Optimisation of Soil Conservation Systems within Integrated Territorial Protection

Miroslav DUMBROVSKÝ and Svatopluk KORSUŇ

Department of Landscape Water Management, Faculty of Civil Engineering, Brno University of Technology, Brno, Czech Republic

Abstract: The objective of this contribution is to provide information on a generally applicable optimisation procedure intended for designing a system of terraces and retention reservoirs within integrated territory protection from the harmful effects of soil erosion. The formulated procedure is a universal tool which can be used for any territory. An optimisation mathematical model was used to find the most suitable combination of various elaborated pre-optimisation variants of the soil conservation and flood prevention measures under the given conditions of each particular habitat. This model was created on the basis of a mixed discrete programming. The model compilation and its analysis on a high performance computer was performed using the model and calculation system GAMS. The model solution was controlled by one or more simultaneously operating optimisation criteria. A system of terraces as an important part of the soil erosion and flood control was chosen to verify the possibilities of the described optimisation procedure utilisation. The system was proposed within the land consolidation in the case study areas of Hustopeče and Starovice cadastral areas. First, the model function and performance were verified. Then the possibilities of experimentation on the model of the solved system of complex conservation measures were tested. The main results of the real and some experimental solutions are summarised. The results of practical applications of the integrated territory protection model validate its functionality and universal applicability.

Keywords: terraces; direct runoff; damage; soil erosion control measures; catchments area; watercourse; conservation measures; optimisation model; optimisation criterion; optimal combination of conservation measures

Extreme hydrological phenomena of recent years have highlighted a well-known fact that it is necessary to pay greater attention to the problems of flood-prevention and soil erosion control in a large part of the Czech Republic. The case study areas are the most endangered territories. Great runoffs occur on these areas and transform into flood waves in watercourses. Forest grounds are also affected, especially in the case of unsuitable transport, wood cut, and growth make-up. The solution of the problems of the territory protection from unfavourable and damaging effects of overland water flow must therefore begin in the catchments areas and particularly during any interference with the landscape. The greatest intervention with the agricultural landscape is complex land consolidation which, apart from other less important objectives, is designed to eliminate completely or at least partly limit the unfavourable effects of runoff (especially soil erosion) and thus to become one of the most important elements of the territory organisation and protection.

Supported by the Ministry of Agriculture of the Czech Republic, Project No. QC1292.

The integrated territory protection can be reached by controlling the runoff by means of the design of terraces as the soil erosion control measures. A number of mathematical models, mostly simulation ones, to solve the water-management problems have been compiled, some of which include the option of exact mathematical optimisation. A certain summary of these models, including their characteristics and application possibilities, were elaborated by Kos (1992). An interesting combination of the application of a simulation and optimisation model techniques in the elaboration of the design of a particular water-management system was described by Major *et al*. (1979), a three-model approach to solve water-management systems was used by Onta *et al*. (1991). Benedini (1988) dealt more generally with the design and possible applications of these models. Most likely, an optimisation model has not been designed, which would enable to attach the territory protection and the measures to eliminate the amount and accumulation of the runoff in catchments areas to the solution of the water-management problems.

The created procedure is a universal tool which can be applied for any territory. It enables to find the most suitable combination of all possible alternatives of various erosion controls and flood protection measures under the given conditions of each particular site. Such sites do not always have to be the land used for farming. They may also include forest or urban areas or site arrays in various territories.

METHOD

The optimisation process of designing the system of integrated territory protection (the IOU system) begins with the processing of the system with organisational, agrotechnical, biotechnical, and technical measures at the individual sites of the case study territory. It is necessary to derive hydrograms of the direct runoff from extreme rainfall events for each of these variants. Further, it is necessary to elaborate the variants of terraces and other conservation measures on all sections of watercourses and those of the designs of retention protection reservoirs. Not only rivers, streams, and brooks are included in the watercourse category within this procedure but sometimes also passed watercourses such as terraces, grass infiltration belts or the lines of stabilisation of the concentrated runoff waterways in the valley lines.

