EROSION AND WATER QUALITY AS MODELED BY CREAMS: A CASE STUDY OF THE SEDLICKÝ CATCHMENT

M. Holý
Z. Handová
Z. Kos
J. Váška
K. Vrána

November 1981
CP-81-35

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

THE AUTHORS

Prof. M. Holý is a research scientist at the International Institute for Applied Systems Analysis, Laxenburg, Austria (he is also a Professor at the Institute for Land and Water Reclamation, Prague Technical University, Czechoslovakia).

Drs. Z. Handová, Z. Kos, J. Váška and K. Vrána are research scientists at the Institute for Land and Water Reclamation, Prague Technical University, Czechoslovakia.

PREFACE

Interest in the environmental problems connected with crop yields continues to increase all over the world. From 1979-1981, the work of the Task "Environmental Problems of Agriculture" focused on the problems of soil erosion and chemical pollution from agricultural lands. The mathematical tool of investigation was the CREAMS model (a field level model), developed by the US Department of Agriculture and run on the IIASA computer.

One of the main aims of the Task was the development of the methodology for investigations on the regional level. The Task Force Meeting held at IIASA from June 2-4, 1980 only raised the question: "How can field level results be aggregated for a larger scale level?" and no clear-cut answers emerged. One possibility however would be to try to use the field level model on a higher level by verifying some coefficients of the model. Such investigations were made with the CREAMS model for the watershed level, by a group of scientists from the Technical University of Prague (CSSR) under the leadership of Prof. M. Holy. Their efforts are summarized in this report.

V. Svetlosanov
Task Leader
Environmental Problems
of Agriculture

ABSTRACT

In the process of verifying and validating the models of agricultural nonpoint source pollution at IIASA, a study was made of the Sedlický brook (Bohemia, Czechoslovakia) case. The CREAMS model, verified at the Samšín research area (Czechoslovakia) has been used as the mathematical instrument.

The validation results of the CREAMS model for the boundary conditions between the field level and the watershed level seem to show that under certain conditions, it can be applied to small watersheds. For large watersheds, modification of the hydrology submodel is necessary in order to describe the comprehensive hydrologic phenomena, particularly, the interflow and some of the subsurface flow.

TABLE OF CONTENTS

EROSION AND WATER QUALITY AS MODELED BY CREAMS: A Case Study of the Sedlický Catchment

M. Holý, Z. Handová, Z. Kos, J. Váška and K. Vrána

1. INTRODUCTION

Water quality and quantity are of prime importance where public water supply is concerned. The quality of surface water becomes an important part of the water management system. The quality of water in an area is threatened not only by point source pollution (e.g., wastewater from industry and sewage systems), but also by nonpoint sources of pollution.

The intensification of agricultural production is accompanied by the application of chemicals, i.e., fertilizers and pesticides, in order to obtain and stabilize high yields. The current method of application does not prevent the percolation of chemicals into surface and subsurface water. This process, together with the erosion phenomena, creates the conditions for pollution by nitrogen, phosphorus, and other elements, and pesticides, which leads to the eutrophication of water in reservoirs. This causes difficulties in the treatment of potable water, and results in even poorer water quality.

These phenomena, together with the hydrologic conditions connected with their occurrence have been investigated since 1975 in the catchment of the Sedlický brook (the catchment of the River Želivka in central Bohemia, Czechoslovakia). The

Sedlický brook flows into the Švihov reservoir on the River Želivka which supplies potable water to Prague, the capital of Czechoslovakia.

The processes and phenomena which influence water pollution in the Švihov reservoir were investigated by means of several models of surface and subsurface flow and models of erosion and chemical changes. From these, the CREAMS model (Knisel, 1980) seems to be the most comprehensive. An accumulated set of measured data was used after some correction,as the input data for this model. The CREAMS model was initially used to describe the investigated phenomena and it was then validated. The parameter values calibrated in preparation for the study carried out in Samšín (Holý et al., 1981) were used. On the basis of comparison of the results and the values gained by measurement, and after some small corrections were made, the model was also used for prediction. The influence on the erosion processes, percolation, and take-off nitrogen, phosphorus, and pesticides, into the streams were subsequently investigated. The results obtained were quite promising.

The area investigated was used to judge whether the CREAMS model could be utilized for the transition from the field level to the watershed level. In the watershed, there are several individual parts which have distinctive characteristics such as the crops grown, the gradient of slopes, the texture and structure of the soil, which to an extent give it some homogeneity. However, when the system is considered as a whole it is heterogenous. For determining the input values of the model parameters, one characteristic item was chosen. This item represented the average conditions for the whole area.

The application of the CREAMS model to the investigated area showed this model to be adequate for the transition from the field to the watershed level, i.e. for small basins. For larger areas it would be necessary to modify the model.

2. THE EXPERIMENTAL CATCHMENT

The experimental subcatchments of the Sedlický area watershed were used for calibration of the CREAMS model. The experimental subcatchments were monitored by the Institute for Scientific Systems of Agricultural Management, and observation data is available for a six-year period for these subcatchments. The Sedlický brook reservoir tributary which is closest to the filter treatment station and the quality of the inflow water can influence the technology of the filter treatment plant. The catchment area is used intensively for agriculture, except for the protected belt situated around the Švihov reservoir. The point-sources of pollution are negligible in this catchment so that the nonpoint source pollution from agricultural land (transport of soil particles and chemicals) is assumed to be the prevailing source of pollution.

