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Levelling and Modelling the Furrow Irrigation Check by Modern Design Methods

Lands levelling preparations-clearring off the irregularities — generally condition the labour productivity in agriculture and especially the furrow irrigation applications. Levelling operation is connected to important works of earth movings. The authors present an automatic computing model — MOPAR programme — written in FORTRAN language which aims:

1) — ascertainment of levelling solution with continuous or variable slope, with minimum volume of earthworks;

2)— with respect the interval of admissible slopes for the technique of furrow irrigation and

3) optimum haul scheme of excavated earth.

The model conceived for IBM 370 computer was applied to the Institute for Land Improvment Studies to the designs of irrigations and drainings for a series of projects in our country and abroad.

1. The practice and made experiences [3, 4] have shown that the furrow irrigation method supposes- for human work facilitation and water saving — a land with an allowance surface — namely without depressions and prominences.

Thus, it is necessary to acheive a plane (levelling) or more geometrical planes (modelling) for each check. These works require — generally — important earth movings which can be made with special machines: drag scrapers, graders, bulldozers etc. The finding of certain solutions for diminishing the volume of earthworks on one hand and for minimizing the moving effort, was the

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Dorina Ştefăneanu, M. Nimigeanu and A. Gutman from the Institute for Land Improvment Studies, have also participated in working out this paper.

