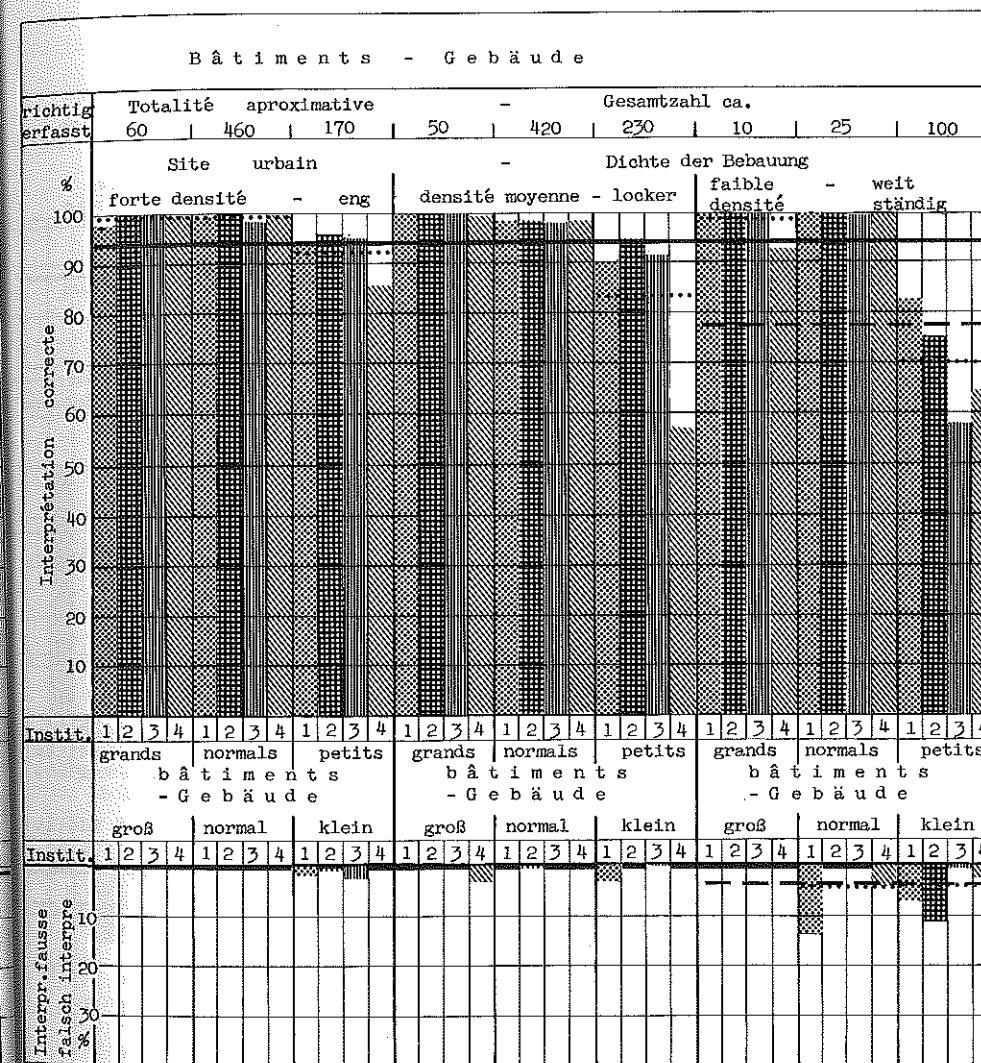
OEEPE / Comm. D

Champ d'Essai "Stuttgart"

Interprétation de la planimétrie

Restitution stéréophotogrammétrique

Echelle d'image 1 / 18 000 - 1 / 25 000

Bâtiments
(Gebäude)

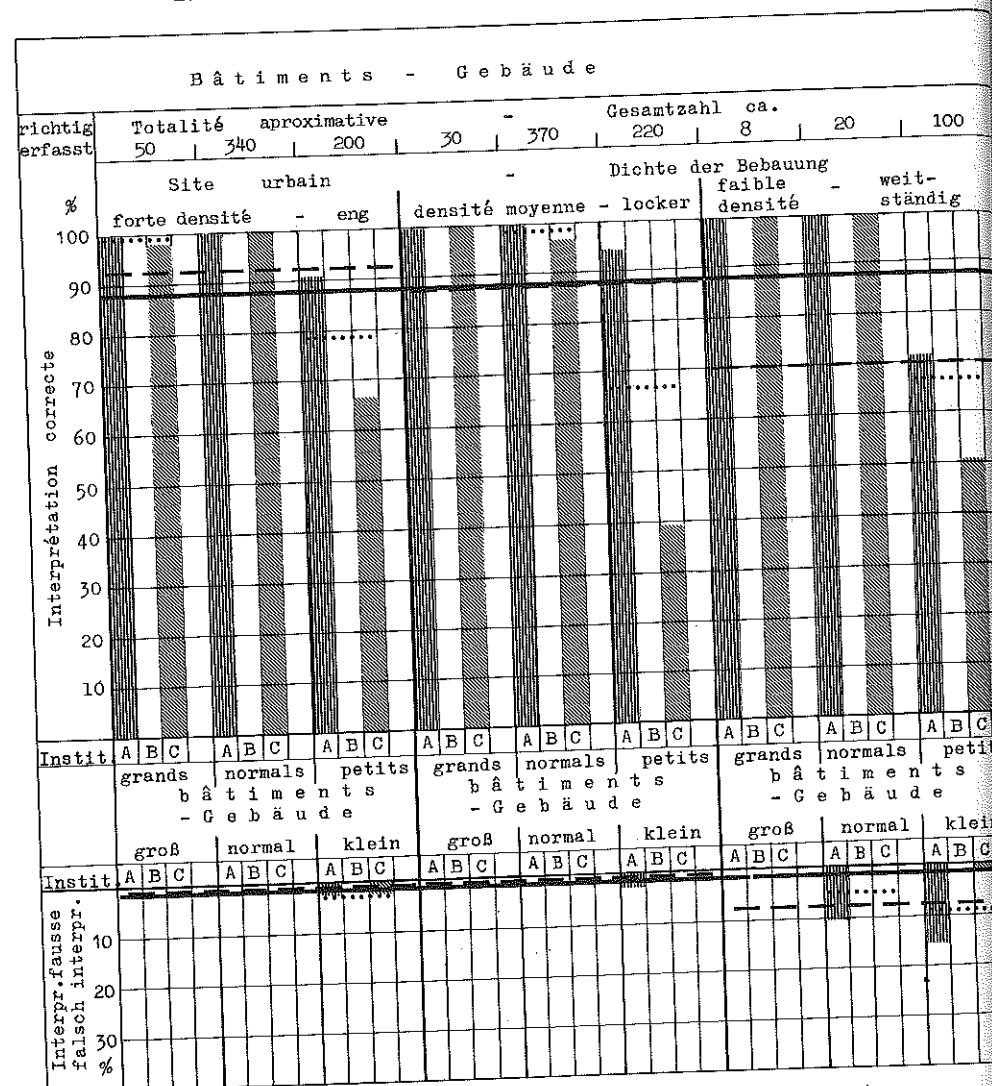
Centres de restitution: 1 = Bundesamt f. Eich-und Verm.Wesen, Wien
 2 = EIRA, Florenz
 3 = Institut f. Photogrammetrie d.Univers. Stuttgart
 4 = Topographische Dienst, Delft

Interprétation de la planimétrie

Restitution orthophotographique

Echelle d'image 1 / 18 000

Bâtiments
(Gebäude)



Centres de restitution: A = Institut f. Photogrammétrie d. Univers. Stuttgart

C = ITC, Enschede

Table 4 - Working methods and use of aerial photographs

process	institute	aerial photo scale	
		group 1	group 2
1	2	3	
stereophot.	1 (Vienna)	1 : 37,000	1 : 25,000
	2 (Florence)	1 : 30,000	1 : 18,000
	3 (Stuttgart)	1 : 37,000	1 : 18,000
	4 (Delft)	1 : 30,000	1 : 18,000
orthophot.	A (Stuttgart)	1 : 37,000	1 : 18,000
	B (Frankfurt)	1 : 37,000 2 ×	—
	C (Enschede)	1 : 30,000	1 : 18,000

Table 5 — Result of the interpretation of buildings

process	aerial photo scale (see table 4, sect. 2.4.2)	buildings (cadastral plan) (exact number)	correctly interpreted buildings (actual quantity)		incorrectly interpreted buildings	
			number	%	number	%
	1	2	3	4	5	6
stereophot.	1 : 30,000 1 : 37,000	1515	1284	85	13	0.9
	1 : 18,000 1 : 25,000	1525	1429	94	11	0.7
orthophot.	1 : 30,000 1 : 37,000	2210	1717	78	30	1.4
	1 : 18,000	1338	1174	88	20	1.5

In connection with fig. 4a to 4d the following conclusions can be drawn from these analyses:

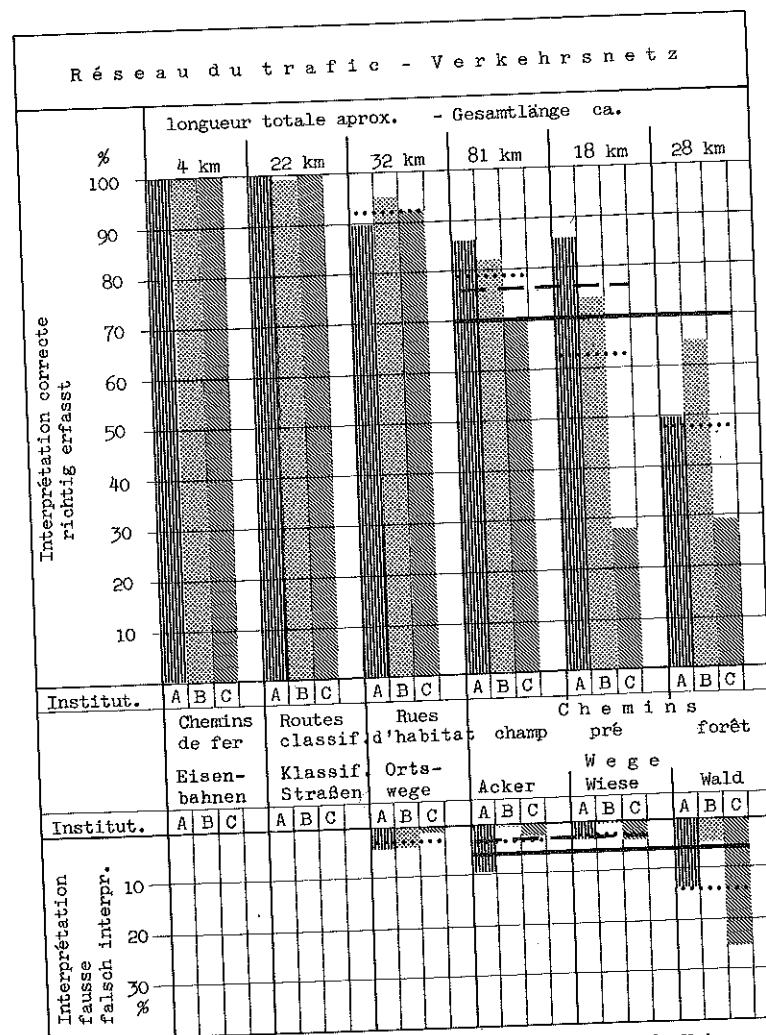
- The numbers of missing buildings are dependent on the size of the objects, their density and the scale of the aerial photos. The smaller the buildings and the photo scales, and the greater the distance between the objects, the higher the imperfection and lack of certainty of the interpretations.
- The gain in the number of interpretations from a smaller to a larger photo scale amounts to 10 % in both cases.

The interpretation success rate for orthophotos is 6 to 7 % lower than for stereophotogrammetry in both scale groups. If this loss is to be made up, the scale of the aerial photo on which the orthophotograph is based must be approx. 1 : 12,000 (roughly calculated from the reduction of the scale denominator from 37,000 to 18,000, the corresponding increase in interpretations of about 10 % and their necessary increase of

Interprétation de la planimétrie

Restitution orthophotographique

Echelle d'image 1 / 30 000 - 1 / 37 000

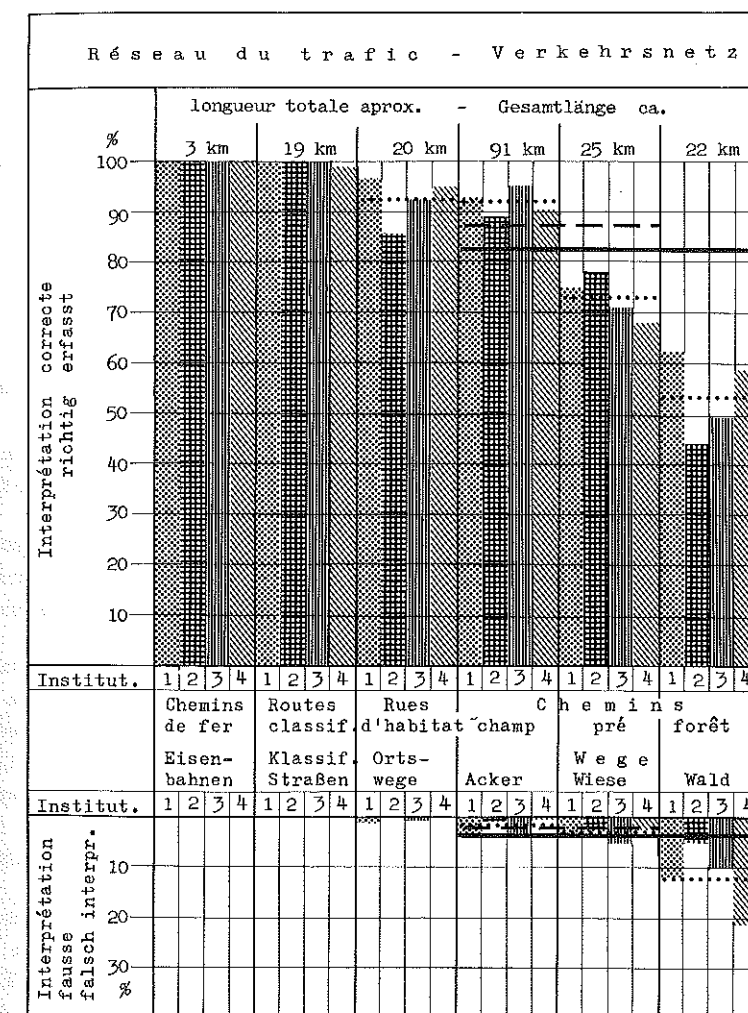
Réseau du trafic
(Verkehrsnetz)

Centres de restitution: A = Institut f. Photogrammetrie d. Univers. Stuttgart
B = IFAG, Frankfurt
C = ITC, Enschede

Interprétation de la planimétrie

Restitution stéréophotogrammétrique

Echelle d'image 1 / 18 000 - 1 / 25 000

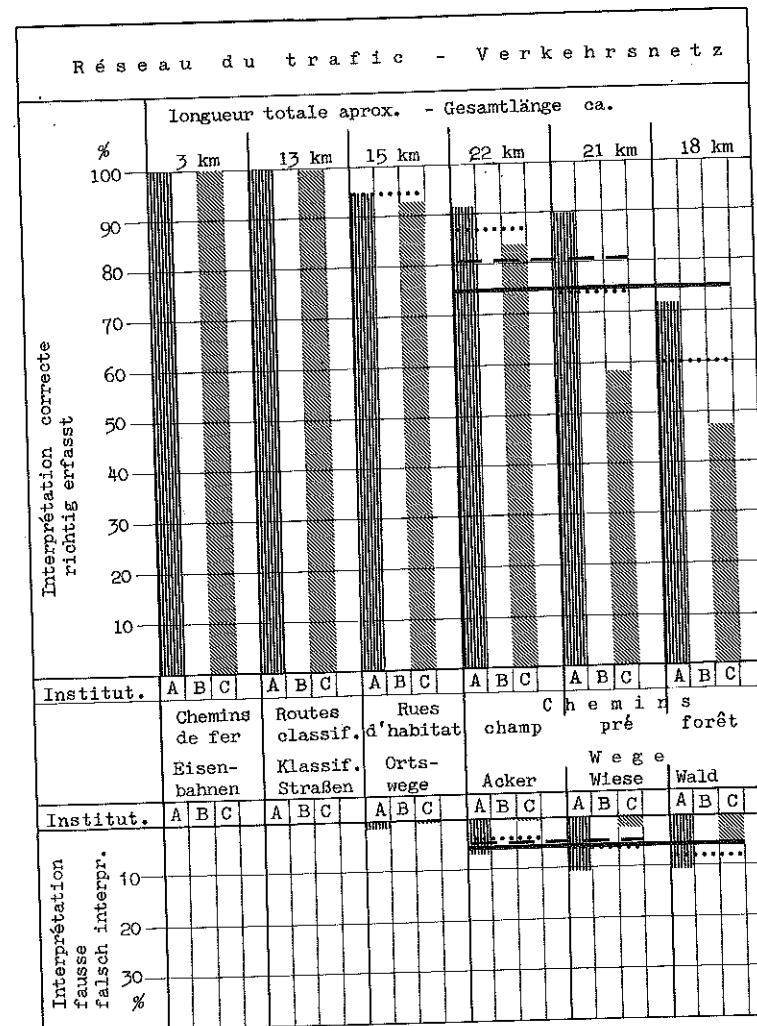
Réseau du trafic
(Verkehrsnetz)

Centres de restitution: 1 = Bundesamt f. Eich- und Verm. Wesen, Wien
2 = EIRA, Florenz
3 = Inst. f. Photogr. d. Univers. Stuttgart
4 = Topographische Dienst, Delft

Interprétation de la planimétrie

Restitution orthophotographique

Echelle d'image 1 / 18 000

Réseau du trafic
(Verkehrsnetz)

The contents of fig. 5a to 5d are summarized as follows:

Table 6 - Results of the interpretation of the traffic network

process	aerial photo scale (see table 4, sect. 2.4.2)	length of roads (exact)	rail- ways	class. roads	town streets	paths		
						total	field meadow	forest
	1		2	3	4	5	6	7
stereophot.	1 : 30,000 1 : 37,000	255 km	100%	100%	91% (1%)	76% (9%)	83% (5%)	56% (23%)
	1 : 18,000 1 : 25,000	177 km	100%	100%	92.5%	82% (4%)	88% (2%)	54% (12%)
orthophot.	1 : 30,000 1 : 37,000	181 km	100%	99.5%	92% (1%)	70% (6%)	76% (4%)	48% (14%)
	1 : 18,000	89 km	100%	100%	94% (1%)	75% (6%)	81% (4%)	60% (8%)

Note: Numbers in brackets = incorrect interpretations in % of the respective exact lengths.