The sedimentation reservoir is under construction at the lowest part of the Sedlický brook near Němcice, so that it will be possible to evaluate the reservoir's trapping efficiency in the near future, by using experimental data.

2.1 Description of the Experimental Zone

The Sedlický brook catchment area is situated at the eastern part of the Benešov district. The shape of the catchment is triangular, with Pravonin in the southwest, Ruzkovy Lhotice in the southeast and Sedlice in the north (see Figure 1). The morphology of the watershed is moderately undulated with the highest point, Zhoř (622 m above sea level) and Jizbický Hill (600 m above sea level) in the southern part of the catchment.

In the catchment area under investigation, annual precipitation is in the range of 650-680 mm, and average annual temperature is in the range of 6.3-7.2° C. The meteorological station in Čechtice is pratically in the centre of the area.

The hydrographic network is made up by the Strojeticky, Cechticky, the Mnichovicky, and the Lucni brooks. The average annual discharge of the Sedlický brook is 0.51 $m^3.s^{-1}$, Q_1 = 13.0 $m^3.s^{-1}$, and Q_{1-} = 31.0 $m^3.s^{-1}$ (Q_1,Q_{10} are floods recurrent in 1 and 10 years).

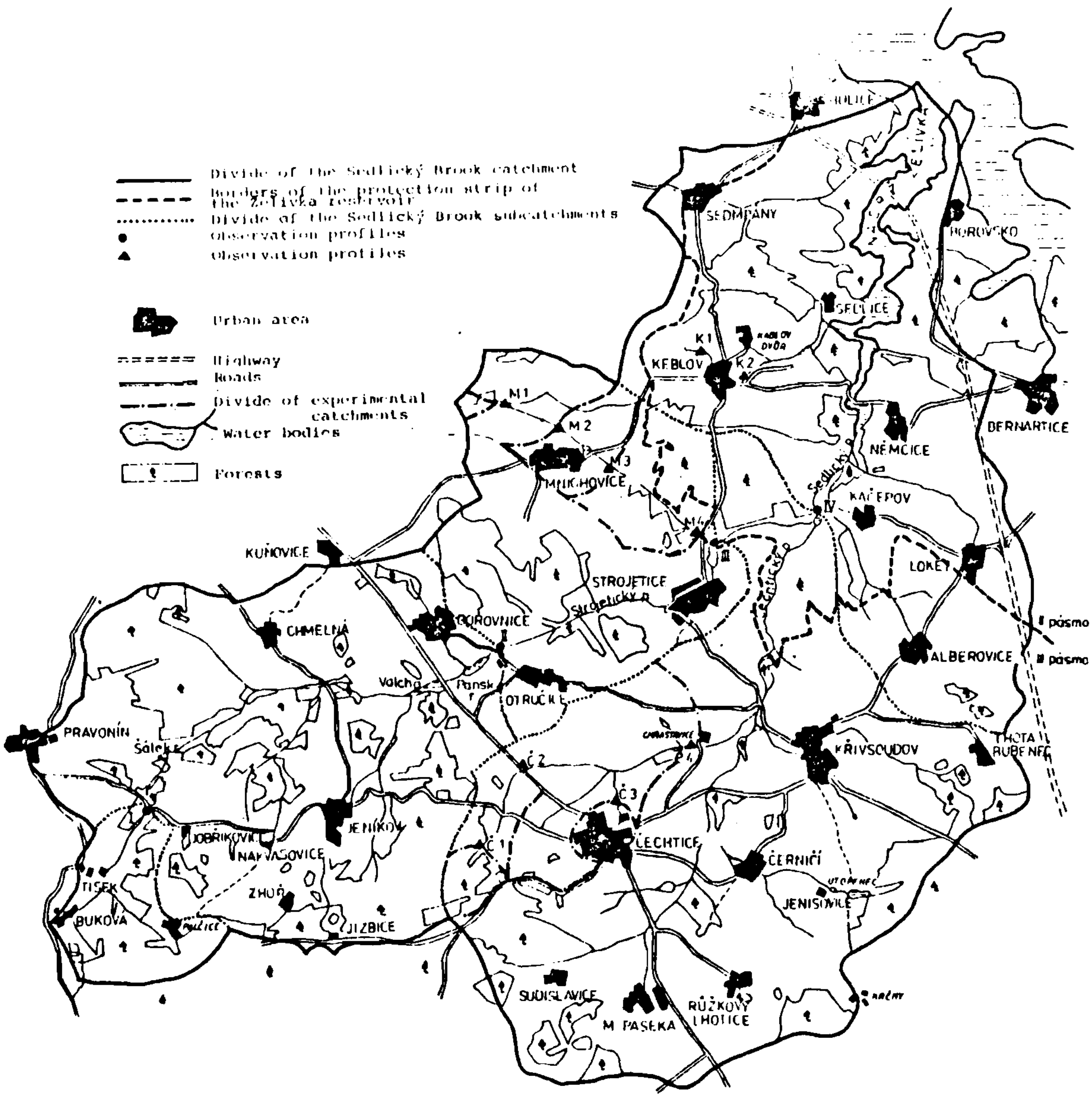

Figure 1. The Sedlický Brook Catchment

The geological formation of the catchment area is paragneiss, covered by moderately deep loamy soils, mostly of brown earth, with processes of leaching and gleying.