A selection of the most suitable combination of all variants prepared is listed. With respect to the necessity of finding optimal dimensions for some of the system elements, there is usually a great number, in the case of a continual solution even infinite number, of the possible combinations. It is therefore necessary to use an optimalised mathematical model to find the most suitable combination. This model was created on the basis of a mixed discrete programming (Korsuň *et al*. 2002; Dumbrovský *et al*. 2006). Its basic building stones are three generally formulated partial models: A – partial model of protective measures at individual sites of the case study area; B – partial model of a watercourse; C – partial model of a reservoir.

It is possible to shape an optimisation model of integrated territory protection (OMIOU) from these partial models for any particular territory. The partial models are repeatedly inserted into the OMIOU as needed so as to copy exactly the modelled system structure. It is necessary to determine in advance one criterion or more simultaneously operating optimisation criteria for each optimisation function. A whole range of criteria can be determined for a given purpose. These can be taken from the sphere of economy but also from those of ecology, water-management, social etc. However, it is necessary to define the most suitable criteria as far as quality is concerned but also to have a chance to quantify the values of each criterion defined. On top of that, it is necessary, in the case of several simultaneously operating optimisation criteria, to assign each criterion its adequate weight with which it will enter the solving process and which will support its effect on the result, so called a compromise solution in competition with the other criteria.

In creating the procedure of the IOU system proposal optimisation in connection with the process of territory organisation, a requirement of maximal protection of inhabited and other areas with the exertion of minimal means was formulated for the solving process on the level of the land consolidation as one of the suitable optimisation criteria. This is a criterion consisting of three simultaneously operating partial economic, but at the same time water-management and socially aimed at their impacts. The criteria include:

– Minimisation of the average annual damage (material damage: it is estimated that the input requirements and conditions will not allow such solutions which could lead to losses of human lives) originated in overland runoffs from the rainfall events and then in their concentration in watercourses.
– Minimisation of the average annual economic losses in farming production related to the realisation of the proposed protective measures on arable land.
– Minimisation of the average annual expenses (the sum of expenses for running and maintenance plus the amortisation of the capital goods) of the proposed conservation measures.

Seeing that in most cases are average annual values, quantified for example in thousands of CZK per year, these criteria can be assigned the same weights 1:1:1 in this reflection.

The optimisation mathematical model is a system of equations, which model a given system behaviour, the variables in the equation describing the system structure and the dimensions of its individual elements. Non-equations found in each model are transformed into equations by means of additional variables in the course of the model solving process, therefore the term equation is only used. The above mentioned partial models were created in the modelling and calculation system GAMS (General Algebraic Modelling System) in its general form (Charamza *et al.* 1993), thus it can be used to model any integrated territory protection system. The nature of the solved problems implies that the defining process considers all the variables used in the model as positive variables. They can be either continuous which are marked x hereinafter or binary ones (they can take on only 0 or 1 values) marked with the symbol x_B. Other symbols are used to mark the variables and coefficients. The activities proceeding in time must be modelled in the whole system according to the uniform timekeeping.

The partial model A is aimed at terraces and other biotechnical, agrotechnical, and organisational conservation measures in the catchments area of a certain watercourse. These measures are usually designed within the land consolidation to decrease the overland flow of the rainfall events and thus to limit the effects of soil erosion and damage in inhabited territories. Various proposals for the protective measures must be elaborated in each individual case before an optimisation model is designed (pre-optimisation) as pragmatically created systems of various, mutually complementary interventions with the individual catchments area elements. Such a partial catchments area element could be, for example, the valley and slope area above one bank of a certain watercourse section in the range from the bank line to the interstream divide line.

The part of runoff from the design rainfall events which will not be caught by the system of the catchments area protective measures (residual runoff) will concentrate in a particular watercourse and will create a design Q runoff or a flood wave. The time T of the passage of the design flood wave through a watercourse will be divided into r of equally long time intervals (TI); time t of the duration of one TI will thus be given by the relation $t = T/r$. For the individual TIs, partial volumes w_1 of the design flood wave are then quantified, $i = 1, 2, \ldots, r$.

In the case of the above mentioned optimisation criterion application, the following indicators must be quantified for each pre-optimisation processed variant of the protective measure set on a partial catchments area element:
– Its estimated effect U expressed financially as an average annual level of damage on the land, growth, buildings, roads etc. which will occur after the variant has been realised (residual damage);
– Estimated average annual economical loss E in farming production related to the realisation of the proposed measures on arable land;
– Realisation costs of a particular variant and its average annual own costs N;
– The amount of residual runoff O_i into a watercourse in the individual TIs.