From this table and from fig. 5a to 5d the following results are obtained:

- Railways and classified roads are mapped in both processes and both scale groups almost in their entirety.
- The missing number of interpreted urban roads is due to external influences (central perspective, unfavourable incidence of light). Otherwise the larger scale ought to have affected the interpretations more strongly.
- The deficit of interpretation totally concerns the field roads. In the stereophot. process it amounts to 12 % in the large scale group and in the open terrain (field and meadow), and to 17 % in the small group. Through that it is nominally up to twice as large (12 % in face of 6 % and 17 % in face of 15 %; see table 5 column 4) as in the interpretation of buildings and is not so readily influenced by photo scale. Aerial photos at larger scale could not essentially reduce the amount of road reconnaissance; the higher photogrammetric costs would not be worth while.
- The loss in the orthophotographic process is in both scale groups about 7 % larger than in the stereophot. process. It cannot be compensated with aerial photos of a larger scale. The drop in performance in face of stereo-restitution is just as large as in the interpretation of buildings. The necessary topographic road reconnaissance is here particularly facilitated and accelerated by the use of orthophotos.
- In forest areas the high quota of incorrectly interpreted paths involves a field check of the complete path network in both processes.

2.4.4. Water (fig. 6a to 6d and annexes 1a to 7c)

According to the arrangement of water in annex 15, page 5 and 6 the analysis of the aerial photo extends over standing and flowing water. Because of their topographic relationship the ditches along the roads are included also in this group of investigations. This underlines how the difficulties of interpretation grow noticeably with the smaller size of the objects.

The lakes to be interpreted are of small length (between 10 and 100 m). Without exception they lie in old disused quarries.

The amount of flowing water is about 1 km/sq. km. Against that the intensity of ditches is twice as high. The shift of analyses into the field of the smallest objects was done to clear up to just what degree the aerial restitutions need terrestrial completion when the demands of the map are high. Or in other words the standard for the qualitative performance of the process was here defined also by detail. This information should show the map-producer what influence the working method exerts on the result and what the consequences are with respect to the quality of the map if field reconnaissance is missing completely or partly.

The scales of the aerial photos for the individual restitutions remain unchanged (see sect. 2.4.2).

The results of the investigations as represented in fig. 6a to 6d have been summarized as follows.

Table 7 — Result of the interpretation of water

process	aerial photo scale (see table 4, sect. 2.4.2)	current water			ditches		
		exact length	(interpreted) actual length		exact length	(interpreted) actual length	
		2	3	4	5	6	7
stereophot.	1 : 30,000 1 : 37,000	15 km	14.6 km	97% (0%)	33 km	16 km	48% (3)
	1 : 18,000 1 : 25,000	11 km	10.9 km	99% (0%)	22 km	11 km	50% (10)
orthophot.	1 : 30,000 1 : 37,000	14 km	13 km	93% (0%)	31 km	11 km	35% (0)
	1 : 18,000	10 km	10 km	100% (11%)	19 km	8 km	31%

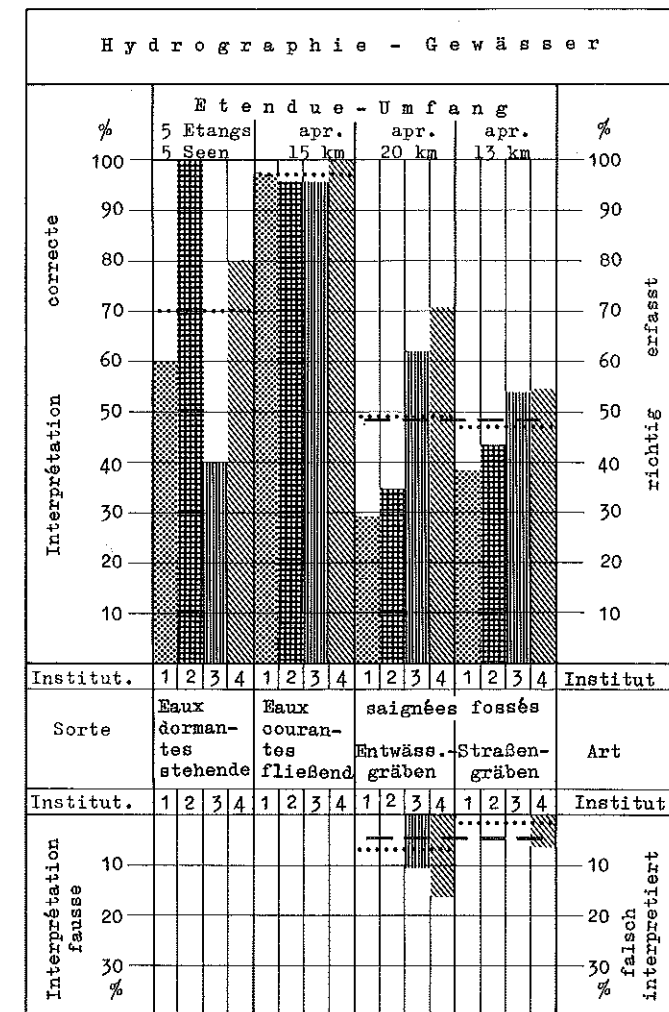
Note: Numbers in brackets = incorrect interpretations.

Interprétation de la planimétrie

Restitution stéréphotogrammétrique

Echelle d'image 1/30 000 - 1/37 000

Hydrographie
(Gewässer)



Centres de restitution: 1 = Bundesamt Wien
2 = EIRA Florenz
3 = Instit.f.Phot. Stuttgart
4 = Top.Dienst Delft

Abb.-Fig. 6b

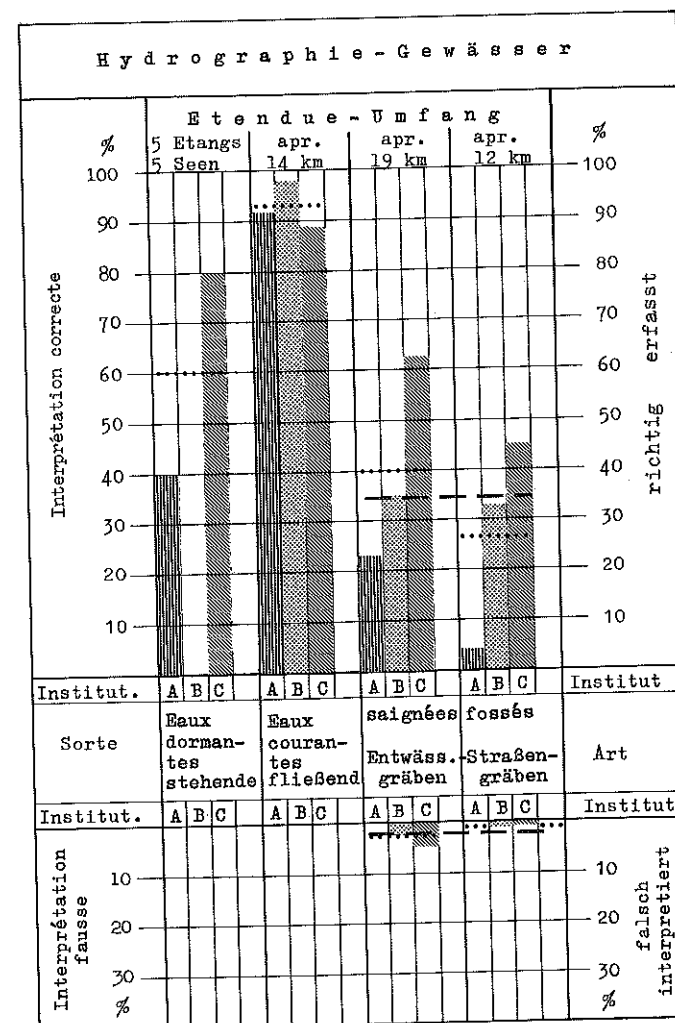
OEEPE / Comm. D

Champ d'Essai "Stuttgart"

Interprétation de la planimétrie

Restitution orthophotographique

Echelle d'image 1/30 000 - 1/37 000

Hydrographie
(Gewässer)

Centres de restitution: A = Instit.f.Phot. Stuttgart
B = IfAG Frankfurt
C = ITC Enschede

Abb.-Fig. 6c

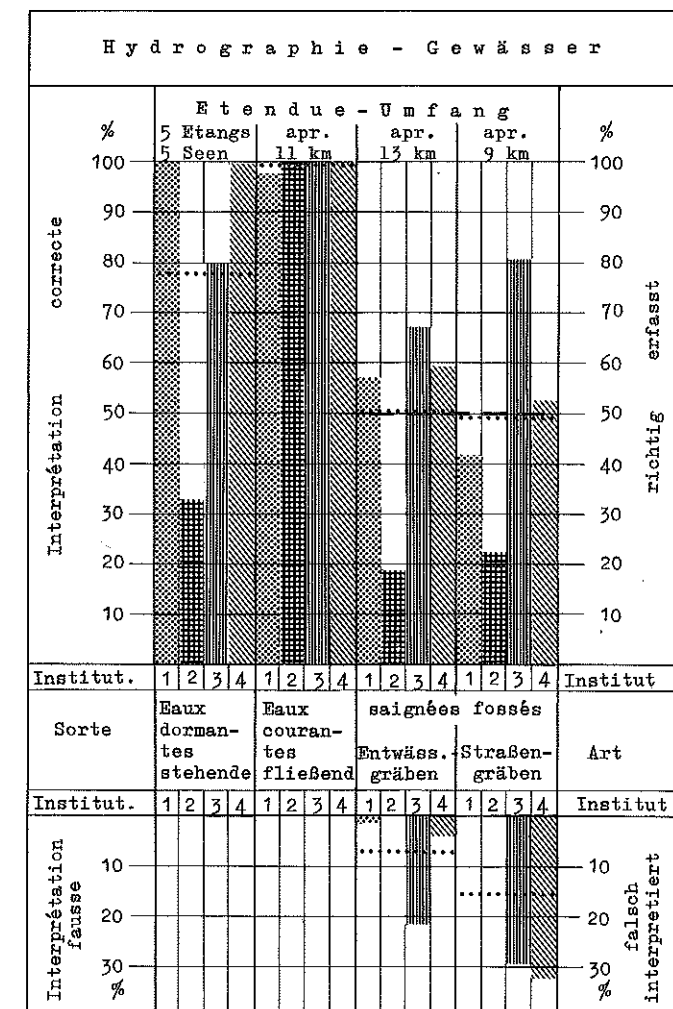
OEEPE / Comm. D

Champ d'Essai "Stuttgart"

Interprétation de la planimétrie

Restitution stéréophotogrammétrique

Echelle d'image 1 / 18 000 - 1 / 25 000

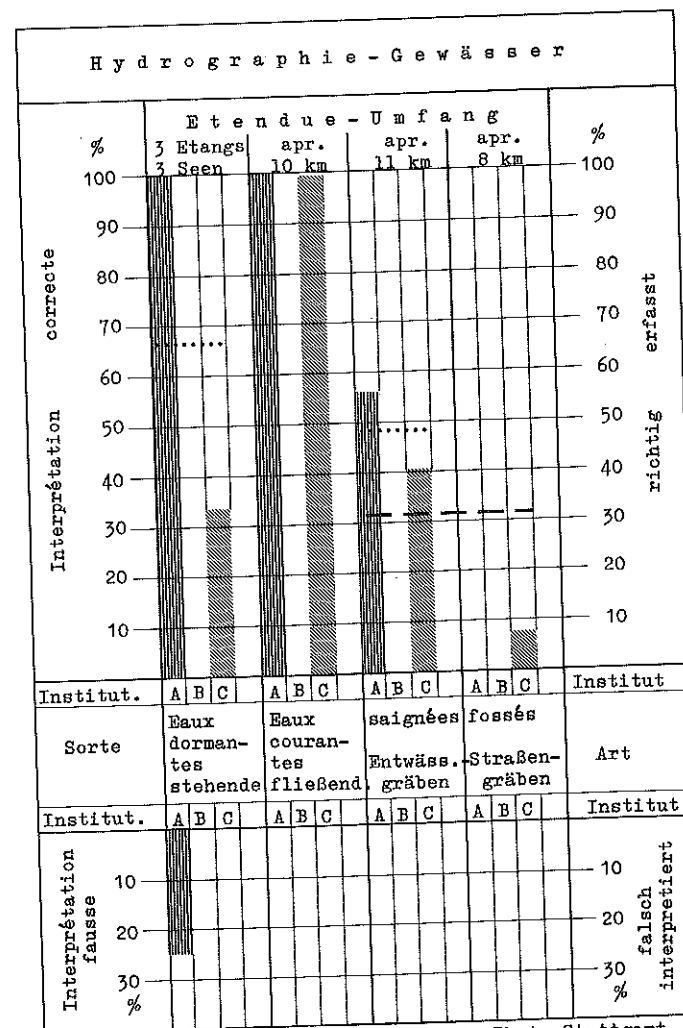
Hydrographie
(Gewässer)

Centres de restitution: 1 = Bundesamt für Eich- und Vermessungswesen, Wien
2 = EIRA, Florenz
3 = Institut für Photogrammetrie der Univers. Stuttgart
4 = Topographische Dienst, Delft

Interprétation de la planimétrie

Restitution orthophotographique

Echelle d'image 1/18 000

Hydrographie
(Gewässer)

Centres de restitution: A = Instit. f. Phot. Stuttgart

C = ITC Enschede

Abb.-Fig. 6d

From table 7 and fig. 6a to 6d the following is concluded:

- Flowing water is almost completely interpreted in the large scale groups in both processes.
- The stereophot. process is more efficient at the smaller photo scale than the orthophot. process at the large photo scale (column 7). The variation from the smaller to the larger photo scale brings for the stereophotogrammetric method a gain of 2 %, but for the orthophoto method a loss in efficiency of 4 %.
- Small objects were stereophotogrammetrically correct up to 50 %, in the orthophoto method on the other hand only to about 30 %.
- Standing water is up to 70–78 % recognised in the stereophoto, whereas only up to 60–65 % in the orthophoto.
- The achievements of both processes are much further apart than in the object groups examined up to now.

2.4.5. Land use (vegetation) (fig. 7a to 7d and annexes 1a to 7c)

Only the most common sorts of land use, contained in pages 17 and 18 of annex 15, were investigated. As the vegetation class "arable land" as such did not exist in the legend its surface had to be concluded from those of the other classes. By doing so the deficits and surpluses in the interpretation of the other classes of soil use influence the result for "arable land". For example, the high quota of 63 % or 1.3 sq. km. of incorrect interpretation of the use of the soil – "meadow" (see fig. 7a) under number 2 is adequately made up for by the deficit under "arable land" in the corresponding column.

The arrangement of fig. 7a to 7d corresponds to the principles of sect. 2.4.2 to 2.4.4. The analyses refer to units of area. The results of the fig. 7a to 7d are arranged in the following table:

Table 8 – Results of the interpretation of vegetation

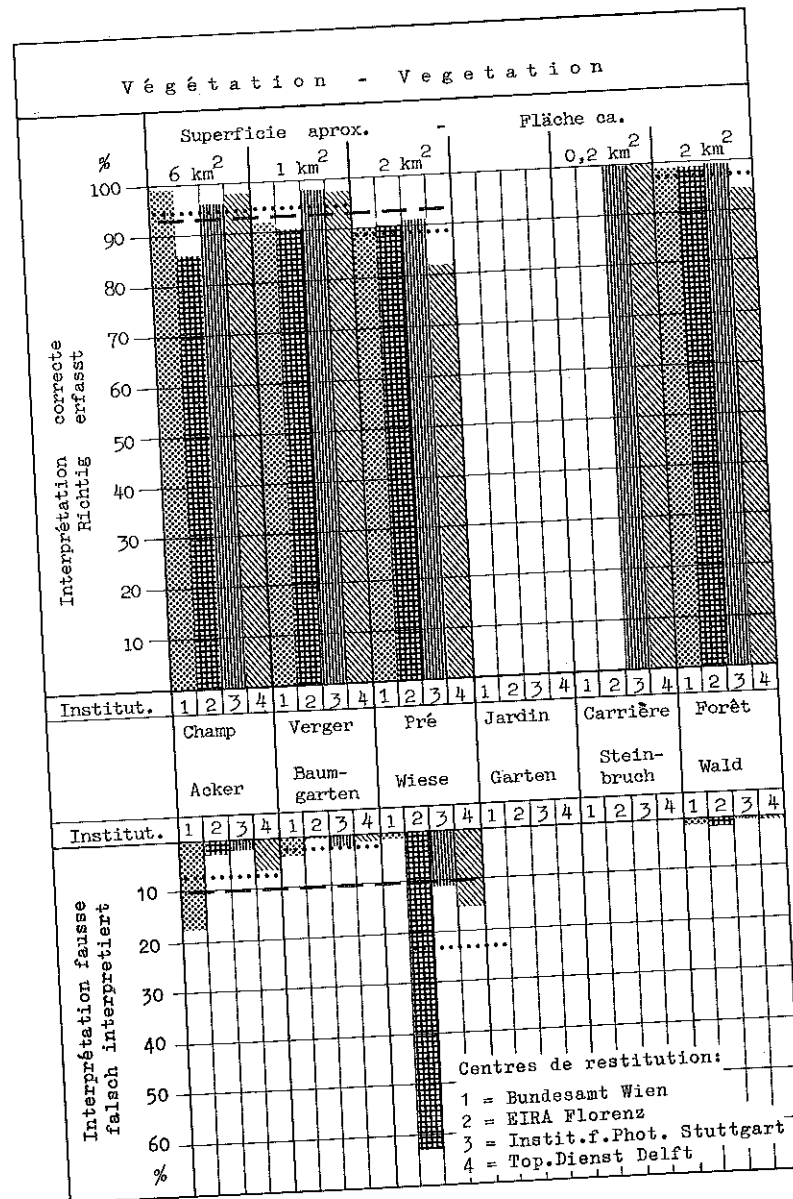
process	aerial photo scale (see table 4, sect. 2.4.2)	exact surfaces	interpreted surfaces	
			arable land, grass- land and orchard	forest
	1	2	3	4
stereophot.	1 : 30,000	11 km ²	93% (10%)	97% (1%)
	1 : 37,000			
orthophot.	1 : 18,000	11 km ²	85% (11%)	96% (3%)
	1 : 25,000			
	1 : 30,000	19 km ²	94% (6%)	97% (1%)
	1 : 37,000			
	1 : 18,000	11 km ²	92% (9%)	98% (0,5%)

Note: Numbers in brackets = incorrect interpretations.