Agricultural land forms 67% of the catchment area, with forest making up 27% and the rest being urban area, water, etc. Fields with a 1 to 10 gradient make up 97% of the arable land. The urban areas have the character of agricultural villages. The highest density of population is in the city of Cechtice, with 110 inhabitants per km^2, which is four times more than the catchment average. Sewage from urban areas and farms are not treated in this area, therefore, the sewage waters go directly into the natural streams.

2.2. Equipment in the Experimental Area

In the Sedlický brook catchment area there is a system of 13 observation stations for the measurement of discharge and water quality and 16 observation points for observing the quantity and quality of drainage water.

At the Strojeticky brook there are 3 gauging stations, namely, I, II and III. Site No. I is equipped with a Thomson measuring weir and water gauge. The drainage area is 336 ha, from this, 154 ha. are agricultural land. Sites No. II and III are equipped with recording gauges and water gauges. The drainage area for site III is 2563 ha, from this, 1621 ha. are agricultural land; site III has 3857 ha, of which 2500 ha. are agricultural land.

At the Cechticky brook there are four stations - C1, C2, C3, and C4. Sites No. C1, C2 and C4 are equipped with recording gauges and water gauges. The drainage areas and agricultural lands for individual sites are: C1 - 71 ha. and 16 ha, C2 - 157 ha. and 73 ha, and C4 - 646 ha and 482 ha, respectively.

Site No. C3 is situated below the biological pond near Cechtice, through which sewage from Sechtice farm goes into the Cechticky brook. The treatment efficiency of this pond is negligible. Site No. C3 is equipped with a Thomson measuring weir and water gauge.

At the Mnichovicky brook there are four water-state-gauging-sites, namely, M1, M2, M3, and M4. All sites are equipped with Thomson measuring weirs and water gauges. The drainage areas and agricultural land of individual sites are: M1 - 29 and 23 ha, M2 - 162 ha and 88 ha, M3 - 255 ha and 146 ha, M4 - 476 ha and 296 ha., respectively.

The observation profile IV just below the confluence of Cechticky and Strojeticky brooks is currently under construction. This profile will be within the network of the Hydrometeorological Institute; apart from the recording gauges, it will be equipped for continuous observation of the quality and turbidity of water.

2.3 Experimental Data

In March 1975, observations began in the Sedlicky brook catchment area. At sites not equipped with recording gauges, samples of water are taken for laboratory analysis, namely, for determination of NO_2, NO_3, NH_4, N, P, Ca, Mg, Na, K, C1, S, pH and loss on heating. In the profiles with inflow of sewage water, samples for the determination of BOD (biological oxygen demand) and the Coli index have also been taken once a week.

2.4 Experimental Zone of the Cechticky Brook Catchment Area

The observation data from the catchment between observation profiles C1 and C2 have been used for the first stage of the case study. The categories of land-use are given in Table 1.

Monthly precipitation (mm) for the observation period are given in Table 2 and monthly average temperature (^{o}C) in Table 3. Monthly runoff (thousands of m^3) from the interbasin C2 - C1 for the observation period are given in Table 4.

Crop rotation (ha/percent of arable land) in the interbasin area C2 - C1 is given in Table 5. Crop yields (q/ha) in the interbasin area C2 - C1 for the observation period are given in Table 6. Chemical fertilizer application rates (kg of chemicals/ha of agricultural land) in C2 - C1 for the observation period are given in Table 7. Average and extreme concentrations of basic chemicals in the Cechticky brook during the observation period are given in Tables 8, 9, and 10.

Table 1. The Characteristics of Land Use

Type/Categories	Catchment up to the Profile C1	C2
Drainage area (ha)	71	157
Agricultural land (ha)	16	73
Agricultural land (fraction of the total drainage area)	22.5	46.5
Arable land (ha)	14	61
Meadow (ha)	2	12
Forest (ha)	55	84
Water (ha)	0	0
Urban area (ha)	0	0

Table 2. Monthly Precipitation (mm)

	1975	1976	1977	1978	1979	1980	Average
I	29.8	118.2	73.6	32.0	44.9	33.3	55.3
II	18.2	18.2	58.8	21.5	28.4	45.7	31.8
III	49.4	25.4	36.9	32.3	100.7	44.3	48.2
IV	38.7	32.8	45.3	36.3	60.3	135.5	58.2
V	86.6	87.7	58.5	86.1	31.7	41.9	65.4
VI	148.8	34.2	76.6	56.0	152.5	107.6	95.9
VII	94.2	50.3	106.5	65.9	64.2	177.5	93.1
VIII	119.1	56.8	183.3	89.8	57.5	33.2	89.9
IX	7.9	48.2	88.0	81.0	101.9	36.3	60.6
X	41.7	62.5	37.9	53.8	24.5	85.4	51.0
XI	54.3	71.8	50.3	47.7	76.1	40.3	56.8
XII	30.0	26.0	36.3	39.5	54.2	45.3	38.6
Total	718.7	632.1	852.0	641.9	796.9	826.3	744.7

Table 3. Monthly Average Temperatures (°C)

	1975	1976	1977	1978	1979	1980	Average
I	2.4	-0.9	-1.7	-0.9	-5.4	-4.7	-1.9
II	-1.2	0.8	1.2	-2.9	-1.5	1.2	-0.4
III	3.4	-0.4	5.8	3.9	3.7	1.9	3.1
IV	6.0	6.8	5.7	6.0	5.9	4.5	5.8
V	12.4	12.5	11.9	10.7	12.7	9.3	11.6
VI	14.0	16.3	15.6	14.2	17.5	14.3	15.3
VII	17.2	18.2	16.0	14.8	14.6	14.3	15.9
VIII	17.2	14.6	15.0	14.3	15.4	16.0	15.4
IX	16.1	11.9	10.9	11.7	12.7	12.5	12.6
X	6.9	9.1	9.0	7.9	6.6	7.2	7.8
XI	1.2	4.1	4.1	2.4	2.7	2.1	2.8
XII	-0.7	-2.4	-1.2	0.5	3.3	-0.6	-0.4
Average	7.9	7.6	7.7	6.8	7.4	6.5	7.3

