From Map to Computer

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A new method of obtaining digital terrain data for earthwork quantity computation is presented. The procedure is being used in the design of a 200-mi section of Interstate highway on new location. Cross-section data are referred to a calculated centerline, which is developed from a study of aerial photographs prior to map compilation. The method permits key punching for electronic computers directly from manuscripts prepared by the photogrammetric mapping contractors.

Although the method was developed primarily for comparatively flat terrain it has also been adapted for use in taking digital data from contours of topographic maps. Time studies were made and comparative costs developed for this technique and for other methods of taking data from contours. These costs will serve as a guide in estimating the probable value of automation as a connecting link between contours of the maps and the computer. Complete automation from plotter to computer by resetting the stereomodels is also discussed briefly.

PHOTOGRAMMETRIC MAPS are a basic source of information for practically all ghway design in California. They are generally at a scale of 1 in. = 50 ft and cover band from 1,000 ft to 1,400 ft in width. In rolling terrain a contour interval of 2 is used. In comparatively flat terrain a grid of spot elevations at 100-ft intervals shown either in place of, or in addition to, the contours. During design the centerne is laid out on the maps and terrain data for earthwork quantities are taken off anually and processed by electronic computers. This paper describes a method rently developed to minimize the labor involved in preparing terrain data for computaon.

DESCRIPTION OF PROJECT

The method was developed and is being used on a project involving 240 mi of Interate highway on new location extending from US 99, south of Bakersfield, to US 50 west Tracy. Most of the route is on the west side of the San Joaquin Valley and immediely adjacent to the foothills. Approximately 170 mi of the location are in flat terrain th the remainder ranging from gently rolling to rolling. There is very little developent in this area with the land being used primarily for agriculture and grazing. Ground ver is negligible.

Available information used for reconnaissance studies consisted of a 1 in. = 2 mi sembly of County Road Inventory maps, 1 in. = 4,000 ft photo-indexes, and 1 in. = 000 ft U. S. Geological Survey quadrangle maps. In some areas these were supplented by 1 in. = 1,000 ft uncontrolled mosaics.

Following adoption of the recommended route by the California Highway Commission, e work of preparing plans and specifications for photogrammetric mapping was start-. The 240-mi route was divided into seven mapping contracts ranging from 25 to

52 mi in length. It was during this stage that plans were made for an improvement in methods of preparing terrain data for electronic computation.

In conformity with current California practice, basic horizontal control monuments were established by use of electronic distance measuring equipment at intervals of fro 2 to 4 mi. Mapping contractors were required to set semi-permanent monuments in the immediate vicinity of the proposed centerline at intervals of from 1,000 to 2,000 f The positions of these monuments were to be established by second order traverses closing on the basic control monuments. In addition to the semi-permanent monument the mapping contractors were required to leave chaining points along the random traverse at intervals of approximately 300 ft. The specifications provided that these chaining points were to be pre-marked and used for both horizontal and vertical photo control.

The purpose of these pre-marked chaining points was twofold. First, they would strengthen the mapping in the central portion of the mapping strip where accuracy is essential for development of earthwork quantities. Second, they would provide controls for laying out and computing the proposed centerline through areas where the terrain was flat and topography would not affect the precise location.

STRIP METHOD IN FLAT TERRAIN

The specifications also provided that in areas of flat terrain, where spot elevation were to be used in place of contours, the contractor was to lay out the coordinate gric plot the position of the pre-marked control points, and deliver the manuscripts togeth with a set of contact prints prior to the start of map compilation.

By studying the contact prints of the 1 in. = 250 ft photography together with available utility maps and other data, it was possible in a very short time to lay out the centerline on the 1 in. = 50 ft map manuscripts. The position of the centerline was computed and 100-ft stations were plotted on the manuscripts which were then returne to the mapping contractor for compilation.

In compiling the maps the contractor was required to show elevations at centerline and at distance of 42, 76, 103, 150, and 200 ft left and right. The first three of these distances corresponded, respectively, to the inside edge of pavement, outside edge o shoulder, and catch point of shallow cuts and fills. Beyond 200 ft left and right, elevations were required at 100-ft intervals. In addition to these specified distances, el vations were also required at all breaks.

In place of copying the terrain data on the usual forms for earthwork computation it was decided to keypunch directly from prints of the photogrammetric maps. Accordingly, strips covering a 300-ft width were cut from prints of the maps. Distance to break points, other than the specified distances previously mentioned, were then scaled and written opposite the elevations. A small portion of one of the strips is shown in Figure 1.