Interprétation de la planimétrie

Restitution stéréophotogrammétrique

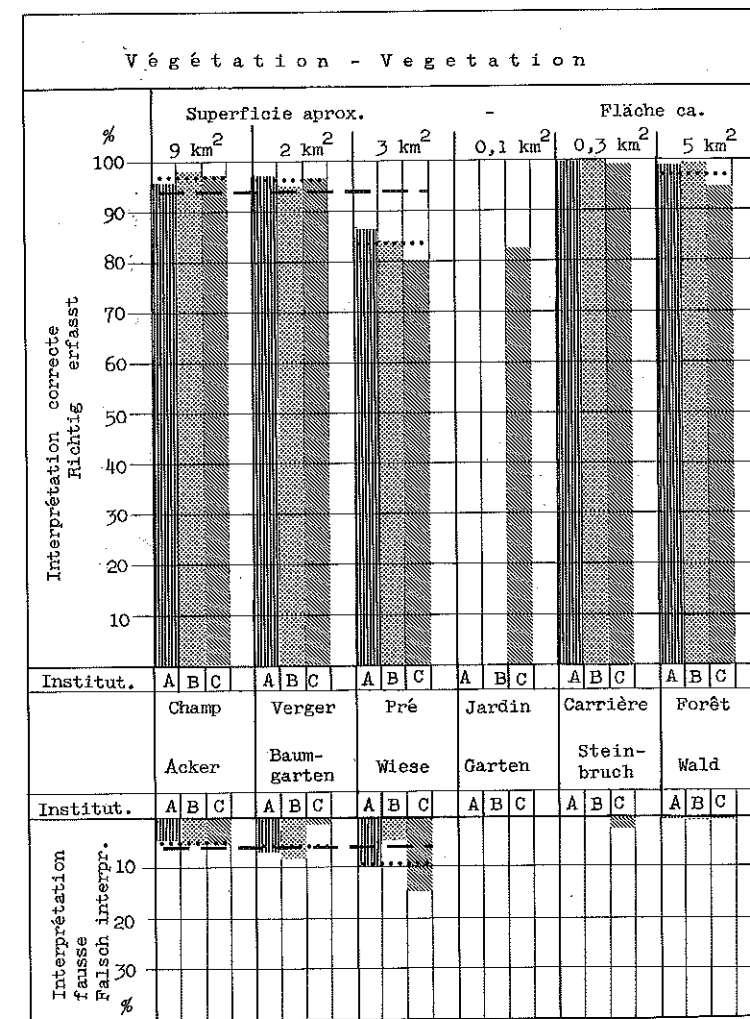
Echelle d'image 1 / 30 000 - 1 / 37 000

Végétation
(Vegetation)

Interprétation de la planimétrie

Restitution orthophotographique

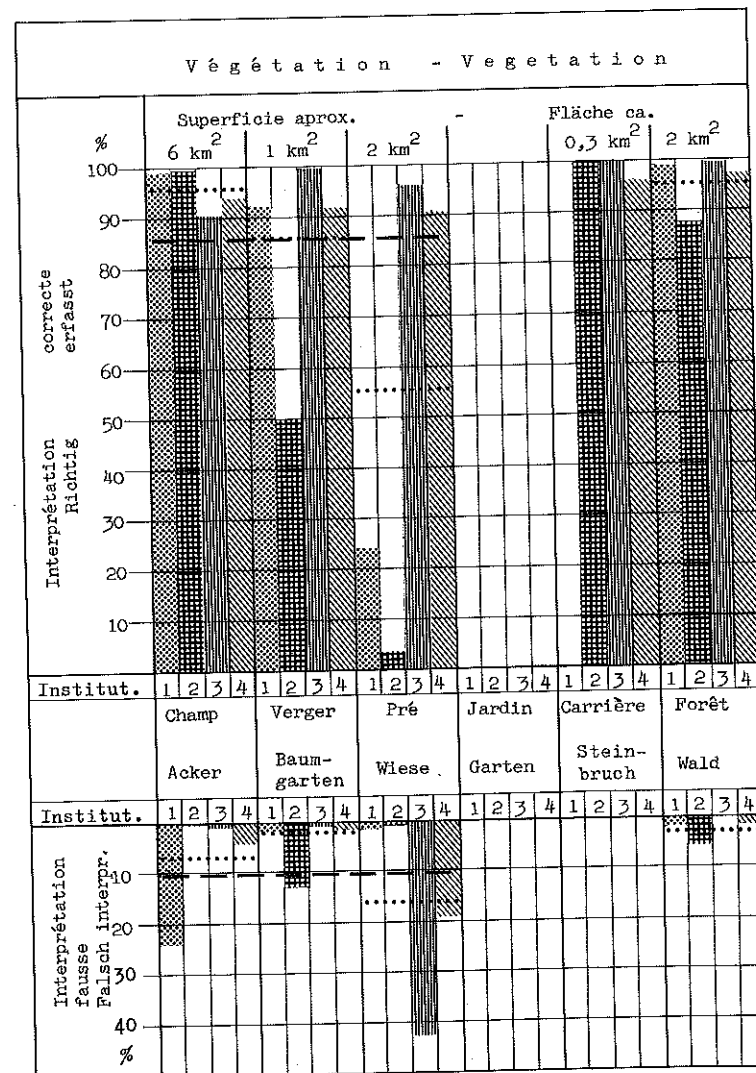
Echelle d'image 1 / 30 000 - 1 / 37 000

Végétation
(Vegetation)

Centres de restitution : A = Institut f. Photogrammetrie d. Univers. Stuttgart
B = IfAG, Frankfurt
C = ITC, Enschede

Interprétation de la planimétrie

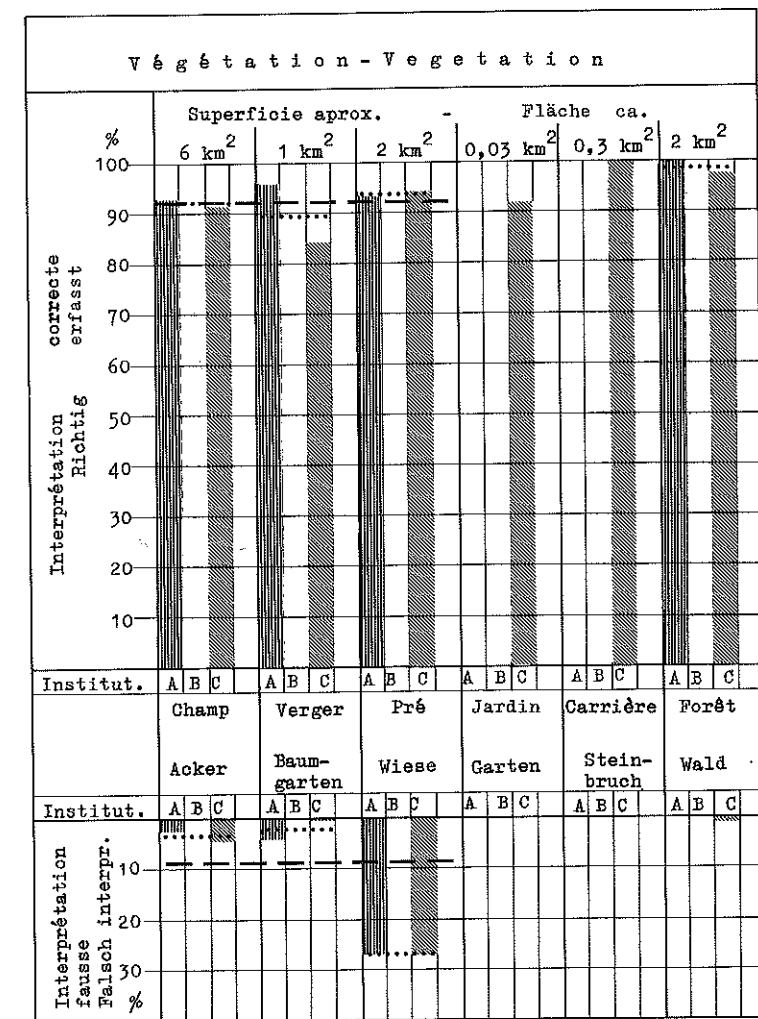
Restitution stéréophotogrammétrique (Végétation)
 Echelle d'image 1 / 18 000 - 1 / 25 000



Centres de restitution: 1 = Bundesamt Wien
 2 = EIRA Florenz
 3 = Instit.f.Phot. Stuttgart
 4 = Top.Dienst Delft

Interprétation de la planimétrie

Restitution orthophotographique (Végétation)
 Echelle d'image 1 / 18 000



Centres de restitution: A = Inst. f. Photogr. der Univers. Stuttgart

C = ITC, Enschede

From this summary and from fig. 7a to 7d the following results are obtained:

- Both processes obtain better results at the smaller photo scale than the larger one. A contradictory statement whose cause is first to be looked for in the individual influence on the restitutions. The differences and the amount of incorrect interpretations of fig. 7a to 7d indicate this.
- Both processes are approx. equally productive.
- The classes of land use stipulated in annex 15, page 17 and 18 raise no difficulties for the interpretation.

2.5. Planimetric accuracy (fig. 8, annex 8 and annexes 1a to 7c)

The accuracy of the photogrammetric and orthophotographic restitutions can be proved analytically and geometrically. In the first case the differences of the coordinates of fixed points are used, and in the second process the differences between the reference map and the test result, in order to establish the degree of their deviation. This process has the advantage that it needs no signalisation, but also the disadvantage that the analyses of the mappings are quite laborious and therefore expensive. In the case in hand there was no choice as to the process, because field work was out of the question.

Two zones (see annex 8) of the built-up area of the village Ehningen (see fig. 1, annex 8 and annexes 1a to 7c) formed the basis of the geometric analyses. Objects of investigation were the planimetric position and shape of the buildings represented.

The deviations of each mapping from the reference map, which annex 8 represents, were arranged in 3 categories: In the first group were classified deviations up to 0.2 mm; in the second group incorrect amounts of up to 0.5 mm and in the third all larger deviations. In this way 26 analyses, which are compared in fig. 8, were the results. The results are assembled together according to scale in the following table. For economic reasons the division of the position- and ground plan accuracy was not undertaken.

Table 9 — Planimetric accuracy of buildings

process	aerial photo scale (see table 4, sect. 2.4.2)	building					
		dense			sparse		
		≤ 0.2 mm	> 0.2 - 0.5 mm	> 0.5 mm	≤ 0.2 mm	> 0.2 - 0.5 mm	> 0.5 mm
stereophot.	1	2	3	4	5	6	7
	1 : 30,000						
	1 : 37,000	34%	45%	21%	33%	38%	2%
	1 : 18,000						
orthophot.	1 : 37,000						
	1 : 18,000	51% (65%)	40% (31%)	9% (4%)	54% (78%)	32% (18%)	14%
	1 : 25,000						
	1 : 18,000	43%	45%	12%	28%	40%	3%

Note: In brackets is the result of the restitution from photo scale 1 : 25,000; % refers to the exact number of buildings in the two zones (annex 8).

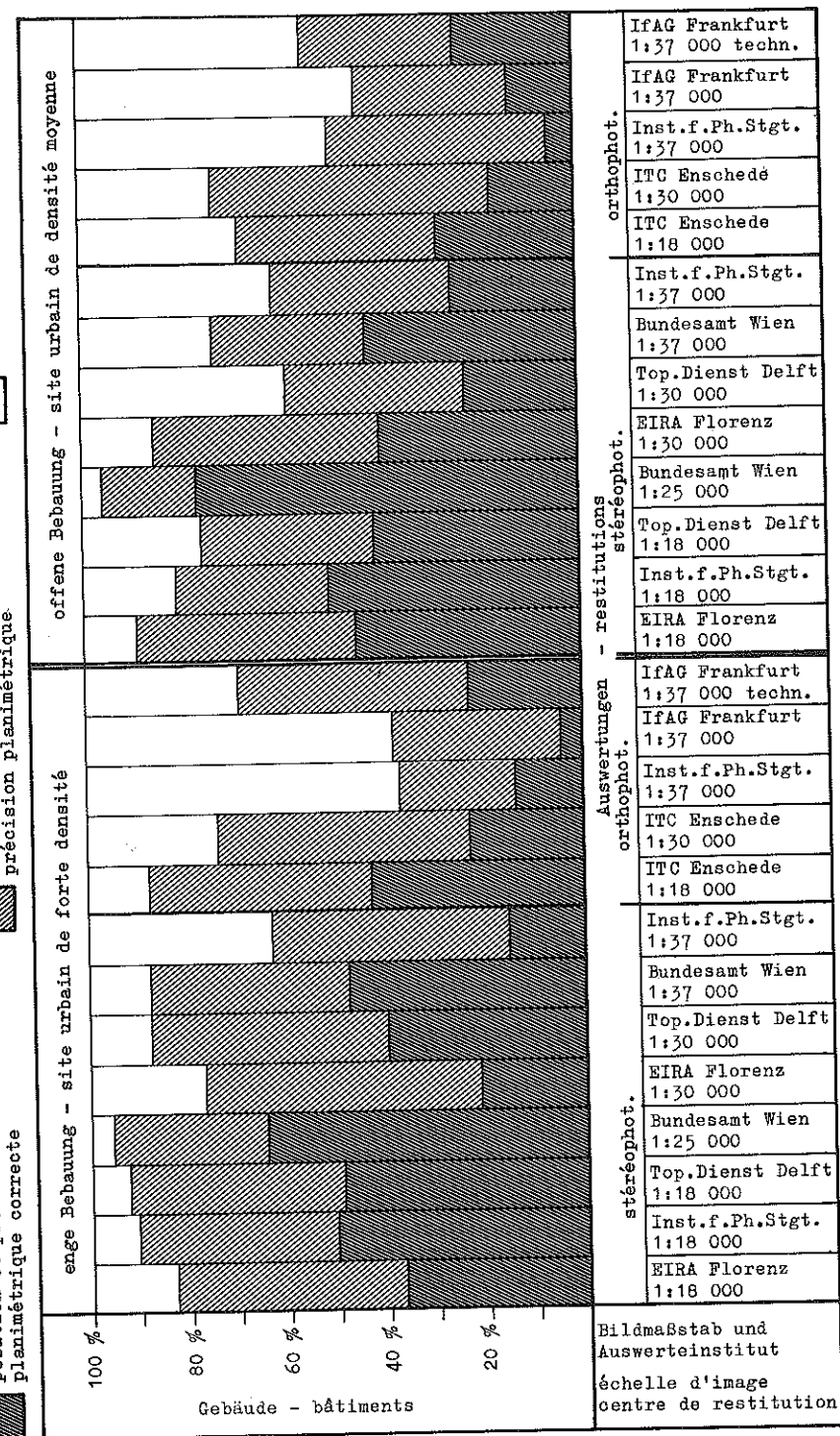
Abb.-Fig. 8

Qualitative Untersuchung der Grundrisssauverhaltung - Gebäude -
Analyse qualitative de la restitution planimétrique - bâtiments -

Fehler $\geq 10,5$ mm
Erreur $\geq 10,5$ mm
Grobe Fehler oder nicht erfasst
fautes ou non restitué

Fehler $\pm 0,2$ mm < Fehler $\pm 0,5$ mm
Grundrissfehler oder Lagefehler
erreur dans position et
précision planimétrique

Fehler $\leq \pm 0,2$ mm
Erreur $\leq \pm 0,2$ mm
Grundrissfehler und Lagefehler
position et précision
planimétrique correcte



From this table and fig. 8 it can be deduced that:

- For the method with orthophotos, aerial photos at a larger scale are necessary in order to decrease the deficit against the stereo-process. At a scale of 1 : 18,000 its loss in the face of this amounts to almost 100 % (column 5) in sparsely built-up areas. The larger photo scale can be calculated corresponding to 2.4.2 to be about 1 : 10,000.
- The variations in the results of the orthophotographic process (cf. columns 2 to 4, and 5 to 7 and totals of columns 2 and 3 and 5 and 6) make one suspect greater differences in the technique and routine of the restitutions.
- The stereophotogrammetric mappings are more influenced by the operator than by the applied method. Only in this way can it be explained why the analysis of aerial photos 1 : 25,000 surpasses those of 1 : 18,000 by up to almost 50 % (column 5).
- The influence of the buildings is less in the stereo-process than in the ortho-process. At photo scale 1 : 18,000 the results of sect. 2.4.2 are confirmed, and by photo scale 1 : 25,000 they are apparently disproved. This contradiction is to be explained by the conditions of the restitutions which are not the same.

For reasons of time it was decided to dispense with a systematic investigation of the exactitude of all mapped objects as according to the grouping in sect. 2.4. In sect. 2.5 it should only be mentioned as an example that the test diagramme used in sect. 2.6 for the representation of terrain can and must be applied likewise and completely to all object groups in the interests of an objective statement about the quality of the whole mapping.

2.6. Height accuracy [8], [9], [10], [11], [12], [13]

2.6.1. Introductory note

The work is usually outlined by the following questions:

- How accurate can the heights of certain objects and terrain points be determined exactly?
- How accurate are the contour lines?
- What is the functional connection between the height accuracy and the slope of the terrain?
- Is the accuracy of the contour lines sufficient for a good representation of detailed terrain forms?

If all the questions are to be satisfactorily answered, the investigation process is again divided in an analytical and a geometrical part. The second results in an optical comparison of the mapped contour lines with the reference contours, and the first to an error-analysis based on the differences between the exact heights and the measured heights of points, which belong either to the fixed-point-net or to a profile net. To save further field work, however, those profiles which had already been measured for the testing of the accuracy of the reference contours (see sect. 2.3.3 and annex 9a) were used. This limited the investigations to the area represented in annex 9a. It is not to be feared that the reliability of the conclusions about height accuracy is reduced by this because the section was so chosen that all land forms contained in the test area were represented in it.