Table 4. Monthly Runoff ($10^3 m^3$)

	1975	1976	1977	1978	1979	1980	Average
I	-	46.42	9.94	7.71	6.53	11.51	16.42
II	-	13.15	32.62	7.98	6.48	19.63	15.97
III	-	8.33	24.57	17.12	41.98	15.38	21.48
IV	5.16	6.02	8.47	8.78	32.33	42.52	17.21
V	6.79	3.88	4.57	11.04	12.53	27.49	11.05
VI	31.46	2.92	2.58	5.59	11.05	11.47	10.85
VII	18.73	1.29	17.0	4.89	9.40	38.46	14.96
VIII	7.83	1.30	39.41	2.83	3.80	10.88	11.01
IX	7.67	1.14	13.86	2.67	7.68	3.67	6.12
X	4.07	1.29	9.97	4.42	6.29	4.39	5.07
XI	4.12	3.98	9.20	3.69	13.28	4.36	6.44
XII	10.02	4.72	8.03	12.37	26.66	4.57	11.06
Total	95.85	94.44	180.22	89.09	178.01	194.33	147.64

Table 5. Crop Rotation (ha/percent of arable land)

Year	Small Grain	Root Crops	Fodder Crops
1975	28.0/59.6	12.0/25.5	7.0/14.9
1976	22.6/48.1	15.2/32.3	9.2/19.6
1977	47.0/100.0	-	-
1978	12.0/25.5	9.0/19.1	26.0/55.4
1979	9.0/19.1	-	38.0/80.9
1980	32.0/68.1	-	15.0/31.9

Table 6. Crop Yields (q/ha = 100 kg/ha)

Year	Small Grain	Root Crops	Fodder Crops
1975	34.8	312.0	39.5
1976	31.6	178.0	49.7
1977	38.1	-	-
1978	46.3	374.7	385.7*
1979	49.6	-	47.10*
1980	41.1	-	323.0*

*undried

Table 7. Chemical Fertilizer Application Rate (kg/ha of Agricultural Land)

Year	N	P	K	Total
1975	112.8	41.2	97.0	251.0
1976	129.4	40.1	50.2	219.7
1977	118.2	32.1	61.5	211.8
1978	138.0	65.2	55.3	258.5
1979	143.1	26.9	61.7	231.7
1980	97.3	26.9	62.0	186.2

Table 8. Concentration of Potassium (K) in the Cechticky brook (ppm)

Year	Profile C1			Profile C2		
	max.	min.	Ø	max	min	Ø
1975	4.05	0.51	2.11	3.19	0.38	2.05
1976	2.80	0.36	1.96	2.65	0.28	1.73
1977	8.00	1.00	3.43	8.00	0.50	3.45
1978	6.50	2.00	3.33	5.25	2.00	2.92
1979	5.00	1.00	2.92	4.00	0.50	2.63
1980	3.58	1.34	2.52	3.11	1.75	2.35
Average	4.99	1.12	2.71	4.37	0.90	2.52

Table 9. Concentration of Phosphorus (HPO_4) in the Cechtichy Brook (ppm)

Year	Profile C1 max.	min.	Ø	Profile C2 max.	min.	Ø
1975	0	0	0	0.03	0	0
1976	0.02	0	0	0.04	0	0
1977	0.14	0	0.03	0.46	0	0.03
1978	0.18	0	0.02	0.08	0	0.04
1979	0.13	0	0.04	0.17	0	0.06
1980	0.08	0.01	0.04	0.11	0.02	0.06
Average	0.09	0	0.02	0.15	0	0.03

Table 10. Concentration of Nitrogen (NO_3) in the Cechtichy Brook (ppm)

Year	Profile C1 max.	min.	Ø	Profile C2 max.	min.	Ø
1975	55.99	28.14	39.34	67.53	38.55	55.18
1976	34.91	22.46	30.50	44.76	23.55	39.24
1977	59.00	14.00	35.47	85.60	20.70	51.94
1978	63.10	23.50	42.94	70.50	25.00	48.92
1979	43.50	14.75	26.60	47.50	5.75	33.59
1980	44.54	20.67	37.76	45.69	24.79	36.72
Average	50.17	20.59	35.43	60.26	23.06	44.27

Nutrient losses (kg) and specific nutrient losses (kg/ha of agricultural land) from catchment C1 and C2 during the observation period are given in Tables 11, 12, and 13.

Consumption of nutrients uptake by crops (kg/ha of agricultural land) in basins C2 - C1 during the observation period is given in Table 14.