A holder with two spools (Fig. 2) was then constructed. A transparent template with marks at the specified distances of 42, 76, 103 and 150 ft was fastened to the holder so that zero on the template would correspond to centerline on the strip. The template is shown at the left in Figure 1.

After inserting a strip, generally about 5 ft in length, in the holder the keypunch operator turns the spool until the template is adjacent to the first station. After keypunching this station, a turn of the spool moves the strip into position for the next station. The keypunch operation is shown in Figure 3. After a minor amount of prac tice it was found that keypunching from the strips could be done at the same rate as from the conventional terrain data forms.

Comparative Costs

A comparison of costs between the strip method with spot elevations along cross-section lines and the conventional method of scaling distances and recording on form is given in the first two lines of Table 1. The cost of 2.1 cents and 4.1 cents per point, respectively, are for all charges involved in getting the data to the computer and include 1.6 cents per point for keypunching.

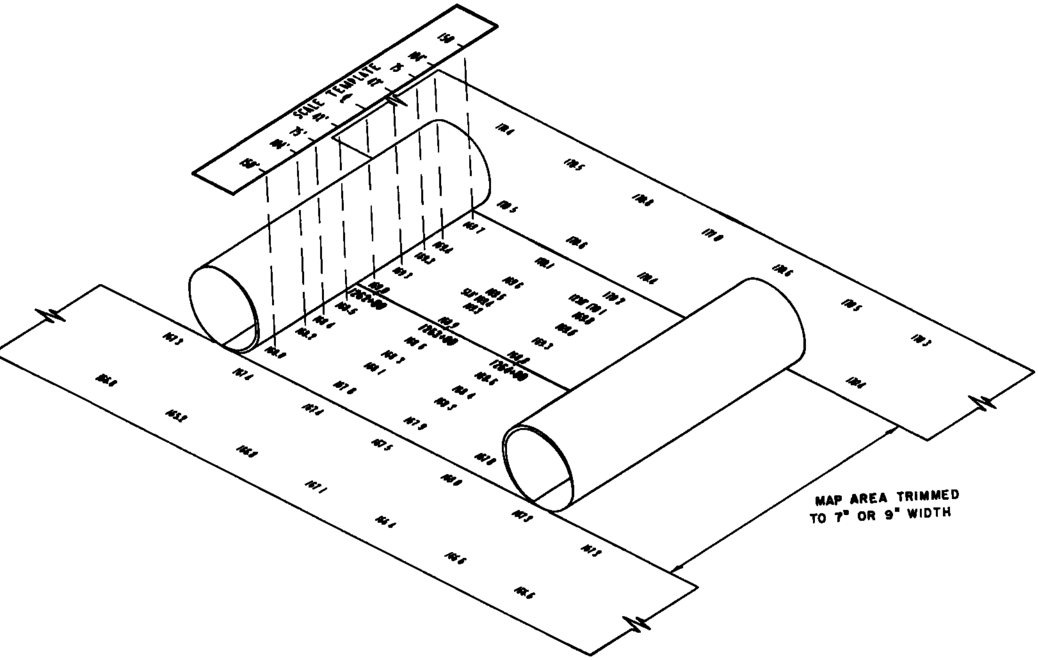

Figure 1.