Table 10 — The accuracy of stereophotogrammetrically determined spot heights

ϵ = measured height (photo measuring) — exact height (terrestrial measuring)

sort of point	point number	exact height	Bundesamt, Wien 1 : 37,000		EIRA, Florenz 1 : 30,000		Inst. f. Photogrammetrie, Stuttgart 1 : 37,000		Topogr. Dienst, Delft 1 : 30,000		IfAG, Frankfurt 1 : 37,000		
1	2	3	4		5		6		7		8		
defined point	3	426.2	427.0	+ 0.8	—	—	426.4	+ 0.2	—	—	—	—	
	4	430.1	430.0	— 0.1	430.0	— 0.1	429.0	— 1.1	430.0	— 0.1	431.0	+ 0.9	
	5	443.3	443.0	— 0.3	444.1	+ 0.8	445.0	+ 1.7	443.0	— 0.3	443.4	+ 0.1	
	6	466.0	465.0	— 1.0	—	—	—	—	466.0	0.0	465.6	— 0.4	
	8	464.5	464.5	0.0	464.7	+ 0.2	466.0	+ 1.5	464.0	— 0.5	466.6	+ 2.1	
	10	455.8	456.5	+ 0.7	457.3	+ 1.5	457.0	+ 1.2	456.0	+ 0.2	457.8	+ 2.0	
	11	443.0	443.0	0.0	444.2	— 0.8	443.0	0.0	443.0	0.0	445.0	+ 2.0	
	13	459.6	459.0	— 0.6	460.3	+ 0.7	—	—	459.0	— 0.6	461.6	+ 2.0	
	14	497.7	499.0	+ 1.3	499.0	+ 1.3	—	—	498.0	+ 0.3	497.8	+ 0.1	
	17	452.7	452.0	— 0.7	452.5	— 0.2	452.0	— 0.7	452.0	— 0.7	452.8	+ 0.1	
	19	511.4	511.0	— 0.4	511.5	+ 0.1	511.0	— 0.4	510.0	— 1.4	512.4	+ 1.0	
	20	491.4	491.0	— 0.4	491.8	+ 0.4	492.0	+ 0.6	490.0	— 1.4	—	—	
	21	469.0	469.0	0.0	470.0	+ 1.0	470.0	+ 1.0	468.0	— 1.0	470.6	+ 1.6	
	22	460.6	460.5	— 0.1	460.2	— 0.4	460.0	— 0.6	460.0	— 0.6	461.0	+ 0.4	
	25	478.4	478.0	— 0.4	479.7	+ 1.3	479.0	+ 0.6	478.0	— 0.4	479.2	+ 0.8	
	26	466.1	467.0	+ 0.9	467.5	+ 1.4	466.0	— 0.1	466.0	— 0.1	467.4	+ 1.3	
	29*)	—	—	—	—	—	—	—	488.0	—	489.4	—	
	30*)	—	467.5	—	—	—	467.0	—	466.0	—	467.4	—	
	31*)	—	433.5	—	—	—	432.0	—	432.0	—	—	—	
	Stand. deviation			± 0.62		± 0.81		± 0.70		± 0.67		± 0.71	
	Standard deviation of well defined points											± 0.69	
landmark	9	460.8	460.9	+ 0.1	462.2	+ 1.4	461.0	+ 0.2	461.0	+ 0.2	—	—	
	15	468.9	468.0	— 0.9	468.2	— 0.7	—	—	466.0	— 2.9	—	—	
	23	498.0	498.5	+ 0.5	499.1	+ 1.1	497.0	— 1.0	498.0	0.0	498.8	+ 0.8	
	Stand. deviation			± 0.60		± 1.10		± 0.72		± 0.14			
Standard deviation of land marks											± 0.77		
watermark	1	416.5	415.0	— 1.5	—	—	416.0	— 0.5	—	—	—	—	
	2	418.2	416.0	— 2.2	—	—	416.0	— 2.2	416.0	— 2.2	—	—	
	28	—	431.0	—	—	—	431.0	—	—	—	—	—	
Standard deviation of water marks											—		

*) No exact heights determined.

Table 11 — The accuracy of stereophotogrammetrically determined spot heights

ϵ = measured height (photo measuring) — exact height (terrestrial measuring)

sort of point	point number	exact height	Bundesamt, Wien 1 : 25,000	ϵ	EIRA, Florenz 1 : 18,000	ϵ	Inst. f. Photogrammetrie, Stuttgart 1 : 18,000	ϵ	Topogr. Dienst, Delft 1 : 18,000	ϵ		
1	2	3	4		5		6		7			
defined point	3	426.2	426.4	+ 0.2	—	—	426.4	+ 0.2	—	—		
	4	430.1	429.8	— 0.3	—	—	430.0	— 0.1	430.0	— 0.1		
	5	443.3	443.2	— 0.1	443.5	+ 0.2	444.2	+ 0.9	443.0	— 0.3		
	6	466.0	465.1	— 0.9	—	—	465.4	— 0.6	465.0	— 1.0		
	8	464.5	464.5	0.0	—	—	464.5	0.0	465.0	+ 0.5		
	10	455.8	456.0	+ 0.2	455.6	— 0.2	456.2	+ 0.4	457.0	+ 1.2		
	11	443.0	443.1	+ 0.1	—	—	442.1	— 0.9	444.0	+ 1.0		
	13	459.6	459.4	— 0.2	—	—	459.0	— 0.6	460.0	+ 0.4		
	14	497.7	498.8	+ 1.1	—	—	498.0	+ 0.3	498.0	+ 0.3		
	17	452.7	451.8	— 0.9	451.2	— 1.5	451.2	— 1.5	452.0	— 0.7		
	19	511.4	510.8	— 0.6	511.2	— 0.2	510.4	— 1.0	511.0	— 0.4		
	20	491.4	490.6	— 0.8	—	—	491.3	— 0.1	491.0	— 0.4		
	21	469.0	468.7	— 0.3	—	—	469.2	+ 0.2	469.0	0.0		
	22	460.6	460.0	— 0.6	—	—	460.2	— 0.4	461.0	+ 0.4		
	25	478.4	478.0	— 0.4	—	—	479.8	+ 1.4	—	—		
	26	466.1	466.3	+ 0.2	468.5	+ 2.4	468.2	+ 2.1	—	—		
	30*)	—	467.9	—	—	—	466.2	—	467.5	—		
	34*)	—	451.4	—	—	—	451.1	—	—	—		
	36*)	—	457.0	—	457.5	—	457.6	—	—	—		
	37*)	—	444.8	—	445.0	—	446.0	—	—	—		
	Stand. deviation				± 0.54		± 0.20		± 0.64		± 0.62	
	Standard deviation of well defined points										± 0.58	
landmark	9	460.8	460.9	+ 0.1	—	—	460.6	— 0.2	461.0	+ 0.2		
	15	468.9	467.8	— 1.1	—	—	—	—	467.0	— 1.9		
	16a	—	487.5	—	487.4	—	—	—	—	—		
	16b	489.2	—	—	—	—	489.0	— 0.2	488.0	— 1.2		
	23	498.0	498.4	+ 0.4	499.3	+ 1.3	498.1	+ 0.1	—	—		
	Stand. deviation				± 0.68		—		± 0.17		± 0.86	
Standard deviation of land marks										± 0.72		
watermark	1	416.5	415.6	— 0.9	—	—	415.3	— 1.2	415.0	— 1.5		
	2	418.2	415.8	— 2.4	—	—	—	—	416.0	— 2.2		
	Standard deviation of water marks										± 1.06	

*) No exact heights determined.

2.6.2. Accuracy of spot heights

In tables 10 and 11 signify: defined points e. g. crossings of roads, paths and railway lines; landmarks e. g. highest points e. g. mountains, hills, summits of the lowest points of valleys and depressions; water marks, fixed points of different sorts on bridges, weirs and channels. The scratched numbers in the tables refer to points, which do not agree with those determined tacheometrically or by levelling.

When not taking those landmarks and water marks whose photogrammetric heights are not reliable because of the difficulty of indubitable identification the following is obtained (combination of standard deviations of tables 10 and 11) as a result for the mean height differences and for the limiting values.

Table 12 — Accuracy of the photogrammetric spot heights in relation to the flying altitude

photo scale	flying altitude h_f	m_h		m_h in ‰ of flying altitude	limiting values $m_{h \max} =$ $= 0.1\% h_f$
		(table 11)	(table 10)		
		1	2	3	4
1 : 18,000	2,760 m	0.62 m (col. 7) 0.64 m (col. 6)		0.22 m 0.23 m	0.28 m
1 : 25,000	3,800 m			0.14 m	0.38 m
1 : 30,000	4,600 m		0.67 m (col. 7) 0.81 m (col. 5)	0.15 m 0.18 m	0.46 m
1 : 37,000	5,700 m		0.62 m (col. 4) 0.70 m (col. 6) 0.71 m (col. 8)	0.11 m 0.12 m 0.12 m	0.57 m

Note: Only the standard deviations of defined points were used, and from them only those which were derived from at least 10 ϵ -values.

From tables 10 to 12 the following results were obtained:

- The orthophotographic process gives no spot heights. For a topographic base map of high quality therefore additional photogrammetric or terrestrial height measurements are necessary.
- A worse result is obtained from a large photo scale than a smaller one. This contradictory result can be assigned to different causes: e. g. deletion of measurements, individual effects on the observations, incorrect identification of points.
- It is confirmed that routine and observation technique have the greatest influence.

2.6.3. Accuracy of contour lines, independent of the inclination of the terrain

Further spot heights have been tested in completion of the investigations of sect. 2.6.2 by help of the profiles represented in annex 9a. The points of intersection of the contour lines with profiles and the profile heights determined by interpolation were the basis of these tests. As an objection to this process it can be noted that the dependence of the height measurement on the inclination of the ground is not considered, and that the photogrammetric contour restitution is mixed up with the determination of spot heights. The fact that the terrain slopes in the analysed part of the test area do not vary much and that therefore relatively equal weight can be given to the measurement speaks for this method. Moreover, the large amount of points guarantees a relatively safe statement on the measurements, particularly with respect to the character of height deviations, e. g. on the effect of possible systematic errors. The following examinations 2.6.4 and 2.6.5 will show with which relative and absolute weight coefficients the results are to be provided.

The lengths of the 8 lines (see annex 9a), along which the shape of the terrain was explored, amount to a little over 5 km. At 100 m as an average five spot heights were determined by tacheometry or levelling. The basic principle was to measure every point where the inclination changed.

All the analysed contours were examined, even the supplementary contours. By so doing the number of test points could be raised to over 1,000. The differences (profile heights of the points of intersection of contour lines with the profiles minus the height value of the contour lines) gave the ϵ -values from which m_h was calculated. Against them were placed the values of the standard deviations, the limiting values and the distribution of the signs of the deviations in connection with arithmetical means. For a better understanding the results were given in the form of table 13a.

The measurements with systematic errors and those which approx. reach or overstep the limiting accuracy values can be established by comparing the values of columns 8, 9, and 10, columns 5 and 11. The ratio of the two numbers in column 10 was the criterion for the detection of systematic errors. Where it was over 1.6 the measurement was excluded from the following observations because of the burdens of systematic errors. Test results whose systematic share does not question the necessary accuracy can possibly also be dropped by this method. The causes and effects of the systematic errors are not analysed. Two results of the stereophotogrammetric method and three of the ortho-process remained. They have been emphasized in table 13a. The following statements can be made:

- The stereophotogrammetric process has a loss of 78 %. It is, however, more accurate in the smaller scale and, therefore, more dependent on the observer than the orthophotographic process.
- The loss in the orthophotographic process (dropped lines) amounts to 50 %. The produced contours show no systematic deviations in the larger photo scale. The accuracy is for 1 : 18,000 only half as great as the accuracy of stereophotogrammetric analysis. In face of the results of photo scale 1 : 30,000 it lies about 30 % behind.

Table 13a — The accuracy of points of the contour lines

institute	scale	process	number of points	$[d]$ (cm)	$[d^2]$	arithm. mean $\frac{[d]}{n}$ (cm)	$m_h = \sqrt{\frac{[d^2]}{n}}$ (cm)	standard deviation $= \sqrt{\frac{1}{n-1} \left([d^2] - \frac{[d]^2}{n} \right)}$ (cm)	number of points with d + —	limiting value $[d] < 3m \cdot \sqrt{n}$ $m = 0.3\% \cdot h_g$ (m)
1	2	3	4	5	6	7	8	9	10	11
Delft	1 : 18,000	stereo	95	1246	182 540	13.12	43.83	42.05	59	36
Stuttgart	1 : 18,000	stereo	66	— 3894	761 378	— 59.00	107.41	90.44	15	51
Florenz	1 : 18,000	stereo	62	— 2853	1 020 477	— 46.02	128.29	120.73	20	42
Wien	1 : 25,000	stereo	65	1851	169 051	28.48	51.00	42.64	50	15
Delft	1 : 30,000	stereo	71	407	313 057	5.73	66.40	66.63	42	29
Florenz	1 : 30,000	stereo	84	— 3172	704 132	— 37.76	91.56	83.91	23	61
Frankfurt 16	1 : 37,000	stereo	79	— 4552	438 424	— 57.62	74.50	47.52	7	72
Wien	1 : 37,000	stereo	51	6817	1 252 911	133.67	156.74	82.67	49	2
Stuttgart	1 : 37,000	stereo	67	— 10908	2 747 928	— 162.81	202.52	121.36	6	61
Stuttgart	1 : 18,000	ortho	94	547	728 073	5.82	88.01	88.29	44	50
Enschede	1 : 18,000	ortho	113	— 2433	1 003 969	— 21.53	94.26	92.18	53	60
Frankfurt 28	1 : 18,000	ortho	51	— 529	519 937	— 10.37	100.97	101.43	27	24
Enschede	1 : 30,000	ortho	58	7031	1 563 683	121.22	164.20	111.71	51	7
Stuttgart	1 : 37,000	ortho	59	— 5915	2 276 061	— 100.25	196.41	170.35	13	46
Frankfurt 11	1 : 37,000	ortho	56	— 17627	6 316 497	— 314.77	335.85	118.17	0	56

$\Sigma = 1071$

Note: d = exact height (measured height or profile height) minus measured height (contour line)

scale	h_g (m)	$m = 0.3\% \cdot h_g$ (m)
1 : 18,000	2 760	0.83
1 : 25,000	3 800	1.14
1 : 30,000	4 600	1.38
1 : 37,000	5 760	1.73

Erreurs moyennes des courbes de niveau Mittlere Fehler der Höhenlinien

This state of affairs becomes still more evident when the results of table 13a, column 8, are expressed in ‰ of the flying altitude and compared with the limiting values also expressed as percentages of the flying height.

Table 13b — Mean height differences — Table 13a, column 8, — as function of the flying altitude

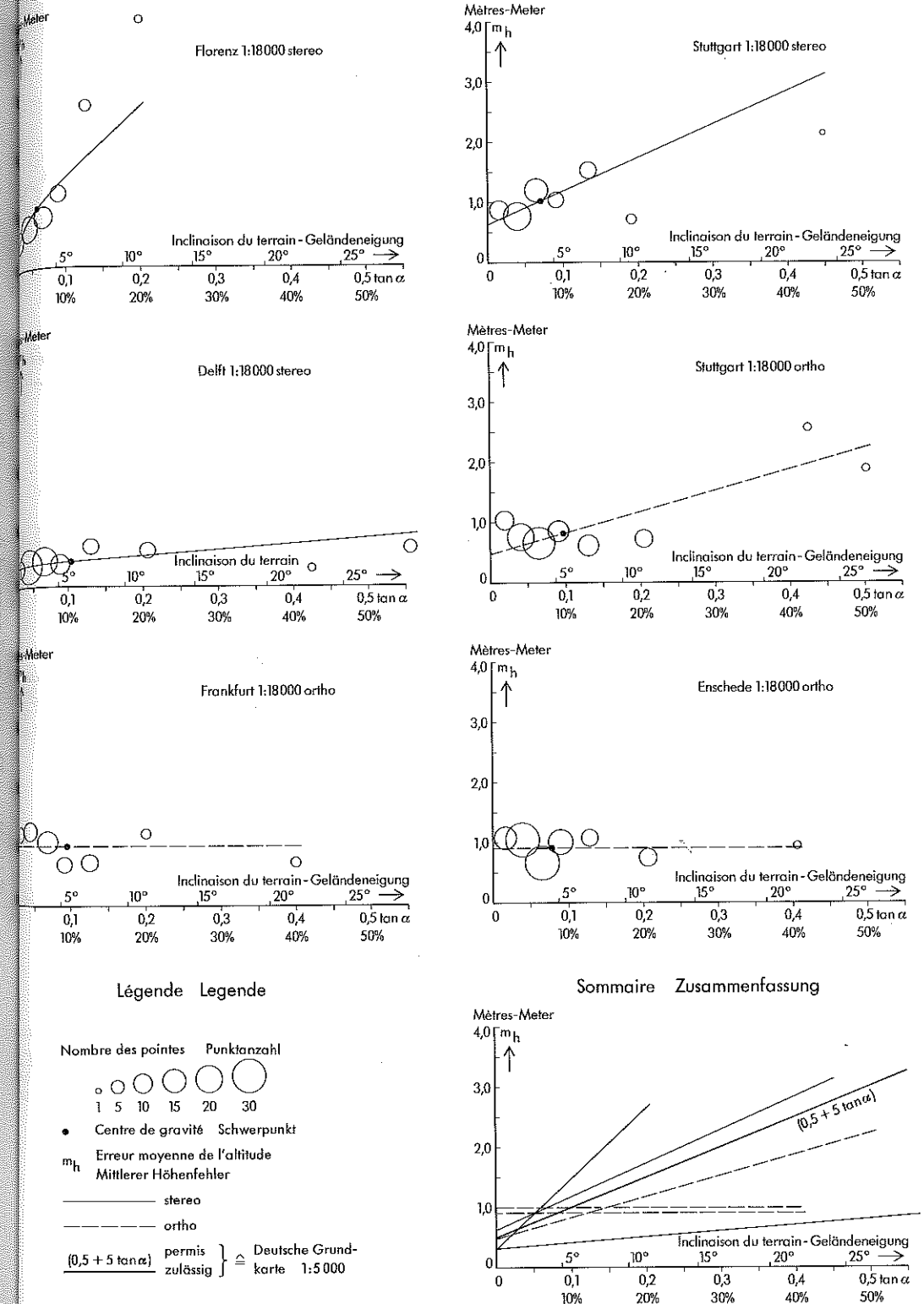
m_h	m_h in ‰ of flying alt.	photo scale	flying altitude	m_h in ‰ of flying alt.	m_h
1	2	3	4	5	6
stereophot. process		1 : 18,000	2,760 m	orthophot. process	
43.83	0.16			0.32	88.01
107.41	0.39			0.34	94.26
128.29	0.46	1 : 25,000	3,800 m	0.37	100.97
51.00	0.13			—	—
66.40	0.14			—	—
91.56	0.20	1 : 30,000	4,600 m	0.36	164.20
74.50	0.13			—	—
156.74	0.27			0.59	335.85
202.52	0.36	1 : 37,000	5,700 m	—	—
—	—			—	—
—	—			—	—

If these values are set against the limiting values according to eq. (9b) and (9c) from sect. 2.3.3 and compared with the results [8], page 98, they can be labelled "good".