Table 11. Loss of Nitrogen (N) (kg/ha of agricultural land)

Year	Profile C1		Profile C2	
	Nurtient Loss	Specific Loss	Nutrient Loss	Specific Loss
1975	784	49.0	3216	44.0
1976	541	33.8	2135	29.3
1977	777	48.6	2921	39.9
1978	479	29.9	1634	22.4
1979	482	30.1	1796	24.6
1980	887	55.4	2808	38.4
Average	658.3	41.13	2418.3	33.10

Table 12. Loss of Phosphorus (P) (kg/ha of agricultural land)

Year	Profile C1		Profile C2	
	Nutrient Loss	Specific Loss	Nutrient Loss	Specific Loss
1975	0	0	1.00	0
1976	0	0	0	0
1977	2.60	0.17	8.24	0.11
1978	1.15	0.07	5.69	0.08
1979	3.31	0.21	14.18	0.19
1980	1.16	0.07	5.83	0.08
Average	1.37	0.087	5.82	0.077

Table 13. Loss of Potassium (K) (kg/ha of agricultural land)

Year	Profile C1 Nutrient Loss	Profile C1 Specific Loss	Profile C2 Nutrient Loss	Profile C2 Specific Loss
1975	177	11.1	507	6.9
1976	124	7.6	335	4.6
1977	322	20.1	834	11.4
1978	160	10.0	420	5.8
1979	227	14.2	605	8.3
1980	255	16.0	771	10.6
Average	210.8	13.17	578.7	7.93

Table 14. Consumption of Nutrients Uptake by Crops (kg/ha of agricultural land)

Year	N	P	K	Total
1975	84.88	15.88	84.07	184.83
1976	98.63	20.04	99.86	218.53
1977	101.11	21.35	81.63	204.09
1978	47.67	19.88	99.46	167.01
1979	85.86	25.82	140.03	251.71
1980	68.54	18.35	76.84	163.73

3. THE HYDROLOGY SUBMODEL

Both options of the hydrology submodel were applied. The first option uses the daily values of precipitation (Option 1), the second one, the distribution of precipitation data for those days (Option 2). The precipitation data were used from the Cechtice station which is located approximately 1 km away from the area of investigation and the Ovesna Lhota station which is located in the same catchment of the Zelivka river circa 27 km away from the area investigated. The year 1977 was chosen as there was a relatively sufficient data base for the whole model and erosion and chemical changes were significantly caused by precipitation during this year.

At the Cechtice station, there were daily values of precipitation. The duration of precipitation was simulated from the Ovesna Lhota station by hydrologic analogy. This made possible the application of Option 2 and verification of the hydrologic submodel for this option as well. In the Samsin locality only Option 1 was verified by Holy et al.,(1981).

The results of Option 2 were used for testing and calibrating the model and for comparison with the results of Option 1 only. For further submodels, the output of the hydrology submodel in Option 1 was used as it was derived on the basis of measured precipitation and the values of calibrated parameters.

3.1 Input Parameters

The values of input parameters were calibrated for the Samsin area. In the area around the Sedlicky brook investigated in this study, these calibrated values,or different values when they were gained by measurement,were used, and/or when the condition differed from those in the Samsin area. In these corrections, the relations obtained by the calibration process were used. For a comparison of the calibrated values from the Samsin locality and the parameters used in this study, both are listed for Option 1 in the following table. For Option 2, some additional parameters had to be determined and their calibration was performed in this study. These values are listed in Table 15.

Table 15. Input Parameters (Hydrology Submodel)

Symbol	Definition	Dimension	Values Sedlice	Values Samsin
DACTE	Field area	Acre	178.2	13.1
RC	Saturated hydraulic conductivity	in/hr	0.020	0.028
FUL	Field capacity/upper limit of storage		0.81	0.67
BST	Initial fraction of soil water storage		0.75	0.87
CONA	Soil evaporation parameter		4.5	4.5
POROS	Soil porosity		0.42	0.43
SIA	Coefficient		0.2	0.2
CN2 SCS	Curve number		79.0	75.0
CHS	Main channel slope		0.044	0.050
WLW	Watershed length/ width ratio		3.17	3.58
DS	Depth of surface soil layer	in.	2.5	-
DP	Maximum rooting depth	in.	33.5	-
GA	Effective capillary tension in Green-Ampt model	in.	10.5	-
RMN	Manning roughness coefficient for field surface		0.023	-
SLOPE	Average field slope		0.055	-
XLP	Slope length	ft.	1967.0	-

Further parameters that are used in Option 1 only are the values UL_i for soil water storage available to plants. From these seven values, the first is for the 1 inch layer, the second for 5 inches and the next five for layers of 6 inches each.

The following values were used:

Table 16. Soil Water Storage

UL_i	1	2	3	4	5	6	7
Sedlice	0.27	1.05	0.95	1.15	1.05	0.84	0.73
Samsin	0.22	0.55	0.66	0.50	0.40	0.40	0.40

The choice of the UL_i values was tested by computation of the average values in the soil profile:

$$\sum_1^7 UL_i = 6.04 \doteq (\text{POROS-B15}) \cdot 36 = (0.420-0.253) \cdot 36 \quad ,$$

where POROS is the average porosity and B15 the average wilting point in the 36 inch layer.

The values of the average temperature and radiation used in the hydrologic submodel were the following (see Table 17):

Table 17. Monthly Temperature and Radiation

Month	Temperature ^oF	Radiation Langley/day
I	29.0	82.0
II	34.2	120.0
III	42.6	202.0
IV	42.5	207.0
V	53.5	365.0
VI	60.1	353.0
VII	60.8	384.0
VIII	59.0	325.0
IX	51.6	198.0
X	48.2	142.0
XI	39.2	96.0
XII	30.0	80.0

In the model, the values of temperature and radiation are not used directly, but are described by a curve for the daily values, therefore, the monthly values printed on the output are modified in this way.