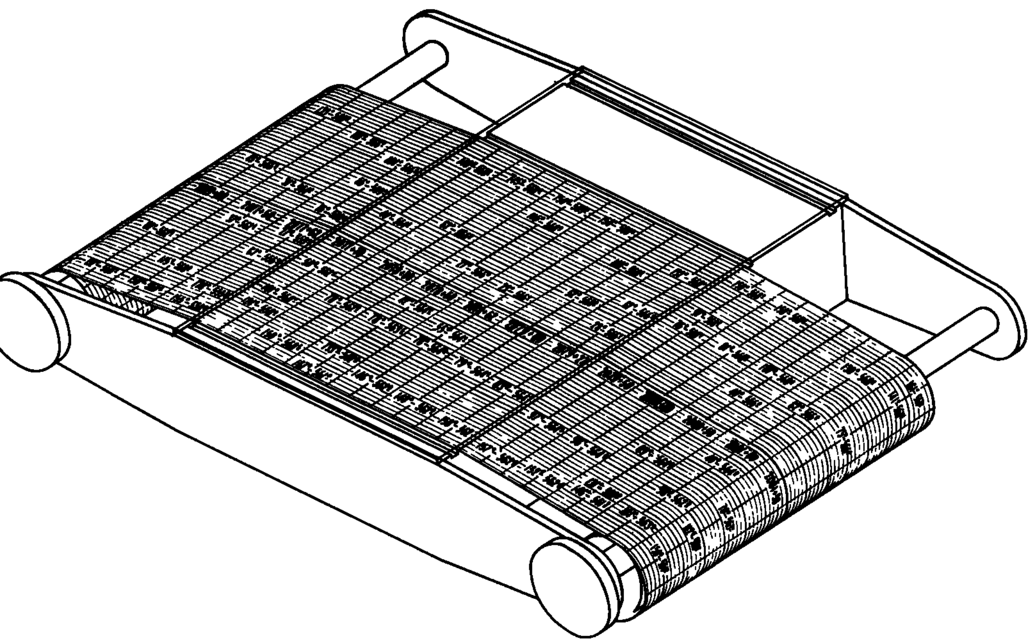

Figure 2.

Figure 3.

It should be noted that the saving of 2 cents per point is by comparison with scaling and recording points which are written along regular cross-section lines. With an arbitrary grid of spot elevations, as usually obtained in California, the mental interpolation required for determining elevations on cross-section lines would require more time. This in turn would result in greater savings for the strip method by comparison.

An alternate solution to this problem would have been to require the mapping contractor to use equipment such as the terrain data translator (1) and furnish the data on punch cards in place of writing the elevations on the maps. However, maps showing elevations are an essential tool of the designer for laying out drainage systems, interchange plans, and many other basic components of the total design. It was therefore considered that the minor savings which could be obtained by full automation of terrain data were more than offset by the value of the maps to the designer.

ROLLING TERRAIN

The success of the strip method in comparatively flat terrain led to an adaptation of its use in rolling terrain where elevations were shown by contours rather than by spot elevations along cross-section lines. In this type of terrain no attempt was made to position the centerline prior to map compilation, as the exact location could best be determined by the designer using the large-scale contour maps.

The conventional method of obtaining terrain data from contour maps is to scale distances along cross-section lines to each contour and/or breaks in the terrain.

TABLE 1

COMPARATIVE COSTS OF DIGITAL TERRAIN DATA

	Time (man-hr)				
ethod	Record	Check	No. of Points	Points per Man-Hour	Cost per Point
ɔot elevations, cross-section lines:					
Conventional	3.17	1.17	525	121	4.1 cents[a]
Strip	0.58	0.25	525	632	2.1 cents[a]
ontour maps:					
Conventional	10.03	6.07	1,050	65	6.2 cents[a]
Strip	6.45	1.58	1,011	126	4.0 cents[a]
Port-A-Punch	4.97	0.90	452	77	4.1 cents[b]
Dictaphone	4.83	2.25	982	138	4.0 cents[a, b]

ased on $3.00 per hour for take-off and check plus 1.6 cents per point for key-
nching and verifying.

ncludes 0.2 cents per point for printing tabulation prior to checking.

levations and distances are recorded in the form of cross-section notes which are en keypunched for electronic compuation.

Using the strip method, elevations and distances are recorded on a 7-in. or 9-in. rip of transparent mylar with a printed grid as shown in Figure 4. The strip is sitioned over the contour map at the station for which a cross-section is desired, a ck mark is placed at each desired contour crossing and at summits and depressions ong the cross-section line. Elevations of these points are written on the strip op- site the tick marks. This operation is then repeated at the next desired station.

It was found best to record elevations at all stations on a strip before determining stances left and right of centerline. Distances are then established by visual inter- lation of the tick marks on the grid and recorded on the left of the tick marks. It obvious that the transparent grid takes the place of the usual scale for measuring stances out from centerline. Scale parallel to centerline is of no importance and n be varied as desired to provide adequate spacing for the cross-section lines. ırves are represented as straight lines on the grid with lines normal to centerline presenting radial lines.

Keypunching was expedited at first by using different colored pencils for stations, evations and distances. After the operators became accustomed to keypunching from e strips this was found unnecessary. The same holder illustrated in Figure 2 is ed for keypunching.

her Methods Tested

After adapting the strip method to taking data from contour maps, tests were made r a 1-mi section to determine comparative time and costs for: (a) conventional meth- , (b) strip method, (c) use of the Port-A-Punch, and (d) use of a dictaphone. The rt-A-Punch is a small device for holding punch cards which are punched manually the same time distances out are scaled and elevations determined.

The costs per point for each of these methods are given in the last column of Table The costs for the conventional, strip, and dictaphone methods include 1.6 cents r point for keypunching. This cost was determined from records compiled for 6,000 points in a two-month period. The 1.6 cent cost includes: supervision, e- ipment rental, office space, and such miscellaneous charges as vacation, sick ave, and retirement. The keypunching costs also include verifying by another opera- r.