These data represent the input information for the partial model A. In the course of the optimisation process, only one – optimal – variant with the most suitable indicators will be selected from the thus prepared variants of the systems of protective measures for each partial catchments area element. The residual runoffs concentrating in a watercourse runway from the watercourse adjacent partial areas protected by optimal systems of measures will cause a gradual accretion of a flood wave passing through the watercourse. The protection from damage which could be caused by this flood wave would be provided by the protective measures on the watercourse and retention protective reservoirs as mentioned later (the partial models B and C).

Binary variables can be used for the modelling of individual variants of the protective measure systems in each of the partial catchments area elements in a discrete way. The total number of catchments area elements will be m. If, for example, n variants of the protective measure systems of a d^{th} catchments area element are modelled by relations to binary variables $x_{B1dp} \in \{0, 1\}$, $d = 1, 2,..., m$, $p = 1, 2,..., n$, the effects of these measure systems for this catchments area element can be written into the model using the following equations:

the equation of protective effects (residual damage)

$$x_{Ud} = \sum_p U_{dp} \times x_{B1dp} \quad (1)$$

the equation of economic damage

$$x_{Ed} = \sum_p E_{dp} \times x_{B1dp} \quad (2)$$

the equation of own costs

$$x_{Nd} = \sum_p N_{dp} \times x_{B1dp} \quad (3)$$

the equation of the residual runoff, i.e. the contribution of a d^{th} catchments area element to the flood wave volume on a particular watercourse section in i^{th} *TI*

$$x_{Oid} = \sum_p O_{idp} \times x_{B1dp} \quad (4)$$

for $i = 1, 2,..., r,$
$d = 1, 2,..., m,$
$p = 1, 2,..., n,$

where:

x_{Ud} – total residual damage in a d^{th} catchments area element,

$x_{E,Ud}$ – total economic loss in a d^{th} catchments area element,

x_{Oid} – total residual runoff from a d^{th} catchments area element in i^{th} *TI.*

Because only one of the protective measure system variants can enter the solving process, the following condition must be valid for the sum of all the binary variables of a d^{th} catchments area element:

$$\sum_p x_{B1dp} = 1 \quad (5)$$

The partial model B captures the passage of the design flood wave through the watercourse sections. The sections are either left in their present state or the optimisation of the river bed or the contour furrow systems design (including the building of protective dams) may be required as well as the reconstruction of the adjustment or protective dams carried out formerly. A watercourse section can also be a water or dry protective reservoir which will be modelled in a way mentioned in the partial model C description.

Flood damage that can occur is quantified for each watercourse section during its modelling. Further, runoffs from the section are calculated in the individual *TI*s of a flood wave passage. With respect to the overland flow from the initial section profile to the last one, it is necessary to determine a time shift which will affect the collisions of flood waves on the main watercourse and at the mouths of its tributaries. The mean value of the runoff volume which can be found in a section (in a river bed or also in an inundation territory) in the course of i^{th} *TI* is at the position of the basic section variable. The values of the other variables are related to this variable: the variables of the water flowing through the section, time of concentration, level of flood damage in the section, and level of runoff from the section. The courses of these non-linear functions are derived from the watercourse pre-optimisation variant designs. They are replaced with linear function part by part in the optimisation model. The formulation of particular equations is mentioned in Chapter 5.1 of Patera *et al.* (2002).

The partial model C is outlined for the designed multipurpose water reservoir with unknown capacities of spaces protective controllable x_{OO}, protective non-controllable x_{ON}, and total x_V. The necessary volumes of the spaces of the dead storage $S \geq 0$ and active storage capacity $Z \geq 0$ are constant – these values result from other than protective requirements. The objective of analysis is to find its dimension which, respecting the requirement to create the spaces S and Z, with its protective spaces will ensure the reduction of the culminated runoff from the reservoir to its optimal level during the passage of the design flood wave. In the cases where the designed water reservoir has only a protective function, the value of the Z variable is zero; the values of both variables are zero $S = Z = 0$ for a dry protective reservoir.

The unknown volume of the total reservoir space is a variable, whose value is limited from above by the maximal value V_{max} corresponding to the biggest realisable variant of the reservoir design during the pre-optimisation solutions. From below it is limited by the minimal variant, still acceptable for practice, with the total volume V_{min}.