The values of the leaf area indexes were chosen as the average values in the locality with harvest in August followed by clover on arable land.

3.2 Output and Results

On the basis of the hydrologic submodel runs in Option 1 the runoff value for the simulated period was 3.09 inches. A comparison with the measured value of the surface runoff (3.90 inches), shows a relatively good agreement of both values. In this computation it was taken for granted that the hydrologic submodel in Option 1 calculates the values of the surface runoff as discussed below. The distribution of the runoff for the individual months shows the relation that is typical for the hydrology of small catchments. The hydrologic submodel does not take into account the storage of water in the whole watershed and does not determine the more prolonged runoff from groundwater. The groundwater in this area does not fall to zero even in a relatively drier period, and its values are governed by the recession curve. Therefore, the measured total flow was divided into base flow and surface runoff and the values computed by the hydrologic submodel were compared with the surface runoff as listed in the following table (Table 18).

The values of the surface runoff modeled in Option 2 are closer to the measured values in the spring period (in Option 1, there are zero values). There is a deviation in Option 1 caused by different modeling of the rain on 31st July, for the rest of the year both options give approximately equal values. In November and December the total runoff is mainly due to subsurface drainage. This fact is not modeled by the hydrology submodel and this drawback of the model causes some deviations in the chemical submodel in the overestimation of denitrification, as stated later.

Table 18. Runoff Values

Month	Total measured runoff (in)	Surface measured runoff (in)	Computed runoff Option 1 (in)	Computed runoff Option 2 (in)
IV	0.47	0.10	0	0.10
V	0.25	0.05	0	0.09
VI	0.14	0.00	0	0.06
VII	0.94	0.85	0.17	0.90
VIII	2.18	2.13	2.15	2.29
IX	0.77	0.67	0.62	0.70
X	0.55	0.07	0.13	0.14
XI	0.51	0.03	0.02	0
XII	0.48	0	0	0

In 1979, the runoff and precipitation were measured by recording measurements in the station C1 and C2 on the Cechticky brook in June. These records were used for calibration of the hydrologic submodel (Option 2). The results of the tests showed that the model in Option 2 is not sensitive to the choice of some parameters as in Option 1 (e.g. the choice of hydraulic conductivity). The average runoff computed by the hydrologic submodel agreed with the measured one; both values were determined in inches per day. In a comparison of the maximum values, it was found that for the area under study, the model systematically overestimated the maximum runoff, as shown by the two examples given in the following Table (Table 19).

According to the following computation in the erosion submodel where the maximum values are used in the third root, the deviations of the maximum values are not significant for the output of the CREAMS model.

Table 19. Comparison of Average and Maximum Runoff Measured and Computed in Option 2

Date	Average runoff inch/day measured	comparison	Maximum runoff inch/hour measured	comparison
7 June	0.19	0.20	0.13	0.20
28 June	0.36	0.41	0.21	0.49

3.3 Summary of Hydrology Submodel

The application of the hydrology submodel in the case study of the Sedlicky brook showed the adequacy of the CREAMS model for the intermediate level between the field and the small watershed level. Differences exist in the hydrology submodel, however, they do not substantially influence further computation in the erosion and chemical submodels. Therefore, the CREAMS model could be validated for the small catchment area investigated.

In the hydrology submodel, two options were tested and the better adaptability of Option 2 was shown. This result is in accordance with the presumption that Option 2 requires more input information and the model used is oriented more toward the physical relations, therefore it can model reality better.

Both options have their relative advantages - Option 1 requires less data, therefore, it is more universal; Option 2 is more correct but it requires intensities of rainfall.

The output of the hydrology submodel seems to show that the area of the catchment is not far from the limit of the applicability of this submodel. For larger areas, the flow of groundwater has to be taken into account in the hydrologic balance to enable computation of the total runoff, not only during rainy periods, but also in relatively drier periods.

4. EROSION/SEDIMENT YIELD SUBMODEL

The erosion/sediment yield submodel has been validated in 4 alternatives for this case study:

Alternative 1 - Overland flow element has been assumed characteristic for the catchment (characteristic overland flow profile is formed by arable land only).

Alternative 2 - Overland flow element has been assumed characteristic for the catchment (characteristic overland flow profile is formed by arable land and perennial meadows situated along the Cechticky brook).

Alternative 3 - Overland flow element (Alternative No. 1) and channel element formed by the Cechticky brook which flows in the catchment valley.

Alternative 4 - Overland flow element (Alternative No. 2) and channel element formed by the Cechticky brook.

The influence of the change of parameters which can be updated for crop stages and management practices (e.g. cropping management factor - CIN, contouring factor - PIN, Manning's coefficient of roughness - MIN) has been tested in all alternatives and, further, the influence of change of channel lining (depth of nonerodible layer - NDN and NDS, critical shear stress - NCR, Manning's roughness factor for channel - NN) has been evaluated for alternatives 3 and 4.

The most complex situation for the erosion/sediment yield submodel of the CREAMS, e.g. combination "overland flow element - channel element" (FLGSEQ = 4) and the influence of channel parameters subject to alteration will be tested in a further stage of the case study for the region of Zebrakovsky brook.

4.1 Input Data

The input data for running the erosion/sediment yield submodel have been obtained from:

- maps,
- results of site visits and surveys,
- soil analyses,
- sets of observed discharge data in observation sites C1 and C2, and
- agricultural management data (crops, crops stages, management practices, etc.).