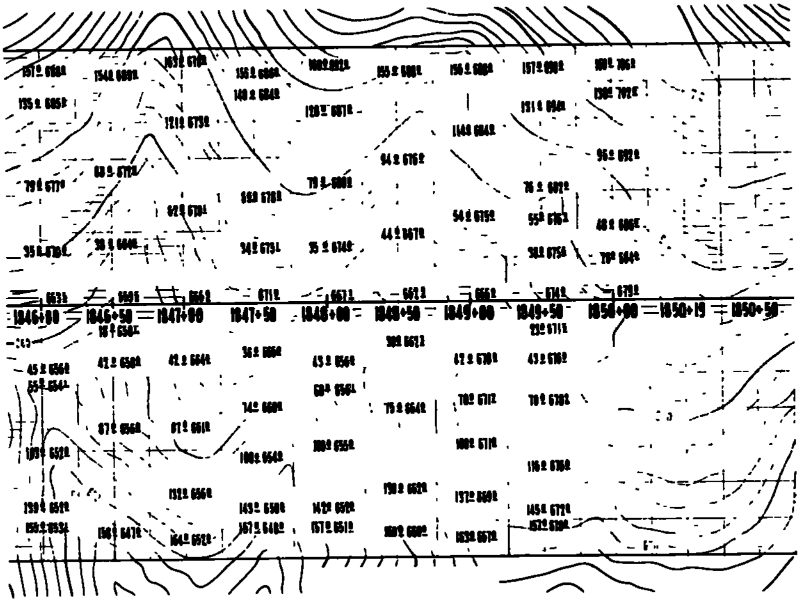

Figure 4.

Although the cost for the strip method was approximately the same as for either the Port-A-Punch or dictaphone it has several advantages over both of these methods. The most important of these is that the strip method can be checked before keypunchi whereas it was found that a satisfactory check of the Port-A-Punch and dictaphone take-off could only be made from the printed tabulation. This required returning the material to the Tabulation Section for correction. The strip method is also much simpler than either of the others, requires less equipment, and needs less practice to become proficient in its use.

Resetting Models

Another method of obtaining digital terrain data which is used in some states is to reset the models in a stereo-plotter after the centerline has been laid out on the larg scale maps. Digital data are then recorded directly on punch cards with the use of special equipment. This method was tried on a previously reported (2) experimental project. The costs involved were approximately 10 cents per point as compared to 4 cents by the strip method.

It has been contended that more accurate earthwork quantities would result from r setting the models, as the elevations are measured directly in the stereo-plotter rath than from contours. However, as C.L. Miller has pointed out (3), statistical accura rather than point accuracy is the essential requirement for accurate earthwork quantities. Therefore unless systematic errors are completely eliminated there is no assurance that any major increase in the accuracy of earthwork quantities can be achie by direct stereo-plotter measurements over those taken from a contour map (2).

Automation from Map to Computer

A method of taking digital terrain data from contour maps with semi-automation i possible through use of the digital scale, developed by Benson-Lehner (4), or the digital terrain data recorder, which is being developed by MIT (5). On the basis of information available at this time it appears that take-off of as many as 800 points pe man-hour may be possible with such equipment, which is estimated to cost approximately $9,000.

Take-off of 800 points per hour would result in a saving of 2 cents per point in ake-off and checking, plus 1.6 cents per point in keypunching or a total of 3.6 cents er point as compared to the strip method. However, to amortize a $9,000 cost in hree years plus rental of $50 per month for keypunch equipment it is apparent that an nnual volume of 100,000 points in one office would be necessary for equal costs beween automation of this type and the strip method. It is therefore obvious that the alue of this type of automation will depend on: (a) the volume of points to be proessed in one office, (b) the cost of the equipment and the rate of amortization to be sed, and (c) the production rate possible with such equipment.

CONCLUSIONS

The following conclusions are drawn from this study:

1. The strip method of terrain data take-off has proved practical for both flat nd rolling terrain. It has the advantages of extreme simplicity and low cost.
2. The savings over conventional methods are in the order of 2 cents per point. lthough at first glance such savings may appear minor, it must be considered that ie California Division of Highways processes earthwork quantities involving approxiiately 1.5 million terrain points annually. Of these it is estimated that more than million points are taken from contour maps.
3. There is a possibility of further savings by automation of the step between map nd computer. The principal obstacle to realizing such savings at present is the high iitial cost of available equipment.

ACKNOWLEDGMENTS

The idea of keypunching terrain data from map strips and its adaptation to take-off om contour maps was conceived and developed by Wm. J. Ellis, a squad leader on e project where the method was first used.

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