We cannot forget such a situation where building a reservoir will not be acceptable due to the optimisation criteria used. It is therefore necessary to introduce a binary variable $x_{B2} \in (0, 1)$ into the set of variable values. If this variable has a zero value, the reservoir will not enter the solving process, if $x_{B2} = 1$, the entry of the reservoir into the solution is cleared. Then the volume of the total reservoir space (without evaporation and percolation) must correspond to the following conditions

$$x_V = (S + Z) \times x_{B2} + x_{OO} + x_{ON}, \quad (6)$$

$$V_{min}\, x_{B2} \leq x_V \leq V_m \quad (7)$$

The equations modelling the passage of the design flood wave through a dam profile, the calculations of the volumes of individual reservoir spaces and of necessary financial means are described in Chapter 5.1 of Patera *et al.* (2002). The partial model C can be also used for an already existing reservoir with a constant volume of the total space.

The model compilation from the fore mentioned partial elements in the presented form requires the introduction of a set of concrete coefficients and variables into the model for the model equation system to copy completely a particular system of IOU. These coefficients and variables should be derived from the pre-optimisation processed background materials. In the case of non-standard requirements of an IOU system structure, it is necessary to introduce other equations in the model. Such new equations would capture these requirements. The model solving process is carried out on a computer by means of some of the GAMS system tools.

MATERIAL

To verify the function and potential of the optimisation procedure already described, a system of integrated territory protection was chosen that was proposed within the framework of the land consolidation on the case study area between the town of Hustopeče and the village of Starovice in the Czech Republic (see Figure 1). The declining ground in this region is mostly used as arable land. Overland flow is concentrated into its main waterway, which enters the residential parts of Hustopeče. Considerable, and frequently repeating damage, is caused by soil erosion under farm crops, sediment transport from arable land, and especially by flooding parts of the town.

The proposed system of integrated protection of this farming territory and the town is based on a system of technical-biotechnical, organisational, and agrotechnical soil erosion control measures on arable land and of two conservation measures: (1) transfer of concentrated runoff from the drainage furrow or channel *K*1 in the main valley line over the terrain into the adjacent valley line and creating a channel *K*2 entering the watercourse, (2) building a dry protective reservoir (polder) *P*1 to catch parts of runoffs from the main valley line and another polder on the channel *K*2 in the adjacent valley line above the village of Starovice.

The IOU system design for the given territory is based on the situation which would occur during a rainstorm with hundred-year periodicity (design rainfall). The protective measures with pre-optimisation were designed in ten different variants (see Table 1), the volume and cost (own costs) functions were derived for both the polders. It is estimated that *P*1 polder filling, which is a side basin for the channel *K*1, will proceed through the channel side overfall. For the individual soil erosion control measure alternatives, volumes and accumulation of overland runoffs, derived from the design rainfall, in the form of runoff hydrograms from two catchments areas: from the polder *P*1 catchments and from the polder *P*2 catchments. The passage of the runoff waves through the dam profiles of both polders takes from 510 minutes in the alternatives 1 and 2 to 195 minutes in the alternatives 9 and 10. It requires limiting the culmination water passages in the river beds below the two polders: below the *P*1 this passage (runoff from the *P*1), which will enter the city sewerage system in Hustopeče, should not exceed 0.125 m^3/s, below the *P*2 the passage limit should be, with regard to the protection of Starovice, chosen at 1.5 m^3/s at the most and in variants of 1.0 and 0.5 m^3/s to determine the effect of this passage size on the IOU system optimal solution.

The optimisation model consists of 3 506 equations with the total of 1 673 structural variables, 539 of which are binary variables. The model objective function (optimisation criterion) minimises the sum of average annual values of flood damage, economic losses and biotechnical measures and