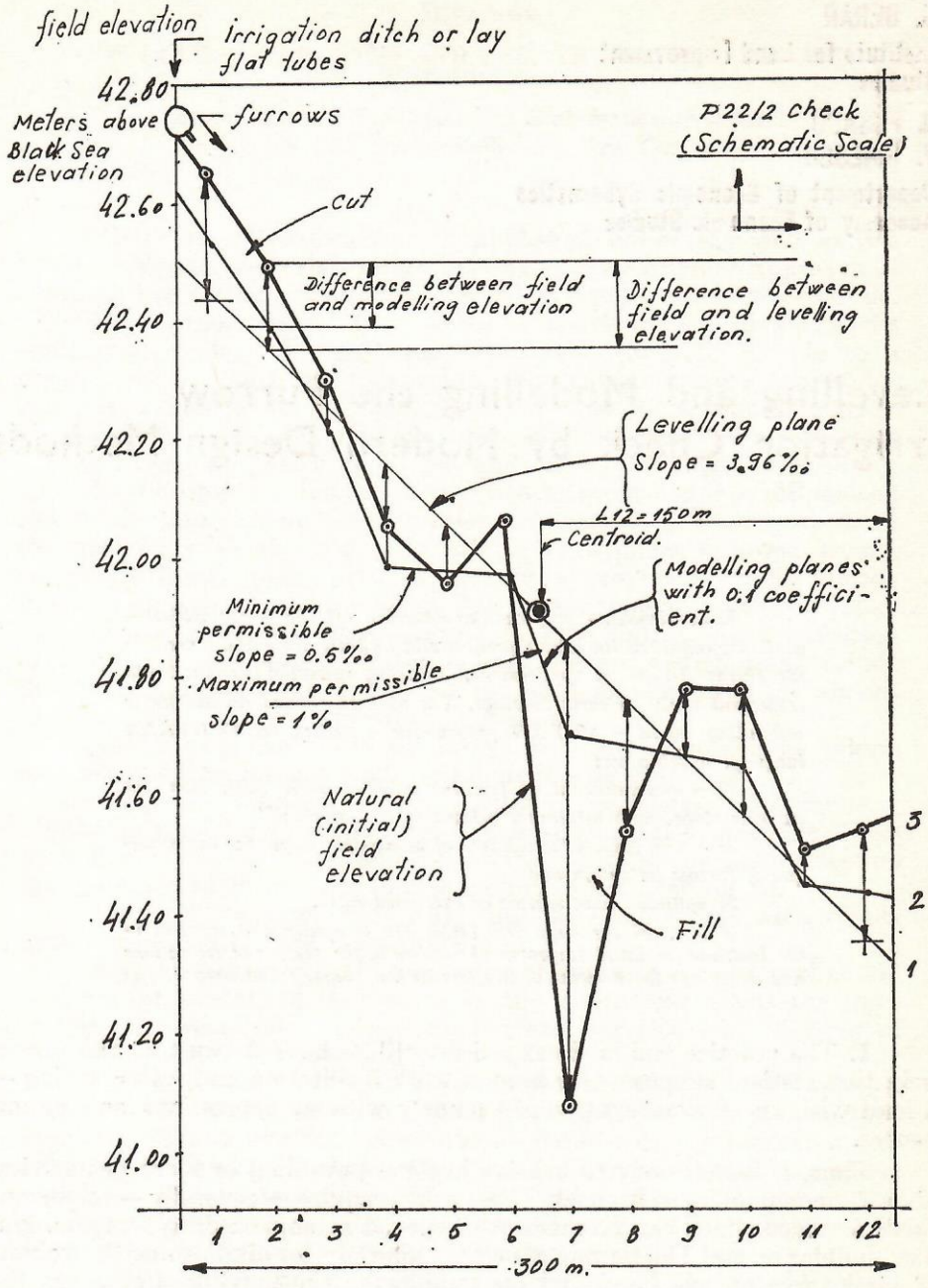


Fig. 1.

Longitudinal Profile of Irrigated and Modelled Check

subject matter of a researchers group within the Academy of Economic Studies and designers from the Institute for Land Improvment Studies. We shall present below the mathematical model and the respective programme called MOPAR (modelling-checks) used at present, which ascertains the optimum solution for slopes, cut and fill and earth haul.

2. Levelling operation consists in finding an optimum geometrical plane of an agricultural land check — with irregular relief (Fig. 1), plane which to assure both the slope and minimum cut and fill.

In certain situations, respectively on the line of natural land — as it is shown in Fig. 1 — the water because of the existent depressions could not flow under good conditions from left to right, namely on furrows direction.

3. The theoretical basis used to solve a given problem consists in applying the known theory of correlation as regards the field elevations [1; 2; 3]. It is known that by this method a plane is ascertained for minimizing the deviations (of the least squares) between the field elevations and the optimum levelling plane elevations. This plane resulted from computation and denoted in Fig. 1, has the following properties:

a) — earthworks volume generated by the differences between the field elevations and the levelling plane is minimum;

b) — fill volume is balanced with the cut one and consequences:

a) — any plane, regardless the angle that it has with the horizontal line and which crosses through point named centroid (Fig. 1), balances the cut and the fill, but only one of the planes fulfils also the minimum condition of earthworks and is ascertained by the correlations computation.

b) — any plane which does not cross through centroid but is paralell to the optimal plane unbalances the relation between cut and fill. But, the solution is minimum as against the situation given by any other plane.

The two properties and their consequences are currently used in substantiating the solution and designing the levelling where the slope resulted from correlations computation — exceeding the maximum admited slope (facilitation of soil erosion) or the minimum one (non-ensuring of water flow) — must be changed to allowance values. An example of the got results is given in table 1.

Table 1

a) *P22/2 Check Results*
Check Length = 300 m; Check Width = 25 m
Grid Side on Horizontal Line = 25 m
on Vertical Line = 25 m

Surface (ha)	Average Field Elevation (m)	Changed Average Elevation (m)	Volume (m^3)		Volume per unit (m^3/ha)	Slope Direction		Depth of Maximum Cut (m)
			Cut	Fill		x m/m	y m/m	
0·8	41·89	41·89	730·3	729·62	973·7	−0·00396	0·0	−0·24

b) *Levelling Plane of P22/2 Check*

Point	E 1	E 2	E 3	D 1	D 2
Field Elevation	42 · 65	42 · 49	42 · 30	42 · 05	41 · 95
Computed Elevations	42 · 44	42 · 34	42 · 24	42 · 14	42 · 04
Differences	−0 · 21	−0 · 15	−0 · 06	0 · 09	0 · 09