Moreover, it can be ascertained that a photogrammetric restitution cannot be assessed by these limiting values alone. Systematic errors which cause e. g. a local or systematic shifting of contour lines and therefore, can more or less question the result, need not necessarily be expressed in m_h . If this were the case, tables 13a and 13b would have to show the same number of unsatisfactory results. According to table 13a 78 % of the contour lines determined stereophotogrammetrically and 50 % of the lines orthophotographically have to be excluded because of the systematic share of errors. According to table 13b, columns 2 and 5 it is, however, 44 % and 100 % and 22 % and 50 %, when the limiting values are ≤ 0.20 ‰ or ≤ 0.35 ‰ of flight altitude. An increased demand for accuracy, therefore, requires a more refined system of investigation.

2.6.4. Accuracy of contour lines, dependent on the inclination of the terrain

If the points recorded in sect. 2.6.3, table 13a, are arranged according to the inclination of the terrain to which they belong, the accuracy of height determination can be represented as a function of the terrain inclination in the well-known way in diagrams. The inclination groups of table 2, sect. 2.3.3 were taken as the basis for arranging the height differences in the present case. The arrangements according to process, photo scale and participating institutes were maintained. The strict determination of the adjusting straight lines of fig. 9a to 9c was renounced. The calculations connected with it would not have

1:18 000
Résultats partiels Teilergebnisse

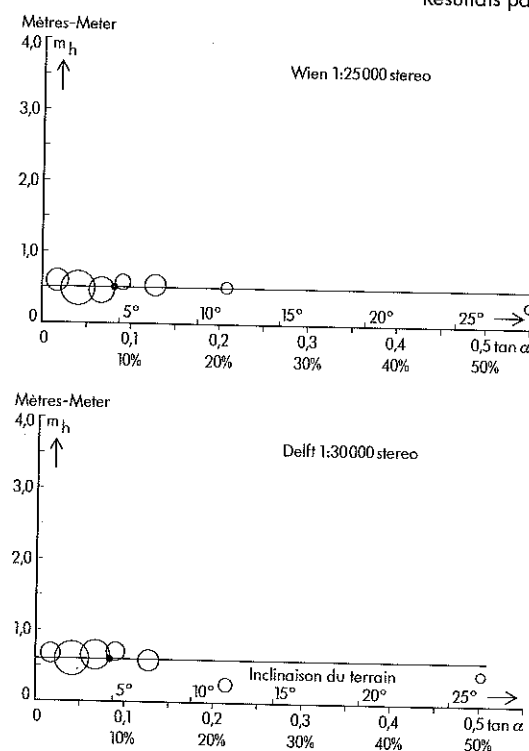
Erreurs moyennes des courbes de niveau Mittlere Fehler der Höhenlinien

Abb.-Fig. 9b

Erreurs moyennes des courbes de niveau Mittlere Fehler der Höhenlinien

1:25 000-1:30 000

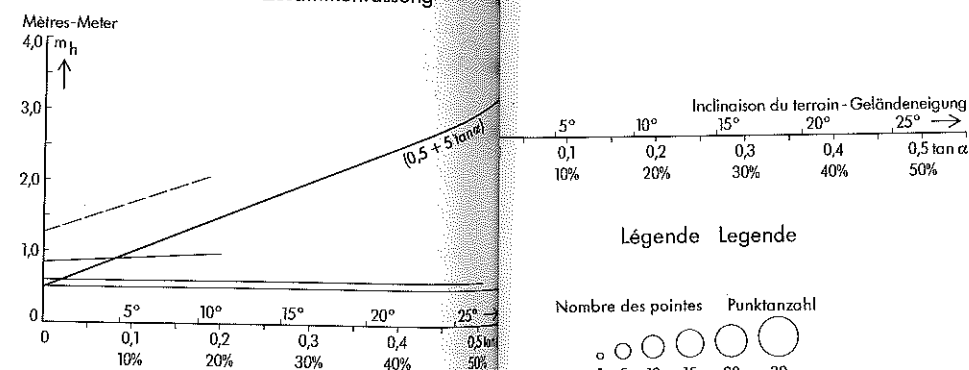
Résultats partiels Teilergebnisse



Légende Legende

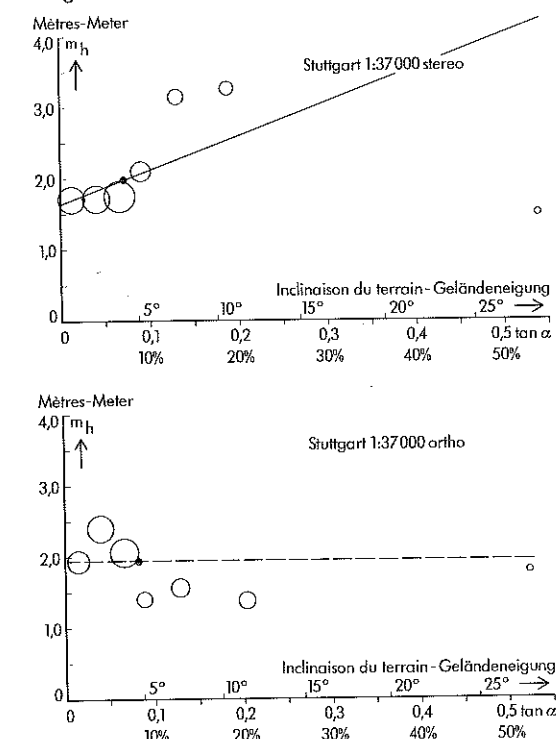
- Nombre des points . Punktzahl
- ○ ○ ○ ○ ○
1 5 10 15 20 30
- Centre de gravité Schwerpunkt
- m_h Erreur moyenne de l'altitude
Mittlerer Höhenfehler
- stereo
- - - ortho
- $(0,5 + 5 \tan \alpha)$ permis } Deutsche Grund-
zulässig } karte 1:5 000

Sommaire Zusammenfassung

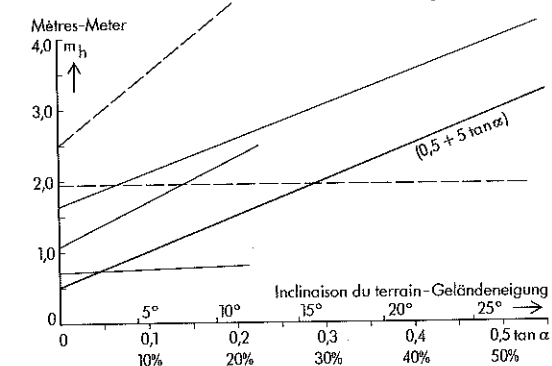


Légende Legende

- Nombre des points . Punktzahl
- ○ ○ ○ ○ ○
1 5 10 15 20 30
- Centre de gravité Schwerpunkt
- m_h Erreur moyenne de l'altitude
Mittlerer Höhenfehler
- stereo
- - - ortho
- $(0,5 + 5 \tan \alpha)$ permis } Deutsche Grund-
zulässig } karte 1:5 000

1:37 000
Résultats partiels Teilergebnisse

Sommaire Zusammenfassung



been worth while. For the semi-graphic method reveals the achievements of the processes reliable enough. The gravity centres of the point groups, which are represented in the figures, were determined according to eq. (5) of sect. 2.3.3. The directions of the adjusting straight lines on the contrary were graphically determined.

In each scale group the individual figures were assembled to one, in which the limiting value, defined by eq. (8a), sect. 2.3.3 is also represented.

The aim of these analyses is to clear the question how far the knowledge gained in sect. 2.6.2 and 2.6.3 is confirmed or is to be questioned.

The figures reveal the weaknesses of these investigations. The measurements spread over relatively flat terrain with inclinations up to 20 %. In the light of the conditions of the sect. 2.1, which the test area should meet, the demand to cover larger built-up areas in the vicinity of Stuttgart had predominance. A high intensity of settlements and a great variety in the inclination of the terrain is hardly ever found together.

Fig. 9a to 9c show varying results. If all the results which lie completely or partially outside the standard are excluded, then the loss amounts to:

Table 14a — Summary of test results

stereophot. process			photo scale	orthophot. process		
analysis	loss (number of tests)	loss (in %)		loss (in %)	analysis	loss (number of tests)
1	2	3	4	5	6	7
1	2	67	1 : 18,000	67	1	2
1	—	0	1 : 25,000	—	—	—
1	1	50	1 : 30,000	100	—	1
—	3	100	1 : 37,000	100	—	2
3	6				1	5

From this compilation and from fig. 9a to 9c it can be deduced that:

- a) The contour lines from the orthophotographic method, not burdened by systematic errors but by a high quota of uncertainty (see column 8, table 13a, m_h) lie outside the reliability intervals except for one case with a photo scale of 1 : 18,000. Five of the six test results or 83 % are thus eliminated. This high deficit is not, however, primarily caused by technical weakness of the process, but by negative individual effects of the observer. The large differences in the figures indicate this. This factor is treated in detail in [8], page 55 and page 58.

- b) The production of contour lines from dropped lines is on the whole, and particularly in flat terrain, less successful than from stereophotogrammetric restitution. These results agree with and, however, contradict at the same time the knowledge which proceeded from the investigations [8] recapitulated on page 103. The widths of the slit and the scanning speeds, which after these examinations have a small or great effect on the accuracy of height, are represented in sect. 4.3.

- c) According to table 14a the result of the stereophotogrammetric process has improved in face of table 13a. The discovered systematic errors of the restitution at 1 : 25,000 do not influence its accuracy. By comparing fig. 9a and 9b it can be seen that the mappings from the smaller photo scale are better than those from scale 1 : 18,000. This result, which contradicts all experience, is qualified by observation.

- d) The contour plots which are qualified as sufficient according to these observations, are presented individually according to the following demands on accuracy:

Table 14b — The accuracy of the contour lines as a function of the inclination of the terrain

m_{hst}	photo scale	m_{ho}
1	2	3
stereophot. process ($0.3 + 1 \tan \alpha$)		orthophot. process ($0.5 + 3.6 \tan \alpha$)
0.5	1 : 18,000	—
0.6	1 : 25,000	—
	1 : 30,000	—

The lack of that part of the equation, which gives the dependence on the inclination of the terrain, in the restitutions at 1 : 25,000 and 1 : 30,000 in column 1 is caused by the relatively flat terrain. The equation in column 3 agrees approx. with the equations [8], page 101.

2.6.5. Evaluation of the contour lines by comparison with the reference contours

At first, as previously mentioned, it was not planned to examine the produced contour lines in the way of sect. 2.6.2 to 2.6.4. It seemed that this problem had been sufficiently examined and treated in the past. The mappings which were made available to committee D stood out, however, in that they could build at least in part on extensive practical experience. Moreover, they had in common a uniform photo-material and process concept. The otherwise conditioned differences in the starting point of photogrammetric tests, which hinder objective judgements, did not exist here. The results of the participating institutes could be given equal weights in the analyses. This opportunity, which was recognised to its full extent when all mapping results became available, is rarely found and should therefore be utilized.

The optical comparison of the contour lines with the reference contours became one of many analyses, with which the quality of the produced contours was checked from many sides. While up to now analytical processes formed the basis of the investigations, the geometrical method is now in the forefront. From the synthesis of the results a final judgement can be reached.

The produced contour plots are combined with the basic planimetric plot in annexes 9b to 14. Optimal register accuracy of this combination is ensured by the mapped grid intersections. The topographic base map and the zone of admissible deviations of the contour lines are represented in black and screened grey (see eq. (6) and (7) as (8a) to (8c), sect. 2.3.3). These bands are only drawn along the 10m-curves. The same is valid for annex 9a. This has been reproduced on transparent material. Their use in connection with annexes 9b to 14 should be made possible by that.

The annexes are arranged according to production process and photo scale. The stereo results are indicated on 4 annexes for the scales 1 : 18,000, 1 : 25,000, 1 : 30,000 and 1 : 37,000, the orthophotographic mappings spread onto 2 annexes for 1 : 18,000 and for 1 : 30,000 plus 1 : 37,000.

Within the annexes the results are divided by colours. The outline can thus be somewhat improved but does not give complete satisfaction. The largest undulations of the mapped contour lines are indicated as the borders of a second band extending along the 10m-contours. This band is printed in screened red. Where it is covered by the grey band the limits of accuracy are fulfilled.

The forest areas, built-up areas and quarries have been screened. Differences in the cartographic treatment of the compilations cannot be overlooked.

A comparison between the compilations (in colour) and the base map (in black) reveals where the accuracy norm has been exceeded, where contour lines have been systematically shifted and where geomorphological detail is deficient. The analytical results are thereby qualitatively supplemented, i. e. improved and the general information shown is increased.

In particular the following can be seen:

Annex 9b: The red screened area lies partially asymmetrical to the back contour lines and, particularly in flat areas, stretches beyond the grey band.
(stereo-photogrammetric method) The systematic influence, quantitatively noted in table 13a columns 8, 9 and 10, is confirmed and qualitatively illustrated by this comparison. Inaccuracies in the compilation, which are thus revealed and which are demonstrated in the values of m_h , have been noted and defined separately.

The geomorphological information shown by the sensitivity of the contour lines to the slightest movements of terrain forms is very different for the individual interpretations.

Annex 10: The picture is characterized by fewer systematic errors, but more infringements of standards of accuracy and a stronger and more varied generalization of the contour lines. This is reflected in the high values for m_h recorded in table 13a.
(ortho-photographical method)

Annex 11 to 14: The smaller the scale, the larger the fluctuations in the compilations, and accuracy standards are increasingly exceeded and systematic discrepancies become correspondingly noticeable. (Asymmetry between the red screened areas and black lines, see annexes 13 and 14; screening was not used in two evaluations.)
(both methods)

2.7. Summary of the results of the analysis

Technical procedure, scale, individual factors, types of landscape, and topographic-cartographic requirements were selected from the parameters which effect the quality of the aerial restitution and examined more or less intensely. An effort was made to submit to all the compilations which have been used to normal, identical professional conditions. A prerequisite which does not apply in each case as has been proved. It was neither intended, nor indeed possible, to set up the studies effectively from all view points and to the finest detail. The analyses could only show the essentials for the individual areas of the parameter.

Clarification of the technical procedure situation revealed that the stereophotogrammetrical procedure is qualitatively more adaptable than the ortho-method. The stereo-method is more discriminating of efficiency under similar internal and external conditions. With regard to the cost/use/time-effect, both methods have alternatives to offer.

The photo scale 1 : 18,000 is sufficient to ensure satisfactory results in stereophotogrammetric restitution. The analyses confirm the general rule $M_{BSI} \sim 200 \sqrt{M_K}$. Against this, the photo scale $M_{BO} \sim 120 \sqrt{M_K}$ had to be used for the orthophotographic method in order to reach the same results as in the other method. It remained an unsolved question to what extent the profit for the additional field surveying was caused by the geometrically correct orthophoto-image. The stereo-restitution reacted more sensitively to changes in scale than the orthophotographical. Specific improvements in the evaluation are easier to obtain by rational matching of the photo scale than by the ortho-method.

The individual influence of the observer is strongest in the stereophotogrammetric process. This over-riding parameter is shown by the differences in the quality of the produced maps in the partial contradictions of the results against the experience in photogrammetrical practice, and in the variations in the cartographical quality of the compilations. The crucial factors of this influence in the ortho-method are less in the scanning of the profiles than in the extraction of the linear map image from the orthophoto.

The parameter „landscape structure“ has a different effect on both methods. It is easier to manage stereophotogrammetrically than orthophotographically. Photo scale here provides an excellent means of compensation. In forest areas, both methods require extensive field surveying support. A close co-ordination between terrestrial and aerial photography and evaluation becomes a technical and economic necessity. The importance of topographical survey lies in small objects in specific landscape areas.

The topographic-cartographic guidelines conformed with conventional principles [1]. They are outlined in the legend and the classification regulations (annex 15). In the main the arrangement of objects within a group is based on topographical criteria. They are, therefore, optimally suited to aerial photo interpretation. One could also say that all classifications which depend on subjective conditions, are unsuitable for photo interpretation. Experiments to determine whether and in which instances these subjective criteria can be assessed either directly or indirectly from the aerial photographs have not yet been carried out. This parameter has therefore been least subject to analysis. It also became apparent that quality demands in the compilations of the individual groups of objects were not equivalent. The contour lines seemed to have a certain precedence over the other objects shown. Analyses have shown how important it is to concede the other features the same priority in order to ensure their cartographical parity. The analytical and geometrical methods for the qualitative examination of the produced maps must always, therefore, be extended to include various groups of features.

3. Cartographic part of the work

3.1. Preamble

If the original objective of defining the production of a topographic base map 1 : 10,000 by means of photogrammetric methods had been realized as the subject of the examination, then the criticism would have been justified that inconsistency to the disadvantage of the orthophotographical potential had occurred. The point of the examination, which should have been to stimulate cartographical mobility by means of a large variety of aerial photograph evaluations, would have been lost by the production limitations of the conventional map. On the other hand time considerations ensured that the evaluations and their analyses were kept within appropriate dimensions. This was possible if the orthophoto was taken into account in proportion to its technical and scientific superiority being obviously significant. However, it was necessary to avoid a re-examination of the rather frequently treated cartographical position and the diversity of its change. In order to establish the difference between linear and aerial photographic maps, it is sufficient to provide suitable examples in the study. The orthophoto map is thereby more demonstratively than instructively taken into account. This also explains the more general drafting of the section "topographical maps to the scale of 1 : 10,000", under which orthophoto maps have also been included.

However, these arguments only emerged for consideration later when the analyses were already in progress and the first results had become obvious and although a revision was unnecessary, the examinations had to be intensified.