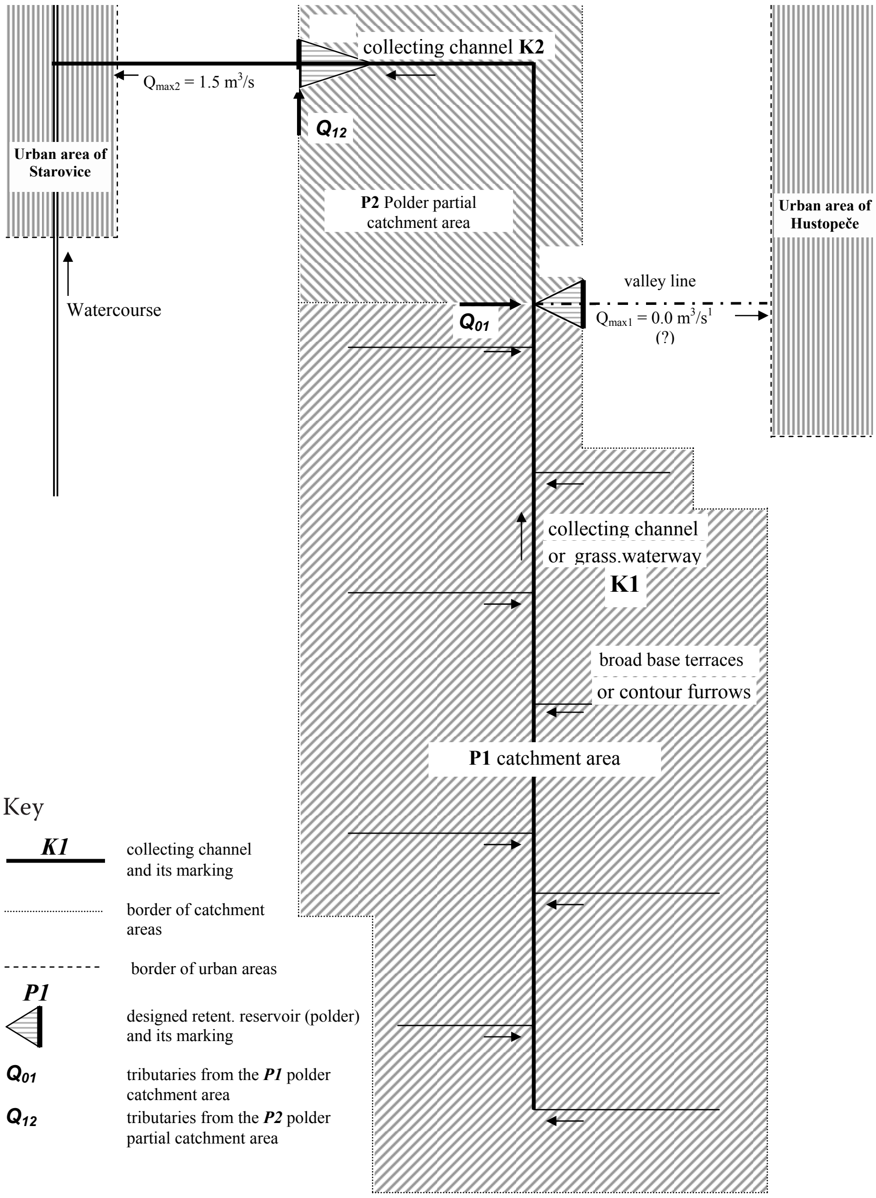

Figure 1. The Hustopeče – Starovice system scheme

polders own expenses in the proportion of 1:1:1. It is ensured that only one protection system alternative can enter the OMIOU optimal solution in both the catchments areas, but it can be different for each of the catchments. These alternatives are marked as *A*1 and a particular alternative number for the *P*1 polder catchments, the *P*2 polder was allocated symbol *2* in a similar way. The polders can but also need not enter the solution. The runoff wave from the *P*1 polder catchments may be partly or completely transferred into the *P*2 polder. Permissible maximum of the water depth is 5.0 m in the *P*1 polder and 4.34 m in the *P*2 polder, respectively. The *P*1 polder low outlet dimensions (the inside diameter of the outlet pipeline of a round shape) is d = 200 mm, there is a possibility of choice from d = 200, 300, 400, 500 or 600 mm for the *P*2 polder.