E 4	D 3	D 4	E 5	E 6	E 7	E 8
42 · 06	41 · 07	41 · 53	41 · 78	41 · 79	41 · 50	41 · 54
41 · 94	41 · 84	41 · 74	41 · 65	41 · 55	41 · 45	41 · 35
−0 · 12	0 · 77	0 · 21	−0 · 13	*−0 · 24*	−0 · 05	−0 · 19

Senders numbers (E) = 8; Destination number (D) = 5

c) *Scheme of Optimum Haul by Linear Programming*

Sender	Destination	Quantity	Distance
1	1	56 · 0	75
1	3	77 · 5	150
2	3	95 · 3	125
3	3	38 · 4	100
4	3	73 · 8	25
5	4	84 · 2	25
6	2	56 · 7	150
6	3	95 · 5	75
7	3	32 · 8	100
8	3	69 · 8	125
8	4	49 · 8	100
8	5	0 · 2	25

The computing scheme used in MOPAR programme has the succession from Fig. 2. Starting from the topographic elevation, the optimum plane (by correlation) is ascertained, the plane is tested with the allowance slopes in designing and calculations of the parameters necessary to carrying out the work.

The levelling can be made depending on the imposed conditions — both on the whole check and on strips (piano key, namely on each furrow of topographic elevation) in several variants;

— a) increasing or diminishing of the resulted slope on one or both directions;

— b) changing the direction of the resulted slope on one or both directions to proposed values;

— c) limitting the cut depth;

LEVELLING.