3.2. Topographic base map 1 : 10,000

3.2.1. Review

A principle in the production of any map series is that they are not based purely on a map legend, as in the early period of topographical cartography, but also on regulations which stipulate which features are to be shown and how. The form and contents of a map are, therefore, regulated by these detailed interpretations of cartographic style. Optimal information shown and geometrical accuracy in all details should characterize a base map.

Starting from scratch, without a pattern or example and without recourse to well-tried and accepted cartographic material would have ended in failure. From the European 1 : 10,000 scale maps, a Belgian example was selected [1]. This was characterized by a legend in the 1 : 10,000 scale map, which allowed the reduced 1 : 25,000 image to be used as a fair drawing. This is an example of rational map compilation which appears to be economically dubious, but which nonetheless encourages compromises in cartographic irregularity. In order to limit these irregularities this example was somewhat modified. The first map originals showed that the dense road network became too strongly exaggerated and too much in the foreground. The road widths have, therefore, been reduced. Nevertheless the cartographic risk could not be eliminated.

3.2.2. Proposed specifications for cartographic work for the production of a topographic map at 1 : 10,000 (line map) — annex 15 and [1]

Firstly, a preliminary directive was compiled, which must be considered as an essential component of the final result. It was then possible for the restitution of the aerial photographs to be carried out immediately after they had been taken. The extension of this cartographic frame into the final map legend was achieved on time. The photogrammetric work and interpretation were not then delayed.

Annex 15 has been arranged according to colours and object pictures. In this arrangement each picture is placed opposite the respective commentary, which is sub-divided into symbols, written explanation and name. Each pictorial element has been as clearly defined in its size as each lettering addition.

Due to the monochrome presentation, the signs and written explanations could not be indicated in their correct colours in annex 15. The respective colours are mentioned in the first column of each page.

All the representations and the lettering are adapted to automated drafting. Annex 15 has been produced by the Landesvermessungsamt Baden-Württemberg.

3.2.3. Map samples

Annexes 16a to 16c and 17 have been set out according to standard principles in different variants and combinations. They are based on annexes 4b and the contour lines shown in brown on annex 12. The multicoloured (4 and 5 colours) samples are the counterpart of the monochrome and screened map. These examples should give an indication of the

cartographic possibilities. The Landesvermessungsamt Baden-Württemberg has compiled annexes 16a to 17 cartographically.

To the question why the reference map from annex 8 was not used to form the basis of these map samples, the answer must be that the topographic extract from the cadastral map was immediately possible. But the contour lines were missing. These could later be produced from a special photogrammetric restitution (see sect. 2.3.3 and 2.3.4). Otherwise it would no longer have been possible to produce the map samples in time.

3.2.4. Cartographic solutions and results

The cartographic position of the compilations from aerial photo evaluations must be arranged within the established stages of overall map production. This plan consists of the three sections — topographical, cartographical and cartographic-technical work. Each of these sections is distinguished by work phases which, in the cartographical section for example, comprise the classification of groups of objects, the subjective and objective description of these same objects and their presentation and configuration on the map. These work phases are again founded on individual stages. The production of preliminary plots (drafts) of the separate groups of features are, for example, to be categorized under classification. The division between the individual positions in such a scheme is, in practice, very hard to define. Rational working methods force co-ordination which significantly amalgamates the individual first draftings of the map for instance.

Photogrammetry, when necessary together with supplementary topographic surveys, equates with the first section topography and contributes more or less comprehensive preparation towards the second, cartographic elaboration. Conditions of techniques and organisation necessary to make this advantage as effective as possible must remain open.

Annexes 1a to 7c and 9b to 14 show routine results for those institutes whose main task is production and revision of maps. All compilations conform with the maxim of producing as many fair draftings as possible from the photogrammetric restitution and thus largely reducing the cartographic work to come.

The length of the process from these compilations to the final pictures is as great as their difference from the final maps (annexes 16a to 16c and 17). There is a strong argument in favour of shortening this process by means of digital mapping. It was considered whether and in what manner this problem should be included within the examination. However, the conclusion had to be drawn that the evaluation of this subject could not be accomplished. The limitation to conventional methods of compilation remained decisive.

3.3. Orthophoto and orthophoto map 1 : 10,000

The possibilities in the compilation of photo maps are set out in [15]. A practical method of using this technique is shown in [16]. The automatic production of contour lines and orthophotos has been dealt with in [17] and [18]. In [12], the relationship between orthophotos and orthophoto maps is investigated. These comprehensive treatments of

these problems render any further examination unnecessary. A short demonstration by means of illustration suffices.

The orthophoto (annex 18) gives an idea of the structure of the landscape. The position occupied by the individual groups of objects is easily noted. More exact and specific information, however, necessitates interpretation experience and interpretation work. The difficulties increase when the planimetric position and shape of the individual topographic features have to be geometrically plotted (see sect. 2.4.2 and 2.4.3, annexes 4a to 5d). Topographical analysis is questionable in wooded areas. The lack of contour lines also decisively limits the effectiveness of orthophotos.

In annex 19 the transition to the orthophoto map has been completed. This step has been accomplished with the contour lines and line image of annexes 16 and 17. The pictures have been reproduced in negative form. Nevertheless the quality of the orthophoto is lessened. The optical deficit is comparable to the loss resulting from the printing of hill shading upon a topographic line map.

Annexes 18 and 19 show that the cartographical possibilities of orthophoto maps remain to be exploited to full advantage. It could, for example, be argued that this contribution should be concentrated on the lettering and kept as concise as possible in order to speed up the production of the map. This provisional solution could then be further developed to the final planned capacity. If the topographical map scale of 1 : 10,000 had been the final aim, the contour lines could have been stereophotogrammetrically added later. A number of optional interim solutions can be built in between the orthophoto and the conventional map, which are initially compatible with time demands, while holding the way open for a linear map.

The topographic road classification has been printed in colour in annexes 19 and 20. This is a trial which cannot be cartographically evaluated. This omission is justifiable with regard to [15].

When the map samples of annexes 16a to 16c and 17 are compared with the orthophoto maps of annexes 19 and 20, the cartographic differences become obvious. Which presentation is selected now or later, depends on the cartographic position in general and on particular hypothetical considerations.

3.4. Summary

The cartographic possibilities are increased if the priorities of a conventional base map are neglected. The orthophoto map can then take over the function of the preliminary map, which is evolved by stages towards the final product, the topographic base map. Regardless of how quickly the final product is achieved depends as much on topographic-cartographic ability and challenge as on tradition and state of development. The different possibilities of photogrammetry can be completed with cartographic compilation systems, which demonstrate the integrated cartographical guidelines for the construction of a basic map series.

4. Performance of methods [14]

4.1. Preamble

After the qualitative achievements of the method in relation to various parameters of internal and external influence on the aerial photograph and its evaluation have been analysed; quantitative contributions must be added to this result. The various work stages which distinguish the production of a base map must likewise be subjected to time analysis. In order to ensure that the time taken is uniformly and differentially enough considered, this was stipulated in a list given to each institute before the beginning of the work. This register form was divided roughly similarly to the work stages set out in sect. 3.2.4. The results of the enquiries are set out in fig. 10a to 10c. Since, however, these statistics do not define the terms of execution adequately, extracts have been included in tables 15, 19 and 20.

Since certain norms [19] and [20] apply in practice to the production time of orthophotos, the institutes' evaluation times have been set out against these standard values (table 17).

The time supplied by the institutes had to be recalculated to conform to a uniform map area of 10 km². Due to the differences in the compilation formats, a direct comparison was impossible; in addition to which a registration of the number of operators working with one instrument was also omitted. The number of hours the instrument was in use has been noted on the time register. Possible differences in expenditure have been ignored. The results of the analyses are hardly affected by this.

4.2. Stereophotogrammetric methods

If the numerical data, shown in fig. 10a to 10c, are arranged according to scale, technical mapping methods and pictures of objects, the following summary is obtained (table 15).

Two models provided the basis for the evaluations of the scales 1 : 18,000 and 1 : 25,000. For the scale 1 : 30,000 and 1 : 37,000 one model had to be plotted. It seems that for one model the restitution time increases proportional to the flying height. This would then be calculated:

$$Z_{Ak} = Z_{Ai} \frac{H_{Fk}}{H_{Fi}} \quad (11)$$

The abbreviations mean:

Z_{Ak} or Z_{Ai} the time taken for the evaluation per model of the scale m_{Bk} of m_{Bi}

H_{Fk} or H_{Fi} the height of the flight which corresponds to scales m_{Bk} and m_{Bi}

If the most strongly established mean value for the scale 1 : 18,000 is used as a basis, the following reference figures are produced for the varying flight heights per model and an area of 10 sq. km. in contrast to the actual values of table 15:

Table 15 — Time consumption for map compilation with stereophotogrammetric methods in hours/10 km²

	planimetric a + b) draft c) classific. draft d) draft/original				contour lines				planimetric (d) + contour lines			
	1				2				3			
	18'	25'	30'	37'	18'	25'	30'	37'	18'	25'	30'	37'
a) compilation built-up areas roads, etc. waters use of land	73	46	61	44								
b) compilation relief features					18	19	16	20				
c) compilation + interpretation stereoscope	106	46	93	44								
d) compilation + interpretation stereoscope + cartographical supplements	121	54	97	80					139	73	113	100

Table 16a — Contour lines: time taken in hours per model and 10 km² surveyed area

scale	1 : 18,000	1 : 25,000	1 : 30,000	1 : 37,000
reference figures acc. to equation (11) and table 1; sect. 2.2	9	12	15	19
actual figures acc. to table 15; col. 2	9	9	16	20

Table 16b — Planimetric + contour lines: time taken in hours per model and 10 km² area

scale	1 : 18,000	1 : 25,000	1 : 30,000	1 : 37,000
reference figures acc. to equation (11) and table 1; sect. 2.2	60	83	100	124
actual figures acc. to table 15; col. 1.d	60	27	97	80

4. Performance of methods [14]

4.1. Preamble

After the qualitative achievements of the method in relation to various parameters of internal and external influence on the aerial photograph and its evaluation have been analysed; quantitative contributions must be added to this result. The various work stages which distinguish the production of a base map must likewise be subjected to time analysis. In order to ensure that the time taken is uniformly and differentially enough considered, this was stipulated in a list given to each institute before the beginning of the work. This register form was divided roughly similarly to the work stages set out in sect. 3.2.4. The results of the enquiries are set out in fig. 10a to 10c. Since, however, these statistics do not define the terms of execution adequately, extracts have been included in tables 15, 19 and 20.

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The time supplied by the institutes had to be recalculated to conform to a uniform map area of 10 km². Due to the differences in the compilation formats, a direct comparison was impossible; in addition to which a registration of the number of operators working with one instrument was also omitted. The number of hours the instrument was in use has been noted on the time register. Possible differences in expenditure have been ignored. The results of the analyses are hardly affected by this.

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$$Z_{Ak} = Z_{Ai} \frac{H_{Fk}}{H_{Fi}} \quad (11)$$

The abbreviations mean:

Z_{Ak} or Z_{Ai} the time taken for the evaluation per model of the scale m_{Bk} of m_{Bi}

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If the most strongly established mean value for the scale 1 : 18,000 is used as a basis, the following reference figures are produced for the varying flight heights per model and an area of 10 sq. km. in contrast to the actual values of table 15:

Table 15 — Time consumption for map compilation with stereophotogrammetric methods in hours/10 km²

	planimetric a + b) draft c) classific. draft d) draft/original				contour lines				planimetric (d) + contour lines			
	1				2				3			
scale 1 :	18'	25'	30'	37'	18'	25'	30'	37'	18'	25'	30'	37'
a) compilation built-up areas roads, etc. waters use of land	73	46	61	44								
b) compilation relief features					18	19	16	20				
c) compilation + interpretation stereoscope	106	46	93	44								
d) compilation + interpretation stereoscope + cartographical supplements	121	54	97	80					139	73	113	100

Table 16a — Contour lines: time taken in hours per model and 10 km² surveyed area

scale	1 : 18,000	1 : 25,000	1 : 30,000	1 : 37,000
reference figures acc. to equation (11) and table 1; sect. 2.2	9	12	15	19
actual figures acc. to table 15; col. 2	9	9	16	20

Table 16b — Planimetric + contour lines: time taken in hours per model and 10 km² area

scale	1 : 18,000	1 : 25,000	1 : 30,000	1 : 37,000
reference figures acc. to equation (11) and table 1; sect. 2.2	60	83	100	124
actual figures acc. to table 15; col. 1.d	60	27	97	80

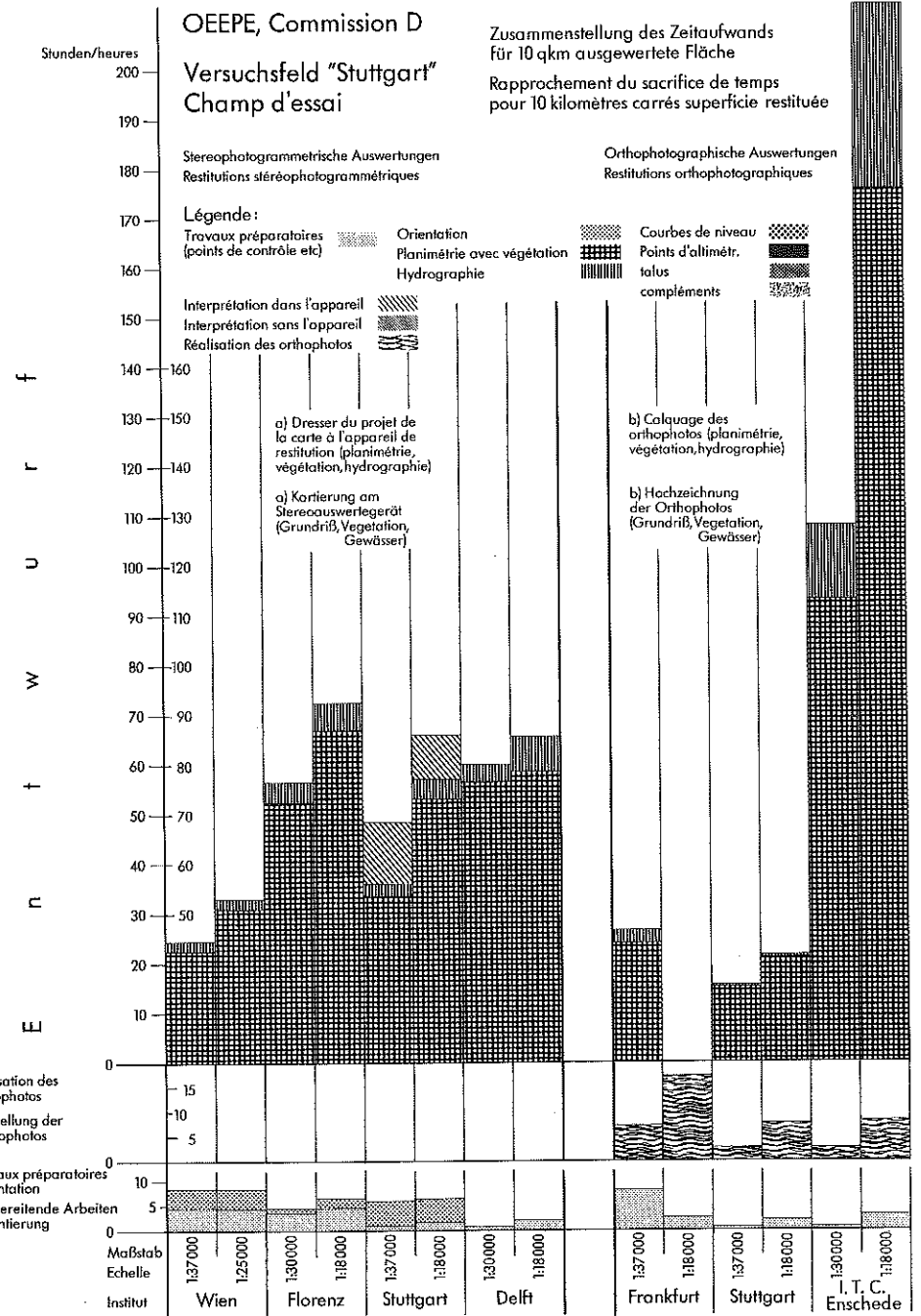
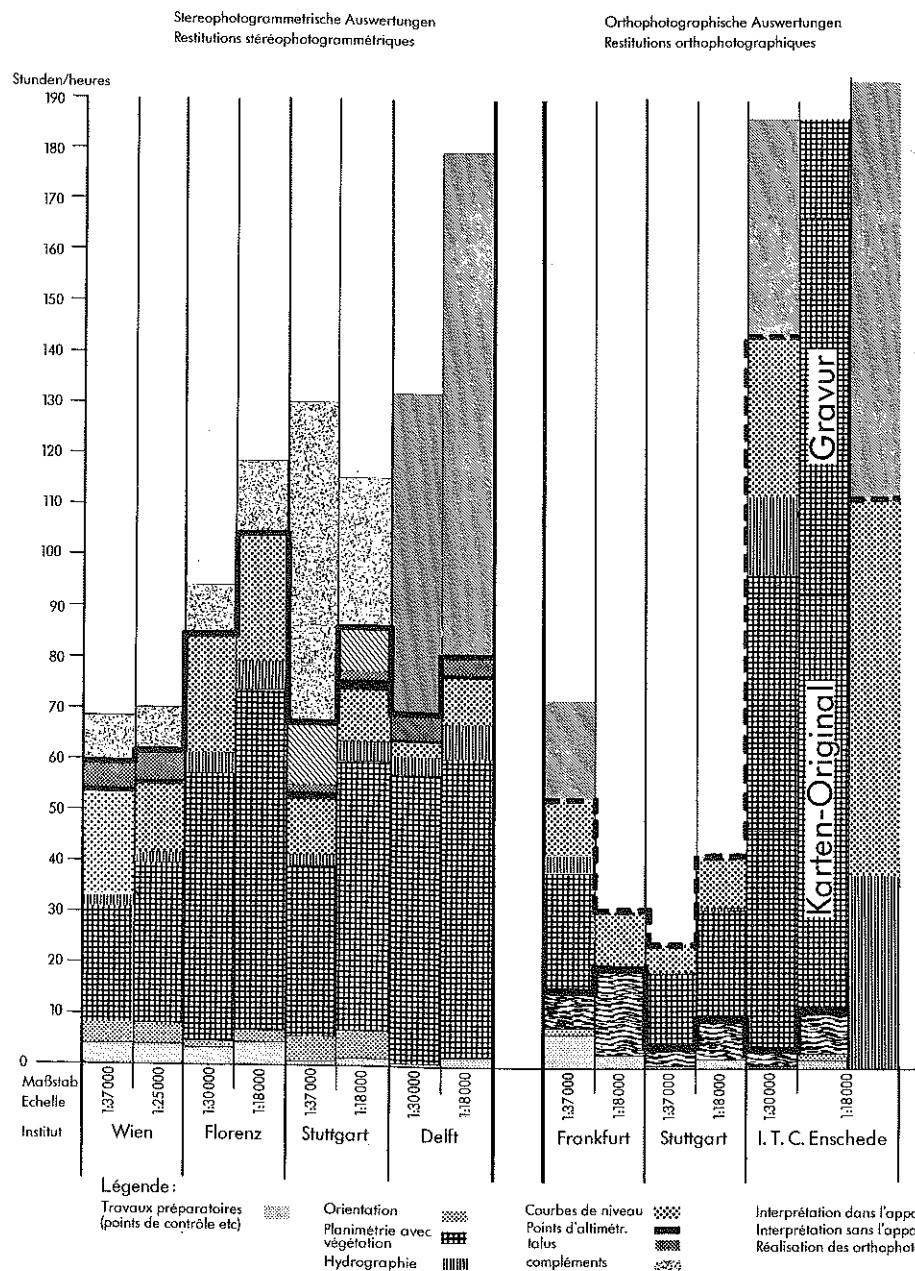
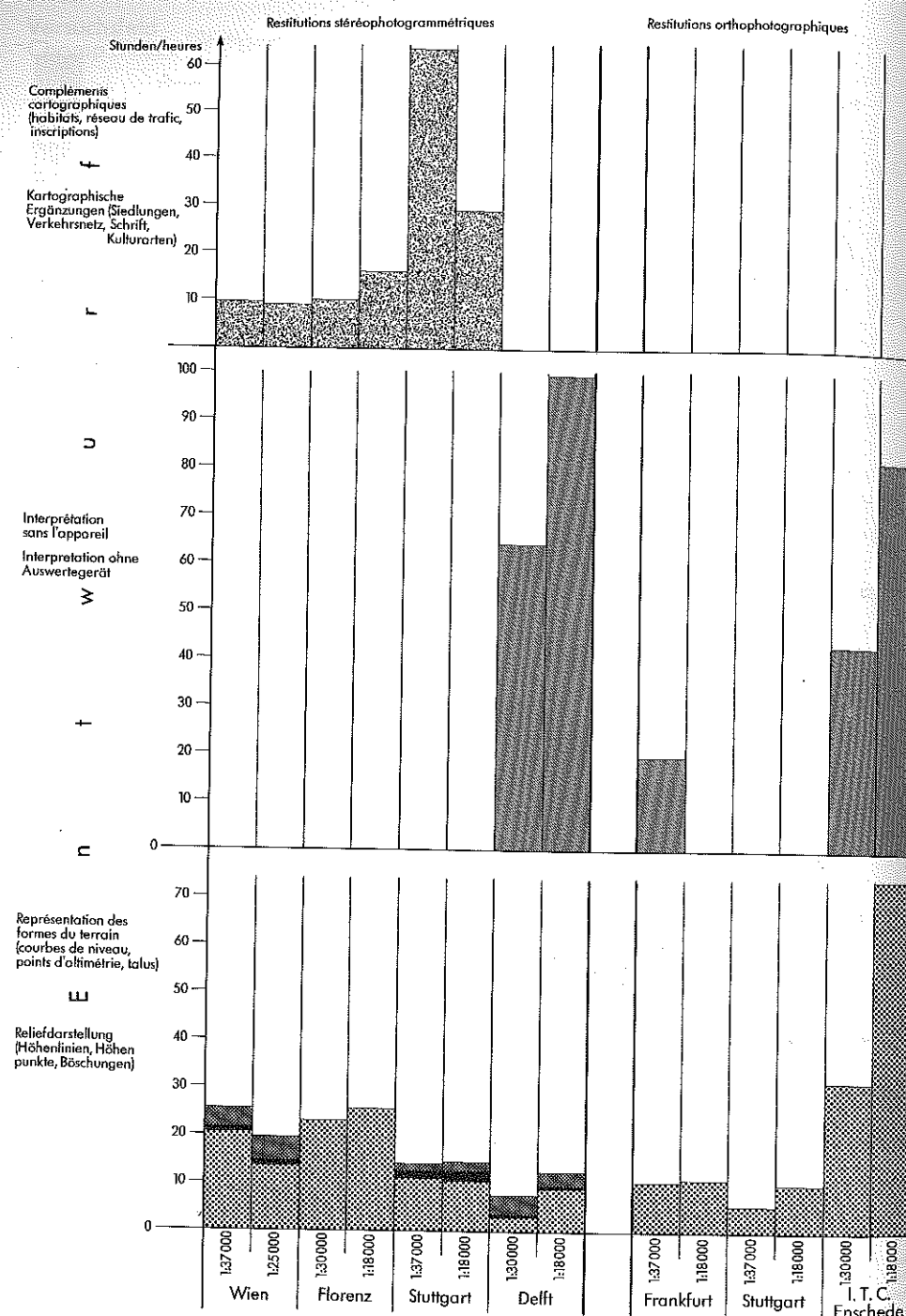