RESULTS AND DISCUSSION

The model function and behaviour were examined first in relation to the project research objectives. Then the possibilities of experimentation on the model of the designed system were tested (Korsuň *et al.* 2002). The optimisation process was carried out with the three above listed values of admissible maximal runoff from the *P*2 polder, and then in an experimental way with various runoffs from both catchments areas: with real runoffs derived from hundred-year rain storms

Table 1. Alternatives of integrated territory protection system of the interest area of Land Consolidation Hustopeče – Starovice

Alternative No.	Alternative characteristics	Average economic indicators (CZK/ha/year)			Total average annual damages, losses and own costs		
		annual damage	annual economic loss	annual own costs of biotech. measures	per area unit (CZK/ha/year)	per the whole catchment area ths of CZK/year	
						to P1 polder (98 ha)	to P2 polder (47 ha)
1	PGG on all the acreage, CN = 61, biotechnical measures, without polders	6000	470	1305	7.775	762.0	365.4
2	PGG on all the acreage, CN = 61, biotechnical measures, with polders	6000	470	0	6.470	634.1	304.1
3	EDC excluded, CN = 72, biotechnical measures, without polders	1849	973	2000	4.822	472.6	226.6
4	EDC excluded, CN = 72, biotechnical measures, with polders	1849	973	195	3.017	295.7	141.8
5	EDC excluded, CN = 76, without biotechnical measures, without polders	1849	0	3500	5.349	524.2	251.4
6	EDC excluded, CN = 76, without biotechnical measures, with polders	1849	0	400	2.249	220.4	105.7
7	EDC left, CN = 75, biotechnical measures, without polders	780	1300	2600	4.680	458.6	220.0
8	EDC left, CN = 75, biotechnical measures, with polders	780	1300	243	2.323	227.7	109.2
9	EDC left, CN = 81, without biotechnical measures, without polder	0	0	7600	7.600	744.8	357.2
10	EDC left, CN = 81, without biotechnical measures, with polders	0	0	700	700	68.6	32.9

PGG – perennial grass growth, EDC – erosion endangered crops, CN = *xx* — runoff curve number defining the catchment area retention capacity

for the individual variants of conservation measures in both the catchments areas, and with fictive multiples of these runoffs. The solution main indicators with real runoffs and their fivefold multiples are summarised in Table 2. The variants with other changes in the input conditions (e.g. without the polders entering the solving process) were calculated for the same reason. The results of these solutions are not listed here. Optimal solutions of variants No. 1, 3, and 5 correspond to the real state of the input conditions. These solution results were derived from overland flows from the grounds and from three real values of maximal admissible runoff from the *P*2 polder above Starovice. The results of the following experiments on the optimisation model led to a number of interesting findings. However, the most important finding is the fact that the experimental locality can be protected as required without any interference with the plant production conditions, i.e. without any (on site) economic loss on the produce only by conservation measures themselves: by draining overland and hypodermic runoffs through contour furrows and channels in the *P*2 polder. This protective system design is valid provided only that the applied optimisation criterion is kept. The resulting design can be different in the case of any change in the criterion (e.g. changes in the weights of the three partial criteria used) or in the case of a different criterion application.

CONCLUSION

The results of the practical application of the optimisation procedure in designing terraces and retention reservoirs within integrated territory protection verify its functionality and applicability. In such cases where it is not clear in advance which of the potential torrential rainfall can be the most dangerous, the model will provide solutions with all rainfalls types chosen for the result to comply with the territory protection requirements.

Table 2. The summary of the selected optimal main design indicators of integrated interest territory protection of Land Consolidation Hustopeče – Starovice given in the variants according to input conditions changes