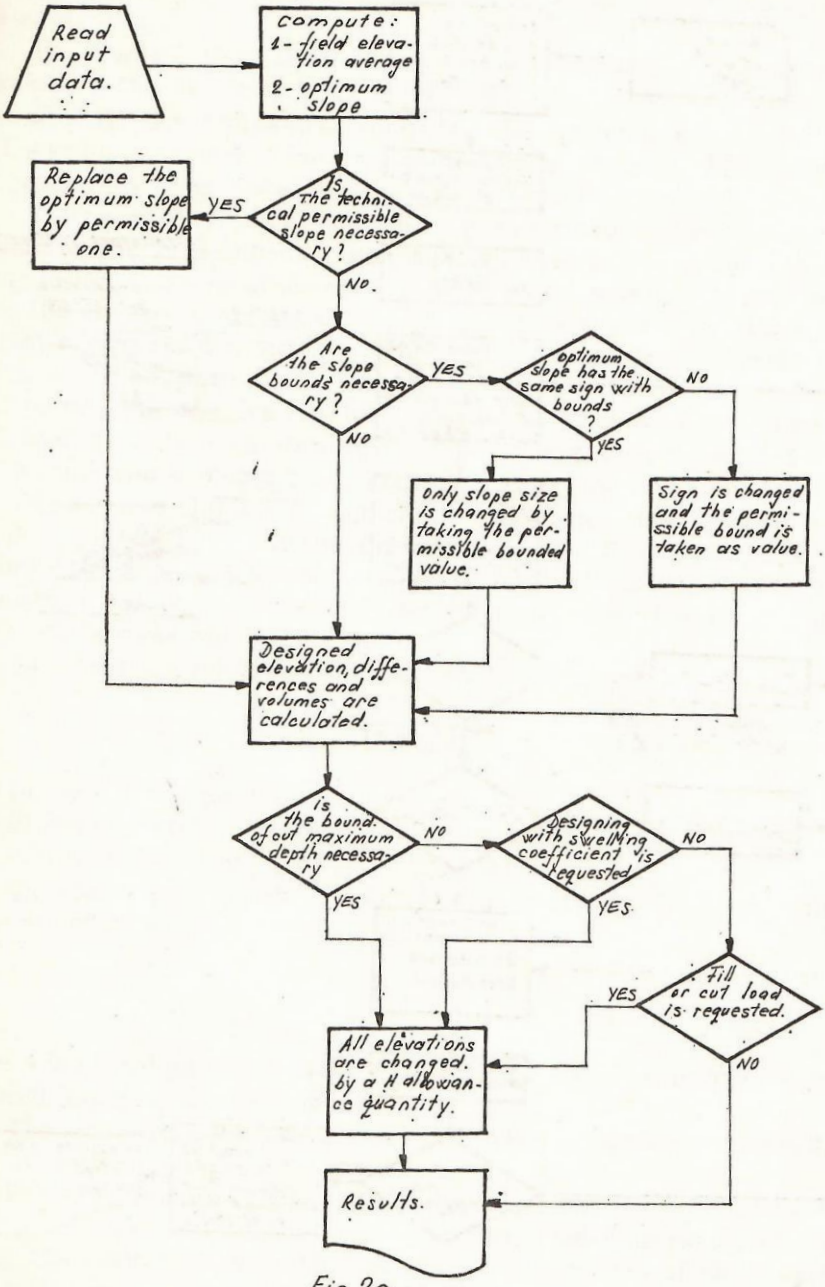


Fig. 2a.