Abb.-Fig. 10c



The large deviations can be attributed to the individual influence of the observer, the technical method used and the cartographical aims. Fig. 10a explains these contents.

4.3. Orthophotographic methods

Orthophotos from aerial photographs at scale 1 : 25,000 have not been produced. Three scales have been used: 1 : 18,000, 1 : 30,000 and 1 : 37,000. The results of the instruments used are given below:

Table 17 — Technical and time expenditure for the production of 1 : 10,000 scale orthophoto for 10 km² surveyed or 10 dm² pictured area

institute	scale	slit width s [mm]	speed v [mm/sec]	time [h]		
				actual	reference on- off- line	
	1	2	3	4	5	6
Frankfurt	1 : 37,000	4	1.3	15	—	13.8
	1 : 18,000	4	1.3	20	—	22.2
Stuttgart	1 : 37,000	4	5	3	4.2	
	1 : 18,000	4	3	9	10.4	
Enschede	1 : 30,000	4	5	3	4.2	
	1 : 18,000	4	3	10	10.4	

Note: The reference times have been taken from the following table 18.

In [19] and [20] the time consumption has been analysed from various perspectives and different methods. The Baden-Württemberg Landesvermessungsamt produced the evaluation result of approximately 27.5 [dm²/h orthophoto] per s = 8 [mm] and v = 10 [mm/sec]. These figures formed the basis for the following table.

Table 18 — Time consumption for orthophoto production

diaphragm width s [mm]	speed v [mm/sec]	result [dm ² /h] orthophoto	orientation per model [h]	10 dm ² time [h]			
				1. mod. on off		2. mod. on off	
1	2	3	4	5		6	
8	10	27.5	2.75	3.1	3.5	6.2	6.6
4	5	6.9		4.2	5.6	8.4	9.8
4	3	4.1		5.2	7.6	10.4	12.8
4	1.3	1.8		8.3	13.8	16.6	22.2

Note: These values agree roughly with [19]. Deviations are due to the differing terms of reference and the difference in the amount of additional work. For off-line production, the projection time was separately added to the total time taken (col. 5 and 6).

The relationship between the false positioning of drop lines and scanning speed has been shown in a diagram in [8] p. 45. The speeds in table 17 are chosen in accordance with professional requirements. The figures shown in table 18 regarding the time required to produce an orthophoto have, on the whole, been confirmed by the evaluation results of the institutes (see table 17, columns 4, 5 and 6). The figures in table 18 can be used in the preparation of timetables. They should be considered as guidelines, in which the photographic development work is not included. The results in columns 5 and 6 would have been improved by this amount. Time calculations should be set up according to the figures in columns 3 and 4. In columns 5 and 6, the time requirement for the cases in question has been recorded. The following generally applies:

$$Z_A = \left(\frac{F_o}{L} \cdot \frac{[\text{dm}^2]}{[\text{dm}^2/\text{h}]} + n_{Mo} \cdot 2,75 [\text{h}] \right) n_{OF}. \quad (12)$$

Key:

- F_o , the format of the orthophoto
 L , performance (column 3, table 18)
 n_{Mo} , number of models per orthophoto
 n_{OF} , number of orthophotos necessary.

The production requirements for orthophoto- and orthophoto map series can be calculated according to equation (12). The production times to be allowed in the case of a topographic base map are shown in the following table 19, which contains extracts from fig. 10a to 10c.

Table 19 — Production expenditure for a topographic base map 1 : 10,000 in hours/10 km² on the basis of orthophoto and drop lines

	orthophoto			contour lines draft			contour lines engraving			planimetric draft			planimetric engraving		
	1			2			3			4			5		
scale 1 :	18'	30'	37'	18'	30'	37'	18'	30'	37'	18'	30'	37'	18'	30'	37'
a) scanning of profile + projection	(see tables 17 and 18)														
b) elaboration of drop lines				11	—	9	—	31	74						
c) Fair drawing map + interpretation										20	—	22			
d) interpretation + fair drawing + engraving map													294	151	—

As shown in fig. 10a to 10c, the figures in table 19 are of varying weight. The tests in column 5, for example, were carried out by only one institute. Similar figures from the profession which could support these figures are often unreliable, since their conditions are not known in detail. It is, therefore, a pity that the cartographical work has come off badly.

4.4. Comparison of the performances of both methods

It is necessary for the working hours listed in table 15 to be divided by the corresponding values of tables 17 and 19 (table 17, column 5, positions 3 to 6, 4 hours for 1 : 37,000 and 1 : 30,000 and 10 hours for 1 : 18,000). The resulting ratios have been set out in the following table 20.

Table 20 — Ratio between the time requirements for the stereophotogrammetric and orthophotographic methods

picture	planimetry				contour lines				mean
	1				2				3
scale 1 :	18'	25'	30'	37'	18'	25'	30'	37'	
a) stereo-compilation planimetry = { orthophoto (table 15, col. 1a/ tab. 17, col. 5, pos. 3 to 6)	7	5	15	11					6 and 13
b) stereo-compilation contour lines = { contour lines, profile hachures (table 15, col. 2/ table 19, col. 2)					1.5	—	—	2	1.5
c) stereo-compilation planimetry draft = { orthophoto (table 15, col. 1d/ tab. 17, col. 5, pos. 3 to 6)	12	5.5	24	20					9 and 22
d) stereo-compilation planimetry draft = { ortho extracts, planimetry — E. (table 15, col. 1d/ table 19, col. 4)	6	—	—	4					6 and 4

The quantitative superiority of the orthophotos is demonstrated in column 3 of table 20. When the linear planimetric map content is taken out of the orthophoto, the time advantage compared to the stereophotogrammetrical method is still considerable. Against this, the advantages of the orthophoto-method in the production of contour lines from drop lines are lessened by about one and a half times. Where orthophoto maps at 1 : 10,00 are sufficient as a cartographic starting point, they only require 5 % to 10 % (column 3, c) of the stereophotogrammetrical production time for a map. This is on condition that the contour lines are not extracted from drop lines, but are compiled automatically [18].

Orthophotos from small scale aerial photos reduce the expenditure by half, thereby doubling the effectiveness. A map series can be produced at least ten times more quickly than by the stereo-method.

5. Final conclusion

The aim of the examination was to review the alternatives for the production of 1 : 10,000 maps, by which the extremes of topographic-cartographic requirements and the potential for map compilation could best be combined. The stereophotogrammetric and orthophotographic results have, therefore, been sufficiently qualitatively and quantitatively examined from all aspects, to be able to decide on rational methods of aerial photo mapping and cartographic development. Emphasis was placed on analysing generally the field of study from an overall point of view, rather than thoroughly examining details merely.

The final concept for the production of topographic base map could be divided into the following sequence:

- a) Definition and arrangement of the respective use/cost/time requirement in order of their priority.
- b) Estimation of production time of a map series with the help of tables 15, 17 and 20 and the various production methods.
- c) Weighing of the qualitative results on the basis of tables 5 to 14b, fig. 9a to 9c, in addition to fig. 4a to 7d and 10a to 10c according to the groups of objects. Comparison of claim for quality with actual quality.
- d) Review of the present and future cartographic situation, including the continuation of the map series. Production of a cartographic planning concept and guidelines for the map presentation and configuration according to the proposal in annex 15.
- e) Statement of a technical concept for aerial photo evaluation using the results in sect. 2.4 to 2.7 and 4.2 to 4.4.
- f) Synopsis of the list of examination methods for planimetric and height accuracy.

The various possibilities should each be linked with a plan from which one can see the type and extent of the quality testing. The test procedures as described in sect. 2.6 for altitude representation, which were used in part for other object pictures as in sect. 2.5, are to be regarded as pilot models in their construction and in the representation of their results. Their systematic use leads to the procedure of an automatic check which can be automated and standardised through computer programmes and test areas. Since, as has been shown, the evaluated results are subject to the changing interior and exterior influences of the photograph and evaluation the systematic application of such test procedures cannot be dispensed with.

Since in principle no snags exist against applying the evolved procedure without exception to the other object groups of the map contents as well concerning the judgement on the quality of the contour lines, it was decided not to proceed individually for reasons of time.

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L'établissement de cartes topographiques au 1/10 000 par voie photogrammétrique

(Version abrégée)

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1. Introduction

Les cartes de base topographiques au 1/10 000 et plus grandes remplissent une fonction double en tant que bases de recherche, de planification et de technique de construction d'une part ainsi que de préparation et de mise à jour de cartes topographiques aux petites échelles de l'autre part. On leur attache de l'importance particulière au début des travaux pour une oeuvre cartographique. Et c'est exactement ici où l'expérience pour l'organisation et le développement cartographiques appropriés ainsi que pour la préparation de ces cartes de base est souvent assez pauvre. Cette situation a favorisé la décision de la Commission D de soumettre la proposition à l'OEEPE demandant à lui confier la première ce domaine de tâches.

L'échelle de 1/10 000 avait été choisie parce qu'elle exige un minimum de travail cartographique, garantie à la photogrammétrie l'usage optimal et permet encore une cartographie sans généralisation. Le nombre de feuilles diminue (à un quart par rapport à l'échelle de 1/5 000 p. ex.) et le rendement supérieur de prise de vues est neutralisé par des techniques photogrammétriques.

Au début, la seule intention était de comparer les rendements quantitatifs des procédés stéréophotogrammétriques et orthophotographiques. Ce n'est que plus tard que l'on a exprimé le désir d'examiner en détail également les possibilités qualitatives des procédés. Par contre, on a porté moins d'attention au potentiel cartographique, particulièrement à sa réunion avec le potentiel photogrammétrique au cours des recherches parce que les instituts participant aux essais ont en général préféré l'évaluation photogrammétrique à l'élaboration cartographique.

La tâche photogrammétrique se divise en l'analyse des résultats obtenus par l'interprétation des sujets topographiques, la précision des mesures planimétriques et altimétriques, le temps, le personnel et les instruments nécessaires à chaque procédé et leur confrontation.

Le but visé en cartographie portait sur l'établissement de directives, un échantillon pour le dessin et des épreuves de carte ainsi que sur la détermination du temps nécessaire à la préparation des ébauches et les rédactions définitives de carte.

2. Ensemble des tâches photogrammétriques

Quant au champ d'essai (voir figure 1, page 14) on a défini les exigences suivantes en ce qui concerne la topographie, la cartographie et la géographie:

- a) Les échelles des photographies aériennes soient 1/18 000, 1/25 000, 1/30 000 et 1/37 000;
- b) l'étendue du champ égale au maximum à 2 images-modèle à grande échelle;
- c) diversité extrême des formes de terrain, haute densité hydrographique, différentes structures des agglomérations, voies de communication bien ordonnées et utilisation variée du sol avec forêts;
- d) disponibilité de cartes topographiques exactes et mises à jour aux échelles supérieures à 1/10 000 ou bien de documents qualifiés permettant l'évaluation de telles cartes;
- e) position du champ à proximité de Stuttgart, le siège du centre pilote, pour être à même d'exécuter des travaux éventuels de reconnaissance, de mesure et de contrôle avec un minimum de dépenses.

Les données aéronautiques sont indiquées dans le tableau 1, page 15. Les photographies aériennes ont été prises avec une ZEISS RMK, A 15/23 avec l'objectif grand'angulaire Pleogon $f = 153$ mm, angle de champ = 104°.

La restitution photogrammétrique avait pour bases: positives sur verre et sur papier des photographies aériennes, points de contrôle planimétriques et altimétriques qui ont été mesurés dans un réseau du nivellement et un réseau trigonométrique suffisamment denses et précis, directives concernant la restitution, 8 mesures de profil distribuées régulièrement sur le terrain (voir annexe 9a) ainsi que cartes cadastrales et cartes de base topographiques. A l'aide de ces profils on a exécuté des études sur la précision de la représentation cartographique des courbes de niveau en tenant compte des relations mathématiques des équations (1) à (9c), pages 16–18, et du tableau 2.

Les documents cartographiques comprenaient: le plan cadastral au 1/2 500, sa réduction au 1/10 000 et leur combinaison avec des courbes de niveau réduites (voir figure 2, page 19) dont l'origine était une restitution au 1/5 000; un échantillon pour le dessin avec épreuves de cartes au 1/10 000 (voir annexes 15, 16a à 16c et 17) ainsi que des directives indiquant quels sujets et de quelle manière il faut les restituer. La répartition des tâches figure dans le tableau 3, page 20.

L'interprétation des photographies aériennes portait sur les qualités objectives et subjectives des sujets topographiques et sa valeur a été déterminée d'après les résultats quantitatif et qualitatif de la restitution des photographies aériennes. Pour chacun des 4 images de sujets — hydrographie, couverture végétale, agglomérations et voies de communication — on a fait la comparaison entre la quantité des sujets levés et leur quantité théorique d'après les cartes de base. On a continué ces statistiques en les subdivisant d'après les procédés de restitution, les échelles-image ainsi que la densité, la position, le type et les environs des sujets tout en s'orientant à l'utilité. Grâce à cette

méthode on a pu découvrir des influences essentielles agissant de l'intérieur et de l'extérieur. Le tableau 4, page 27, montre la répartition des procédés et des photographies aériennes aux échelles différentes sur les centres de restitution.