Indicator	Ordinal numbers of input conditions changes variants					
	1	2	3	4	5	6
	admissible runoff maximum from *P2* polder					
	1.5 m^3/s		1.0 m^3/s		0.5 m^3/s	
	multiplies of runoffs from catchment area					
	1×	5×	1×	5×	1×	5×
Optimality criterion value (ths of CZK/year)	233.7	679.9	243.7	686.8	253.3	737.8
Of which: average own costs – biotechnical measures	0.0	127.4	0.0	127.4	0.0	95.4
– polders	132.2	419.3	142.2	426.2	151.8	409.2
– total	132.2	546.7	142.2	553.6	151.8	504.6
total average annual losses (damage + economic losses)	101.5	133.2	101.5	133.2	101.5	233.2
Measure alternative in *P1* polder catchment area (–)	A1 – 10	A1 – 8	A1 – 10	A1 – 8	A1 – 10	A1 – 4
Measure alternative in *P2* polder catchment area (–)	A2 – 10	A2 – 10	A2 – 10	A2 – 10	A2 – 10	A2 – 10
Polder *P1*						
Total volume (ths of m^3)	0.0	0.0	0.0	0.0	0.0	0.0
Maximum water depth (m)	0.0	0.0	0.0	0.0	0.0	0.0
Dam height (m)	0.0	0.0	0.0	0.0	0.0	0.0
Ordinal number of time interval of maximal filling of the polder (–) runoff from *P1* into sewerage in Hustopeče (m^3/s)	0.0	0.0	0.0	0.0	0.0	0.0
Inner diameter of round pipeline of the low outlet (mm)	0.0	0.0	0.0	0.0	0.0	0.0
Edge length of side overfall from *K1* channel into *P1* polder (m)	0.0	0.0	0.0	0.0	0.0	0.0
Average own costs (ths of CZK/year)	0.0	0.0	0.0	0.0	0.0	0.0
Capital costs (m of CZK)	0.0	0.0	0.0	0.0	0.0	0.0
Polder *P2*						
Total volume (ths of m^3)	27.6	138.7	29.8	142.6	32.0	133.0
Maximum water depth (m)	2.172	4.283	2.245	4.334	2.316	4.209
Dam height (m)	2.772	4.883	2.845	4.934	2.916	4.809
Ordinal number of time interval of maximal filling of the polder (–)	8	12	8	13	9	15
Runoff from *P2* into water course (m^3/s)	1.5	1.5	1.0	1.0	0.5	0.5
Maximum height of water stream falling over the overfall (mm)	0.357	0.317	0.263	0.274	0.061	0.173
Inner diameter of round pipeline of the low outlet (m)	600	500	500	400	400	300
Average own costs (ths of CZK/year)	132.2	419.3	142.2	426.2	151.8	409.2
Capital costs (m of CZK)	3.1	10.7	3.4	11.0	3.6	10.4

The created model can be used to find either one optimal solution or, if it is necessary to verify the position of the optimal solutions with the changes of some input conditions and requirements, more times in more versions with variables and coefficients modified by these changes. The possibility of multiple application of this model and of obtaining a whole set of optimal solutions visualises much better the character and behaviour of the designed system in reaction to modifications of the input conditions and requirements, and enables to improve significantly the process of making decisions on the design of the final shape.

A great advantage of the model lies in the general formulation of its components – partial models of the conservation measures at individual sites of the experimental locality, watercourse and reservoir. This should enable its problem-free application for the optimisation design of integrated territory protection under any conditions and at any site

References

Benedini M. (1988): Developments and possibilities of optimisation models. Agricultural Water Management, **13**: 329–358.

Charamza P. *et al.* (1993): Modelling System GAMS. MFF UK, Praha. (in Czech)

Dumbrovský M. *et al.* (2006): Optimisation of the system of soil and water conservation for runoff minimizing in certain watershed in the process of land consolidation. [Final Research Report NAZV-QC1292.] VÚMOP, Praha. (in Czech)

Korsuň S. *et al.* (2002): Creating and verification of the model for optimisation of soil and water conservation. [Final Research Report A01-NAZV-QC1292.] FAST VUT, Brno. (in Czech)

Kos Z. (1992): Water management systems and their mathematical models during climate changes. Vodní Hospodářství, **7**: 211–216. (in Czech)

Major D.C., Lenton R.L. *et al.* (1979): Applied Water Resource Systems Planning. Prentice- Hall Inter., Inc., London.

Onta P.R., Gupta A.D., Harboe R. (1991): Multistep planning model for conjunctive use of surface and groundwater resources. Journal of Water Resources Planning and Management, **6**: 662–678.

Patera A., Váška J., Zezulák J., Eliáš V., Korsuň S. *et al.* (2002): Floods: prognosis, water streams and landscape. ČVUT/ČVVS, Praha. (in Czech)

Received for publication April 7, 2008
Accepted after corrections March 30, 2009

Corresponding author:

Doc. Ing. Miroslav Dumbrovský, Ph.D., Vysoké učení technické v Brně, Fakulta stavební, Ústav vodního hospodářství, Žižkova 17, 602 00 Brno, Česká republika
tel.: + 420 541 147 773, fax: + 420 541 147 771, e-mail: dumbrovsky.m@fce.vutbr.cz