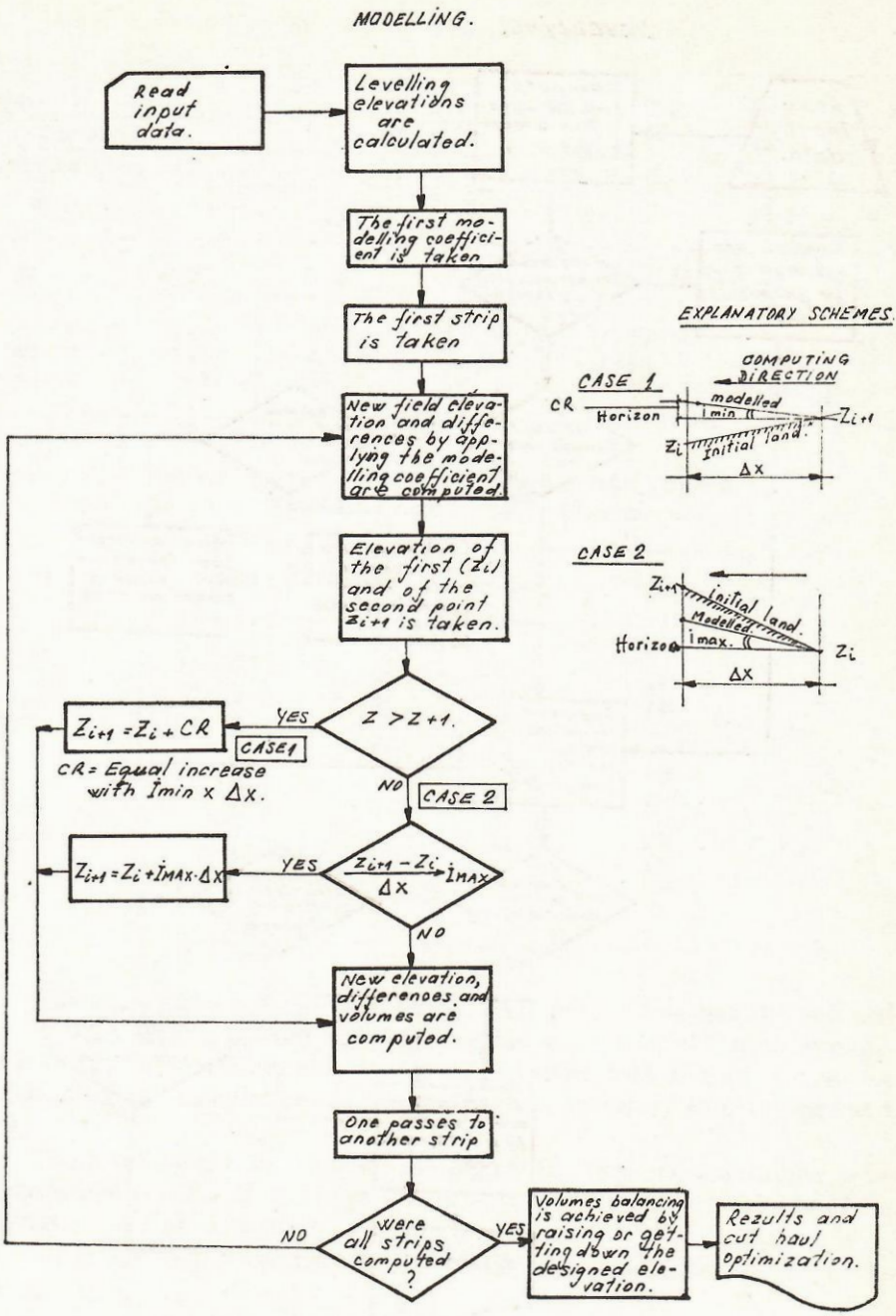


Fig. 26.

Logical Schemes of Modelling and Levelling Programme

— d) raising or reducing of all designed field elevations having in view some execution necessities on the respective check, as soil embankment or soil excavatings.

We mention that all these interventions have as a consequence the increase of the obtained volume per unit.

Finally, the programme computes the optimum scheme for hauling by linear programming, according to the known method (table 2a and figure 3a) using the programme called "TRANSPORT"

4. The method of land modelling was proposed, method which consists in transforming the resulted unique slope, possible corrected by the levelling computation, into a set of slopes which to be accepted as regards their gradient, since the earthwork volume resulted from these computations (table 1 a, b, c) and table 2 (a, b) are sometimes rather high making unprofitable the application of furrow irrigations.

So far, the negative effect of a succesive slopes set on one furrow was not experimentally ascertained, even if this furrow does not exceed the allowance minimum and maximum values regarding the irrigation quality.

Modelling is obtained by reducing the differences between field elevation and design elevation by multiplying with a coefficient which appears in table 2a under the provisional denomination of modelling coefficient. This theoretical method has as a consequence the reduction under the same proportion of the earthworks volume.

We shall use for proof the relation:

$$V = D \cdot S, \tag{1}$$

where

V = fill or cut volume (m^3)

D = difference between the field elevation and the designed one (m)

S = influence surface of topographic point (m^2).

In order to get a reduced volume, both sides of equation (1) are multiplied by a subunitary coefficient:

$$K = \frac{A}{S}$$

where A is a constant (between 0.4 and 0.8) and S is the mean square deviation of check topographic elevation.

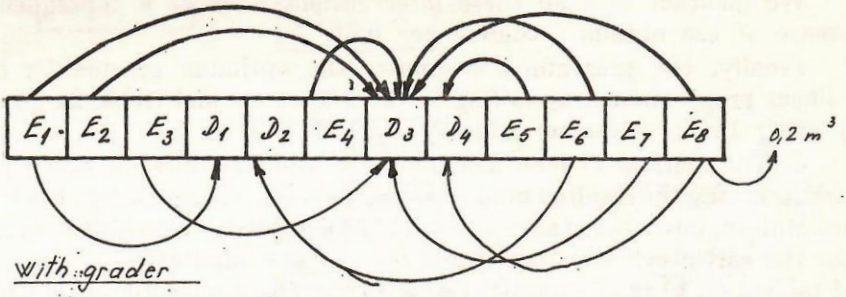
The computing scheme used in MOPAR programme for modelling is given in Fig. 2.

Figure 1 presents a check example for which the levelling and modelling solution was applied to. In table 2 (a,b,c,) the modelling results of a check having the coefficient $K = 0.5$, are given. The solution of earth optimum haul with the aid of the known method of linear programming (Fig. 2b) results from table 2c.

LEVELLING

With scraper.