For evaluating the input data, the results of verification of the CREAMS model for the Samsin area (Holy et al., 1981) have been considered by using the calibration relations.

The following assumptions have been accepted for the preparation of input data:

- the experimental zone has been approximated by characteristic overland flow profile;
- the shape and slope of the characteristic overland flow profile are average for the catchment:
- the length of the characteristic overland flow profile is half of the average catchment width (the channel element - Cechticky brook - forms an axis of the catchment);
- soil conditions of characteristic overland flow profile have been evaluated as average, from soil analyses of ten soil pits scattered in the catchment area (the experimental catchment is nearly homogeneous in soil conditions);
- arable land forms the total length of the characteristic overland flow profile (alternatives 1 and 3) or, upper part of the profile (95% of the total length) is arable land and the lower part of the profile has perennial meadows (along the Cechticky brook);
- the crop planted in the catchment is small grain;
- crop stage for the small grain has been divided into five periods:

Period 1 (1.4-1.5): Seeding. Seedbed preparation to 1 month after seeding (CIN = 0.65, MIN = 0.014).

Period 2 (1.5-1.6): Establishment. Up to 2 months after spring seeding (CIN = 0.40, MIN = 0.018).

Period 3 : Growth and maturation of crops. Up to harvest (1.6-15.8) (CIN = 0.06, MIN = 0.018).

Period 4 (15.8-1.10): Stubble period (CIN = 0.25, MIN = 0.023).

Period 5 (1.10-31.12): Autumn plowing, rough fallow (CIN = 0.60, MIN = 0.046).

For these periods, updatable parameters for vegetative cover and management practices (soil loss factor C, Manning's roughness coefficient for overland flow) have been determined. The bottom and sides of the channel are lined with rubble paving for the total length of the channel element.

A list of the input data for all the alternatives tested is given in Appendix A. The input data used for verification of the CREAMS model for the Samsin area are given for comparison in Appendix A as well.

4.2 Results of Validation

The results of validation of the erosion/sediment yield submodel of CREAMS for all the alternatives tested are given in Table 20.

The results show a significant influence by perennial meadow on the total soil loss (alternatives Nos. 2 and 4). In spite of the length of the meadow strip which is small in comparison with the length of the characteristic overland flow profile (5% of the total profile length), the soil loss has decreased by 3 times.

The results of alternatives 3 and 4 show the influence of channel lining by nonerodible material (TDN = TDS = 0.1 ft). In the case study, the influence of the depth of the nonerodible layer has also been tested. In case the channel is built in erodible soil without any lining (TDN= TDS = 1000.0 in the

Table 20. Results of Validation (Soil Loss = t/acre)

Month	Cechticky Brook Catchment Area Alternative 1	Alternative 2	Alternative 3	Alternative 4
April	-	-	-	-
May	-	-	-	-
June	-	-	-	-
July	0.29	0.07	0.29	0.07
August	2.87	1.17	2.83	1.32
September	0.86	0.28	0.86	0.29
October	0.05	0.04	0.05	0.04
November	-	-	-	-
December	-	-	-	-
Annual Soil Loss	4.07	1.56	4.03	1.72

CREAMS Manual) the total soil loss will increase four times while soil loss in the channel element will increase nearly a hundred times. No sediment transport observations were available at the observation site C2. Therefore, the soil loss predicted by the erosion/sediment yield submodel of CREAMS has been compared with results obtained by using the erosion model developed by the Institute of Land and Water Reclamation of the Technical University, Prague, using measured data from experimental plots located in North Bohemia and the results of laboratory experiments (Holy et al., 1980). It is possible to use the method of analogy for this comparison, as the soil conditions, climate, and vegetative cover are similar for both the Cechticky brook watershed and the experimental plots. The results of this comparison are given, for individual storms, for the overland flow element in Table 21.

From Table 21, it is obvious that prediction of soil loss by the erosion/sediment yield submodel of CREAMS agrees well with the soil loss predicted by the erosion model developed for the conditions prevalent in Bohemia.

Table 21. Results of Comparison (Soil Loss in t/acre)

Date	Runoff (in)	Alternative 1		Alternative 2	
		CREAMS	Erosion Model	CREAMS	Erosion Model
77212	0.15	0.29	0.135	0.07	0.033
77213	0.13	0.16	0.108	0.07	0.026
77214	0.14	0.15	0.122	0.08	0.030
77226	0.02	0.01	0.006	0.0	0.001
77230	0.13	0.14	0.108	0.04	0.026
77231	0.38	0.50	0.582	0.17	0.141
77233	0.34	0.47	0.489	0.17	0.119
77234	0.93	1.33	2.371	0.61	0.576
77239	0.10	0.11	0.071	0.03	0.017
77244	0.45	0.65	0.759	0.21	0.184
77246	0.16	0.16	0.149	0.06	0.036
77251	0.05	0.05	0.024	0.01	0.006
77283	0.13	0.05	0.108	0.04	0.026
Total	3.11	4.07	5.032	1.56	1.221

4.3 Conclusions on Erosion Submodel

The results of the case study show the possibility of applying the erosion/sediment yield submodel of CREAMS to a small watershed. To be applicable, the four assumptions for which the CREAMS model was developed should be met, namely,

- uniform land use;
- relatively homogeneous soils;
- spatially uniform rainfall; and
- uniform management practices.

It is also very important to approximate the small watershed by carefully choosing an overland flow profile which adequately characterizes the morphology of the area. Calculation of the four alternatives verified the running sequence "overland flow element - channel element" of the erosion/sediment yield submodel of CREAMS.