Le résultat de l'interprétation des bâtiments figure dans les annexes 1a–7c et l'analyse correspondante dans les figures 4a–4d, pages 23–26 et dans le tableau 5, page 27. On peut en tirer les conclusions suivantes:

- a) Le succès de l'interprétation dépend des dimensions des sujets, de leur densité et de l'échelle des photographies aériennes.
- b) Le gain quantitatif de la restitution à grande échelle s'élève à 10 % environ par rapport à celle à petite échelle.
- c) La perceptibilité des sujets est sur les orthophotos dans tous les deux groupes d'échelle de 6–7 % inférieure que sur les clichés du procédé stéréophotogrammétrique.
- d) On pourrait compenser le déficit de ce rendement en mettant

$$M_{\text{image}} \sim 120 \sqrt{M_{\text{carte}}}$$

L'interprétation des routes et chemins avait été divisée en classes de sujets qui sont indiquées dans l'annexe 15, page 15, sous forme topographique. Mais on avait compensé ces classes pour des raisons d'utilité. Les 3 groupes restants comprennent: routes classifiées, chemins à travers champs et prés et chemins forestiers ainsi que rues à travers de terrains bâtis. Les annexes 1a–7c montrent des exemples tirés des représentations cartographiques et les figures 5a–5d, pages 29–32 et le tableau 6, page 33 traitent les résultats obtenus de cette interprétation. Les voies ferrées sont incluses dans ces études. On peut en conclure comme suit:

- a) Les chemins de fer et les routes classifiées sont presque complètement représentés par voie cartographique dans tous les deux procédés (orthophotographique et stéréophotogrammétrique).
- b) Le déficit des rues restituées est causé par des influences externes; c'est pourquoi des échelles-image agrandies n'en seront pas le remède.
- c) Les lacunes d'interprétation se concentrent sur les chemins. Dans le procédé stéréophotogrammétrique, leur pourcentage s'élève à 12 % à grande échelle et sur le terrain découvert, et à 17 % à petite échelle. Nominalelement il atteint quelquefois le double (12 % par rapport à 6 % et 17 % par rapport à 15 %, voir tableau 5, colonne 3) de celui des bâtiments et les possibilités de l'influencer par l'échelle-image sont petites.
- d) Le procédé orthophotographique donne dans tous les deux groupes d'échelle des résultats qui sont de 7 % moins bons que ceux du procédé stéréophotogrammétrique.
- e) En ce qui concerne les forêts, les deux procédés donnent des résultats tellement incertains de manière qu'un levé topographique des chemins forestiers est inévitable.

La perceptibilité de l'hydrographie (voir tableau 7, page 34, les figures 6a-6d, pages 35-38, et les annexes 1a-7c) donne le résumé suivant:

- a) Tous les deux procédés permettent une représentation cartographique presque complète des eaux courants.
- b) Le procédé stéréophotogrammétrique donne plus de détails même à petite échelle que le procédé orthophotographique à grande échelle.
- c) On avait saisi par voie photogrammétrique environ 50 % des petits sujets, mais par voie orthophotographique seulement 30 % environ.
- d) Ici, les résultats des restitutions des deux procédés divergent plus qu'avec les images de sujets étudiées jusqu'à maintenant.

Les extraits des images sur la couverture végétale (voir tableau 8, page 39, figures 7a-7d, pages 40-43 et les annexes 1a-7c) montrent que

- a) dans la plupart des cas, tous les deux procédés donnent de meilleurs résultats à petite échelle qu'à grande échelle;
- b) tous les deux procédés ont à peu près le même rendement;
- c) la photogrammétrie convient à la représentation cartographique des types de l'utilisation du sol définis dans l'annexe 15, pages 17 et 18.

Un autre critère pour la qualité de la restitution est la précision de la représentation cartographique des sujets topographiques. Très souvent la restitution altimétrique en sert de contrôle. Dans ce cas, une petite partie de ces recherches s'étend également à la restitution des bâtiments. Mais le manque de temps et de personnel était la cause pour quoi on a renoncé à étendre systématiquement les analyses à tous les images des sujets. On voulait seulement démontrer à l'aide d'un exemple — ici la représentation cartographique de bâtiments — qu'il vaut la peine d'appliquer la systématique, avec laquelle on avait examiné la qualité de la restitution altimétrique, également dans le même degré à toutes les autres restitutions. Les procédés d'examen pour la qualité des restitutions altimétriques sont généralement valables et sont applicables de manière correspondante à toutes les représentations cartographiques. Il est possible de perfectionner ce système de contrôle pour obtenir une routine automatique contrôlant chaque restitution objectivement et minutieusement.

La précision planimétrique et altimétrique des représentations cartographiques de bâtiments est indiquée dans le tableau 9, page 44, dans la figure 8 ainsi que dans les annexes 1a-7c. Cette étude a donné les résultats suivants:

- a) Par rapport au procédé stéréophotogrammétrique, l'offre orthophotographique en cas de construction discontinue et au 1/18 000 est à peu près inférieur de 100 % (voir colonne 5, tableau 9). Cette perte de qualité peut être compensée par des photographies aériennes à plus grande échelle (voir pages 76 et 77 de cette version abrégée).

- b) Il semble que les divergences des résultats lors du procédé orthophotographique sont causées par des différences de la technique et de la routine pendant la restitution, c'est-à-dire par des différences individuelles.
- c) Les représentations cartographiques effectuées par voie stéréophotogrammétrique subissent plus les influences exercées par les restituteurs que celles exercées par les procédés techniques.
- d) L'influence des zones bâties et, par conséquent, de la densité des détails de l'image est moins grande avec le procédé stéréophotogrammétrique qu'avec le procédé orthophotographique. Il est évident que les résultats contredisant à ce principe à l'échelle-image de 1/25 000 se ramènent à des conditions non paritaires de la restitution.

Le problème mesures sur clichés et précision altimétrique a été traité sous forme numérique dans les tableaux 10 et 11, pages 47 et 48, dans le tableau 12, page 49, dans les tableaux 13a et 13b, dans les diagrammes 1-3, pages 53-55, et dans les tableaux 14a et 14b, pages 56 et 57. Dans les recherches on a également inclus les annexes 9b-14 contenant des courbes de niveau restituées et des données. Les résultats des analyses ont été résumés comme suit:

- a) La qualité de la restitution des photographies aériennes a été étudiée en fonction du procédé, de l'échelle-image, des facteurs individuels, des structures du paysage et des exigences topographiques et cartographiques.
- b) Quant à la qualité, le procédé stéréophotogrammétrique s'adapte mieux à des conditions extérieures et intérieures de prise de vues et de restitution que la restitution orthophotographique.
- c) Tous les deux procédés offrent une alternative en regard de dépenses, utilité et temps.
- d) La règle forfaitaire de $M_{\text{image}} \sim 200 \sqrt{M_{\text{carte}}}$ pour le procédé stéréo est confirmée. Par contre, la restitution des orthophotos devrait se fonder sur la relation $M_{\text{image}} \sim 120 \sqrt{M_{\text{carte}}}$. On n'a pas pu déterminer l'avantage que donnent les orthophotos à la reconnaissance.
- e) Dans tous les deux procédés, l'influence qu'exerce l'opérateur l'emporte sur toutes les autres effets. Ce fait s'exprime dans les grandes divergences des restitutions de photographies aériennes équivalentes, dans les contradictions des résultats par rapport aux expériences acquises dans la pratique ainsi que dans la diversité de la qualité cartographique des représentations.
- f) Des différences dans la structure du paysage ont une influence moins grande sur le résultat stéréophotogrammétrique que sur le résultat orthophotographique. Dans les régions forestières, tous les deux procédés nécessitent des compléments par l'intermédiaire de reconnaissances et de mesures topographiques. Il s'impose un enlacement rationnel et étroit des techniques photogrammétrique et terrestre de prise de vues, de levé et de restitution.

- g) Il s'est avéré bon de fonder les descriptions des sujets sur des caractéristiques topographiques, c'est-à-dire objectives à l'opposition des qualités subjectives des sujets, fonctionnelles en majeure partie. Par conséquent, les descriptions des caractéristiques des sujets, compilées dans l'annexe 15, peuvent être considérées comme appropriées aux photographies aériennes. On n'a pas exécuté des études sur l'interprétation de caractéristiques subjectives à partir des photographies aériennes. C'est pourquoi on ne peut pas répondre à la question sur la nécessité d'une révision à cet égard de la feuille type (annexe 15).
- h) L'examen de la précision cartographique avec laquelle les courbes de niveau sont représentées, ou bien en général de la précision de la restitution altimétrique d'après un seul des procédés utilisés ne fournit pas de renseignements approfondis sur la qualité. Ce n'est que par la combinaison des trois procédés numériques (déviations des points cotés, altitudes des lignes avec dépendance ou non de l'inclinaison du terrain) avec le procédé graphique (comparaison des courbes de niveau représentées par voie cartographique à celles données) que l'on reçoit des renseignements sûrs concernant le type, la gravité et la direction des déviations. Pour l'autocontrôle des restitutions de cette sorte on pourrait se servir de programmes de calcul orientés à des données réelles et théoriques, rendues au préalable, ainsi qu'aux méthodes d'examen utilisées.
- i) En utilisant ces programmes et ces procédés d'examen pour tous les groupes de sujets et en observant des limites forfaitaires des déviations on serait sûr d'obtenir la même qualité pour toutes les représentations cartographiques des sujets.

3. Ensemble des tâches cartographiques

La partie centrale des études se concentrait sur la mobilité cartographique et sur sa stimulation par un maximum de possibilités variées pour la restitution de photographies aériennes. On a pu atteindre cet objectif en étudiant non seulement la carte conventionnelle, la carte à lignes; mais aussi, en abandonnant l'intention initiale, l'orthophotocarte. Etant donné que ces cartes ont déjà été largement traitées en regard de leur structure cartographique et de leur force d'expression, on a évité les problèmes matériels et techniques et on a saisi en premier lieu le temps nécessaire à la production.

La proposition concernant les directives pour les travaux cartographiques à la préparation d'une carte topographique au 1/10 000 (carte à lignes) — annexe 15 — a été élaborée sur le modèle de la carte belge au 1/10 000. Cette base cartographique a été divisée d'après des groupes d'image et des images de sujets. A chaque planimétrie on a attribué les caractéristiques objective et subjective avec sa force d'expression cartographique (symbole, explication écrite ou le nom). La forme et la façon des symboles cartographiques sont concordées avec une représentation cartographique par voie automatique.

Les annexes 16a—16c et 17 contiennent des maquettes de différentes gradations de couleur, préparées d'après ces directives. Les représentations cartographiques des annexes 4b et 12 (courbes de niveau, brun) sont les bases de ces maquettes.

Les extraits de carte présentés dans les annexes 1a—7c et 9b—14 ont été établis en partie par des instituts qui travaillent principalement dans les domaines de la préparation et de la mise à jour de cartes topographiques. Toutes les représentations cartographiques sont établies d'après le principe: recevoir autant de rédaction définitive que possible au cours de la représentation cartographique par voie photogrammétrique pour ainsi réduire largement les travaux cartographiques consécutifs. Les travaux photogrammétriques ainsi que topographiques et cartographiques sont proportionnés d'après des critères personnels, organisationnels, techniques et matériels. C'est pourquoi dans les annexes les degrés de l'approche à l'original désiré de la carte montrent une grande variété. Les cas dans lesquels il est possible d'égaliser représentation cartographique et carte ou bien d'égaliser représentation cartographique et projet ne se déterminent pas seulement d'après la préparation de cartes, mais aussi d'après les exigences des cartes. Les mêmes critères décident le choix entre l'orthophotocarte et la carte à lignes ou bien l'emploi d'une combinaison de toutes les deux. Cet ensemble de problèmes se manifeste en comparant les annexes 16a—16c et 17 avec les annexes 19 et 20. En général on peut constater que les possibilités cartographiques augmentent quand on renonce à la priorité de la carte de base conventionnelle. L'orthophotocarte peut alors prendre la fonction d'une carte provisoire susceptible d'être développée pas à pas en une carte topographique de base (carte à lignes).

4. Efficacité des procédés

Jusqu'ici, les études exécutées ont traité l'efficacité qualitative des procédés. Les perspectives quantitatives intéressent très souvent dans le cas où il est important de préparer le plus vite possible une carte de base pour satisfaire aux premiers besoins. Il faudrait inclure dans ces études non seulement le sacrifice de temps pour la photogrammétrie mais aussi pour la cartographie. Malheureusement les études sur ce complexe ne donnent que des renseignements insuffisants. Les possibilités cartographiques et le manque d'expérience ont été des obstacles pour l'établissement des rédactions définitives. Pourtant les analyses restantes ouvrent en substance des perspectives sur les exigences et les dépenses totales d'une préparation de cartes. On a prêté une attention spéciale aux différences qui existent entre la préparation conventionnelle de cartes et la production d'orthophotocartes. On trouvera des renseignements à ce sujet dans les tableaux 15, page 65, les figures 10a—10c, les tableaux 16a et 16b, page 65, les tableaux 17 et 18, page 69 ainsi que les tableaux 19 et 20, pages 70 et 71.

5. Conclusion

Le programme pour la préparation d'une carte de base peut être divisé dans les phases comme suit:

- Ordonner les exigences en utilité, dépenses et temps en vue de leur urgence,
- estimer le temps de préparation d'une série de cartes en employant les tableaux 15 et 17—20,

- c) peser le succès en qualité à l'aide des tableaux 5—14b, des diagrammes 1—3 (fig. 9a—9c) ainsi que des figures 4a—7d et 10a—10c,
- d) évaluer les possibilités et exigences cartographiques d'aujourd'hui et de l'avenir. Dresser un plan cartographique et les directives pour la préparation et la mise à jour de cartes. Elaborer les principes pour la représentation et la conception de la carte correspondant à la proposition dans l'annexe 15,
- e) définir le projet sur la technique des procédés de la restitution de photographies aériennes en tenant compte des résultats des interprétations de photographies aériennes, des mesures sur les clichés et de la précision de la représentation cartographique de la planimétrie et de l'altimétrie ainsi que de l'efficacité quantitative en stéréophotogrammétrie et en orthophotographie,
- f) faire le sommaire du catalogue des procédés d'examen pour les représentations cartographiques de tous les sujets et groupes de sujets.

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List of Some Terms Utilized in the Figures and Annexes

A	analyse qualitative de la restitution planimétrique — bâtiments — avec	qualitative analysis of the planimetric restitution — buildings — with
B	bâtiments grands normaux petits	buildings large normal small
C	calquage des orthophotos carrière carte de photo aérienne centre de gravité centres d'image centres de restitution champ champ d'essai chemins chemins de fer compléments compléments cartographiques (habitats, réseau de communication, écritures, sortes de culture) courbes de niveau courbes noirs	tracing of the orthophotos stone quarry photo map centre of gravity centres of photographs restitution centres field, land under cultivation test field tracks railways supplements cartographic supplements (settlements, communication network, lettering, culture types) contours black contours
D	densité de construction forte moyenne faible dresser le projet de la carte à l'appareil de restitution	construction density close mean weak plotting with stereo-restitution instrument

E	eaux courantes	running (waters)
	eaux dormantes	stagnant (waters)
	échelle-image	photo scale
	écriture	lettering
	erreur dans la précision planimétrique ou dans la position	planimetric error or positional error
	erreurs grossières ou non restitué	gross errors or not restituted
	erreurs moyennes des courbes de niveau	mean errors of the contours
	étendue	extent
	exactitude planimétrique et position correcte	topographic planimetry and positional accuracy
F	forêt	forest
	fossés	ditches
G	gravure	engraving
H	heures	hours
I	inclinaison du terrain	inclination of the terrain
	interprétation avec (sans) appareil de restitution	interpretation with (without) restitution instrument
	interprétation correcte	correct interpretation
	interprétation de la planimétrie	interpretation of planimetry
	interprétation fausse	wrong interpretation
J	jardin	garden
L	lacs	lakes
	largeur des rubans	width of strips
	limite de la région restituée	limit of restituted region
	limites des photos aériennes	limits of aerial photos
	limites d'erreurs permis	admissible error limits
	longueur totale	total length

M	mode	kind
N	nombre des points	number of points
	numéros des photos aériennes	numbers of photos
O	original de la carte	map original
P	points cotés	spot heights
	points de contrôle	control points
	points de terrain	terrain points
	points d'objets topographiques	object points
	points hydrographiques	hydrographic points
	pré	meadow
R	rapprochement du sacrifice de temps pour 10 kilomètres carrés surface restituée	compilation of the time spent on restituting an area of 10 km ²
	réalisation des orthophotos	preparation of the orthophotos
	représentation du relief	relief representation
	réseau de communications	communication network
	restitution orthophotographique	orthophotographic restitution
	restitution stéréophotogrammétrique	stereophotogrammetric restitution
	résultats partiels	partial results
	routes classif.	classified roads
	rues d'habitat	local tracks
S	saignées	drainage ditches
	sommaire	summary
	surface	area
T	talus	slope
	totalité approximative	total number approx.
	travaux préparatoires (points de comparaison etc.)	preparatory work (check points etc.)
V	verger	arboretum
	voir aussi	see also

Liste des publications de l'OEEPE

— Etat: May 1976 —

- [1] *L. Solaini; C. Trombetti*: Relation sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). 1^{ère} Partie: Programme et organisation du travail. — Photogrammetria XII (1955—1956) 3 (Spec. Publ. O.E.E.P.E., No. I), pp. 79—92, 12 fig. (en langue anglaise: pp. 93—99).
- [2] *L. Solaini; P. Belfiore*: Travaux préliminaires de la Commission B de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.) (Triangulations aériennes aux grandes échelles). — Photogrammetria XII (1955—1956) 3 (Spec. Publ. O.E.E.P.E., No. I), pp. 100—110 (en langue anglaise: pp. 111—121).
- [3] *L. Solaini; C. Trombetti; P. Belfiore*: Rapport sur les travaux expérimentaux de triangulation aérienne exécutés par l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (Commission A et B). — Photogrammetria XII (1955—1956) 3 (Spec. Publ. O.E.E.P.E., No. I), pp. 122—127, 2 tabl. (en langue allemande: pp. 128—134; en langue anglaise: pp. 135—140).
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- [9] *L. Solaini; C. Trombetti*: Relations sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). 2^e partie. Prises de vues et points de contrôle. — Photogrammetria XV (1958—1959) 3 (Publ. Spéc. O.E.E.P.E., No. II), pp. 77—95, 12 fig., 3 tabl. (en langue allemande: pp. 96—104; en langue anglaise: pp. 105—113).

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