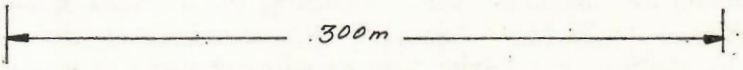
Cut = 730 m³ (according to table 1c)



With grader

Sφ = 673,200

Average distance = 92 m



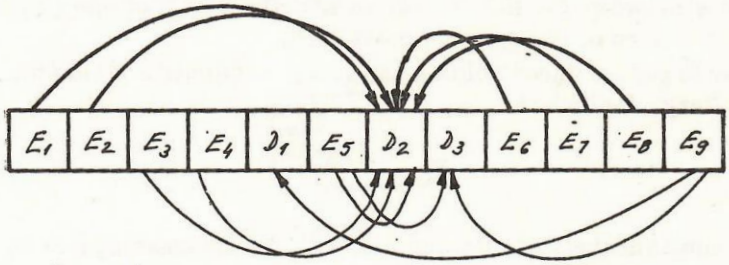
ⓐ

MODELLING (0.5 coeffic).

cut = 684 m³

(according to table 2c)

With scraper



With grader

Sφ = 489,000

Average distance = 96 m.

ⓑ

Fig. 3

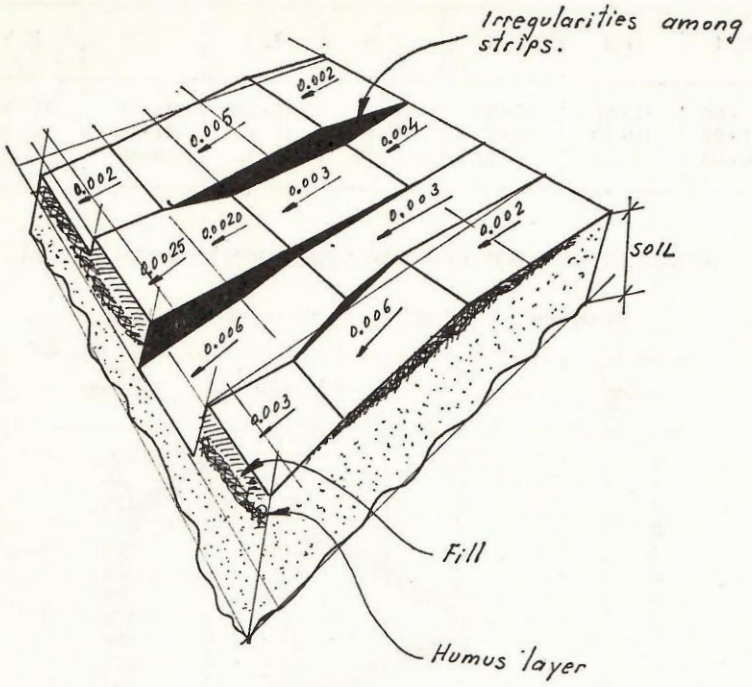


Fig. 4.

Axonometric Representation of Modelling Solution

Table 2

a) *Modelling results of P22/2 check*
Modelling with the modelling coefficient: 0.50
Grid size Dx = 25m, Dy = 25 m.

Surface (ha)	Volume per unit (m^3/ha)	cut (m^3)	fill (m^3)	Depth of maximum cut (m)
0 · 750	696 · 1	522 · 1	522 · 10	−0 · 15

MAXIMUM ALLOWANCE SLOPE = 0.10 m/m

b) *Modelling plane of P22/2 check*
East-West furrows direction is conventional

Point	E 1	E 2	E 3	D 1	D 2
Field elevations	42 · 65	42 · 49	42 · 30	42 · 05	41 · 95
Computed elevations	42 · 51	42 · 38	42 · 24	42 · 06	41 · 98
Differences	−0 · 14	−0 · 11	−0 · 06	0 · 01	0 · 03

E 4	D 3	D 4	E 5	E 6	E 7	E 8
42 · 06	41 · 07	41 · 35	41 · 78	41 · 79	41 · 50	41 · 54
41 · 97	41 · 70	41 · 69	41 · 68	41 · 64	41 · 44	41 · 41
−0 · 09	0 · 63	0 · 16	−0 · 10	−0 · 15	−0 · 06	−0 · 13

SENDERS NUMBER (E) = 9 DESTINATION NUMBER (D) = 4

c) *Optimum Haul Scheme by Linear Programming*

Sender	Destination	Quantity	Distance
1	2	18.3	100
1	3	68.1	150
2	3	67.3	125
3	3	38.8	100
4	3	56.5	25
5	3	61.7	50
6	4	95.7	50
7	1	8.3	175
7	3	27.7	100
8	3	74.4	175
8	4	5.0	100
9	2	0.1	25

5. Comparing the levelling solution (table 1b) with the modelling one (table 2b), we notice that the solution qualities of levelling are also met in the modelling, namely the cut is equal to the fill and the total volume diminishes according to the imposed slopes. Sometimes, during the computation of differences between field elevation and levelling elevation with the subunitary coefficient, designed levels could appear which to lead to inverse slopes — too high or too small— which would facilitate both the water stagnation or soil erosion. In this case, one intervenes into the computation by a subroutine which re-establish the situation, getting the respective elevations to a corresponding size of admissible slopes. Compensation mistuning of cut as against the fill which could occur are solved by general raising or getting down of all designed modelling elevations.

Table 3 presents a comparison between the modelling and levelling solutions. It results from the table that the minimum volume solutions may not be considered as being optimal from the other points of view as for instance of haul effort, of fill, etc, and that the choosing must be done by taking into account all concurent factors. Further, a graphical comparison (figure 5) between the two methods and the possibilities offered by the designer are presented.

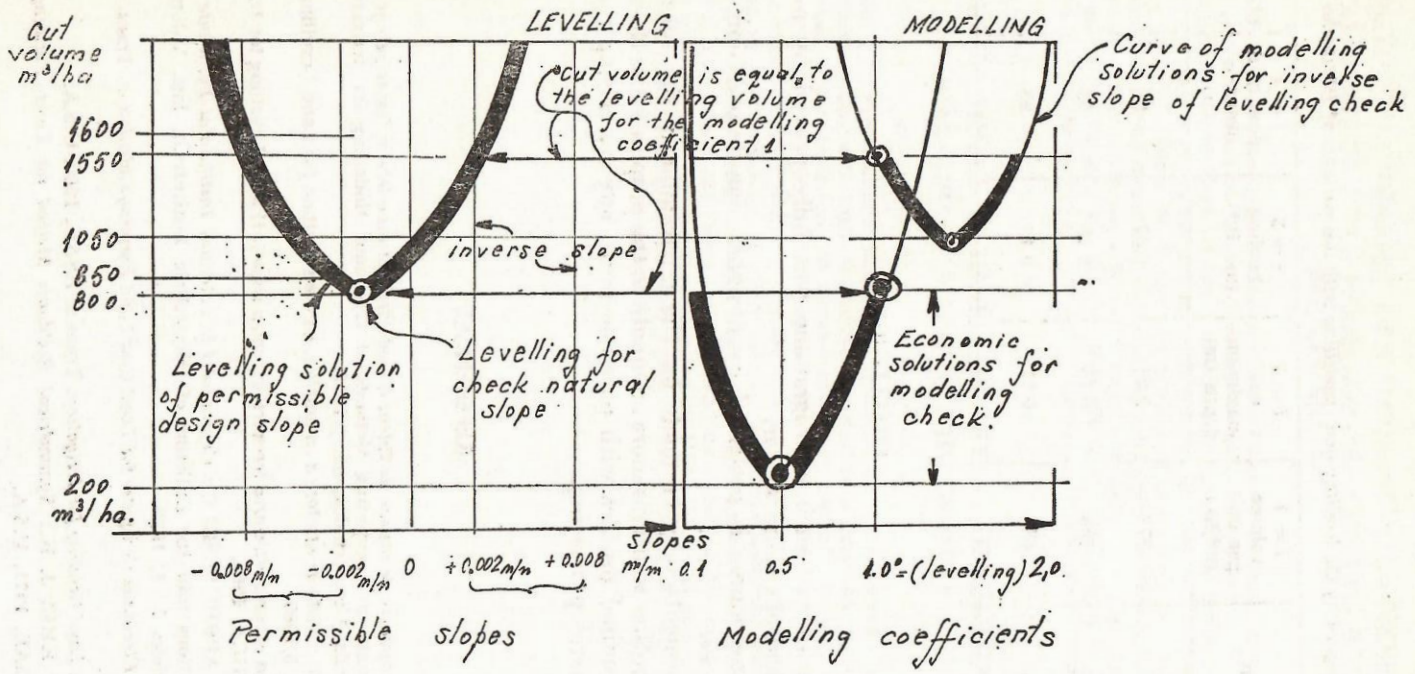


Fig. 5.

Diagram of Cut Volume in the Case of Check Modelling and Levelling for Several Permissible Slopes and Modelling Coefficients.

Table 3

Results regarding the levelling and modelling with two variants of P22/2 check

Specification	$i = 1$ volume per unit (m^3/ha)	$i = 2$ cut maximum depth (m)	$i = 3$ hauling ($m \times 10^6$)	$i = 4$ mean haul distance (m)	$i = 5$ fill maximum width (m)
Variant $j = 1$ levelling $k = 1$	973	0.24	0.67	92	0.77
Variant $j = 2$ modelling $k = 0.5$	696	0.15	0.49	93	0.63
Variant $j = 3$ modelling $k = 0.1$	684	0.11	0.48	95	0.63

CONCLUSIONS

1. The utility of such a programme was fully proved by numerous practical applications done so far.

2. The programme is preferred by designers for its precision, rapidity and conveniences.

3. Improvments may be made for the programme in the future, both by searching another solutions more adequate to the proposed aim (for instance levelling longitudinal profiles with parabole form) any by raising the degree of data automatic processing.

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METHODES MODERNES DE CALCUL DANS LA PROJECTION DU NIVELAGE ET LE MODELAGE DES TERRAINS IRRIGABLES PAR LES SILLONS

Les travaux de nivelage des terrains — élimination des irrégularités — conditionnent, en général, la productivité du travail en agriculture et surtout l'application des irrigations par les sillons. L'opération de nivelage est liée à d'importants travaux de terrassements. Les auteurs présentent un modèle de calcul automatique — le programme MOPAR — écrit en langage FORTRAN qui tient compte de: 1) choix de la solution de nivelage, à inclinaison continue ou variable, ayant un volume minimum de terrassements 2) respect des valeurs des pentes admissibles pour la technique d'irrigation par sillons et 3) schéma optimale du transport de la terre excavée.

Le modèle conçu pour l'ordinateur IBM 370 a été appliqué dans les projects ISPIF d'irrigations et dessèchements pour une série de travaux effectués en Roumanie et à l'étranger.

СОВРЕМЕННЫЕ МЕТОДЫ РАСЧЕТА В ПРОЕКТИРОВАНИИ ВЫРАВНИВАНИЯ И МОДЕЛИРОВАНИЯ ПОЧВЫ

Работы по выраниванию почвы — устранение нерегулярностей — обусловливает вообще производительность труда в сельском хозяйстве и особенно применение орошения посредством борозд. Операция по выравниванию связана с крупными земельными работами. Авторы представляют модель автоматического расчета — программу МОПАР — написанную языком ФОРТРАН, которая имеет в виду: 1) установление метода разрешения выравнивания, с непрерывным или изменяемым склоном, с минимальным объемом земляных работ; 2) соблюдение расстояния между склонами, примлемое для техники полива по бороздам и 3) оптимальная схема транспортировки вырытой земли.

Модель, составленная для счетной машины ИБМ 375, была использована в проектах Проектно-исследовательского института мелиоративных работ по орошению и осушению ряда работ в нашей стране и заграницей.

23. XII. 1975