The results clearly show the influence of perennial grass strips for decreasing the transport of soil particles from fields into waterbodies and the importance of this for water quality control. The results also proved the influence of choice of depth of the nonerodible layer and the channel lining on detachment and transport of soil particles by concentrated flow.

To conclude, it may be stated that at this stage of the case study it is clear that the CREAMS model is applicable for the prediction of soil loss for small catchment areas.

5. CHEMICAL SUBMODEL

The chemical submodel of CREAMS has been applied for modeling nutrients and pesticide transport from a small catchment in a case study of the Sedlicky brook. The catchment has been approximated by characterictic overland flow profile and channel flow under the assumptions mentioned in Section 4.1.

The input data have been prepared for arable land only and these data have been used for running all four alternatives of the erosion/sediment yield submodel. Planting small grains (wheat) on arable land has been considered in agreement with the real management of the experimental catchment in 1977. The use of single input data for the chemical submodel is based on the assumption that perennial meadows would greatly influence erosion processes and transport of nutrients and pesticides adsorbed on sediment. The concentration of these substances dissolved in surface runoff will only be influenced slightly. The other parameters (loss by leaching, denitrification, plant N-uptake) will be influenced mostly by hydrology and erosion outputs rather than by the relatively small area with perennial meadows.

5.1 Input Data

The measured input data were derived mostly from results of laboratory soil analyses and agricultural management data of the area. The values for enrichment ratio coefficients for phosphorus and enrichment ratio exponent for nitrogen and phosphorus were used according to the calibrated values from Samsin (Holy et al., 1981).

The differences in the input data between the Cechticky brook catchment and the Samsin area are caused by differences in the condition of soil, agriculture, meteorology and vegetation or by values measured on site (e.g. the different nitrogen content in precipitation).

A list of input data is given in Appendix B. In the same Appendix, the input data used for verification of CREAMS for the Samsin area are given for the sake of comparison.

5.2 Results

Using hydrology and erosion outputs for individual storms, the transport of nutrients and pesticides has been modeled by the chemical submodel of CREAMS for the Cechticky brook catchment. The processes of denitrification, nitrification, plant N-uptake, adsorption, and extraction of nutrient by surface runoff and percolation, have been considered.

The results of modeling nutrients transport by overland flow, erosion process, leaching, denitrification and plant N-uptake are given in Tables 22 and 23 for all alternatives of the erosion submodel.

By comparing Tables 18 and 22, a very close relationship between the loss of nitrogen in runoff and the modeled runoff of water can be seen. The loss of nitrogen in sediment is proportional to the soil loss in individual by investigated alternatives - alternatives 2 and 4 giving approximately one half of the values given by alternatives 1 and 3. Again the influence of perrenial meadows along the brook on the output was shown.

The values of denitrification are different from zero in November and December. The modeled values are overestimated.

Table 22. Nitrogen Loss (Values from the Chemical Submodel of CREAMS in kg/ha)

Month	Loss in Runoff	Loss in Sediment Alternative				Leaching	Denitrification	N-uptake
		1	2	3	4			
IV	-	-	-	-	-	-	-	13.53
V	-	-	-	-	-	-	-	35.39
VI	-	-	-	-	-	-	-	7.08
VII	0.27	1.98	0.60	1.98	0.60	-	-	0.35
VIII	2.66	17.66	8.31	17.53	9.06	-	-	3.65
IX	0.56	5.54	2.15	5.58	2.20	-	-	-
X	0.16	0.42	0.40	0.42	0.40	-	-	-
XI	0.01	0.02	0.02	0.02	0.02	0.85	52.40	-
XII	-	-	-	-	-	1.36	75.67	-
Annual Loss	3.66	25.62	11.49	25.53	12.28	2.21	128.07	60.01

Table 23. Phosphorus Loss (Values from the Chemical Submodel of the CREAMS in kg/ha)

Month	Loss in Runoff	Loss in Sediment Alternative			
		1	2	3	4
VI	-	-	-	-	-
V	-	-	-	-	-
VI	-	-	-	-	-
VII	0.0073	0.509	0.151	0.509	0.150
VIII	0.0932	4.570	2.127	4.534	2.323
IX	0.0264	1.428	0.546	1.438	0.559
X	0.0055	0.050	0.100	0.105	0.100
XI	0.0005	0.005	0.005	0.005	0.005
XII	-	-	-	-	-
Annual Loss	0.1329	6.618	2.929	6.591	3.138

It is mainly caused by the conditions considered in the hydrology submodel where the wet soils are modeled without any natural drainage of the upper layer of groundwater. In addition, the simplified evaluation in the chemical submodel as the exponent of the number of days from the last rainfall is used.

In Table 23, a similar relation can be observed in the loss of phosphorus in sediment as compared with the loss of nitrogen in sediment.

The chemical submodel results have been compared with experimentally obtained data of annual nutrient loss and plant N-uptake (see Table 24).

Table 24 contains the annual losses of nitrogen, i.e. losses in runoff, sediment, and leaching; N-uptake by plants is given separately. In this table, values of denitrification are not stated as these values are not measured in the area investigated. Also the modeled values are different from those obtained under

Table 24. Comparison of Observed and Modeled Values of Nutrient Loss (without the denitrification process) and Phosphorus Loss (in runoff only in kg/ha)

	Model Values Alternative 1	2	3	4	Observed Values
Applied N			138.88*		138.88
Applied P			25.87*		25.87
N Loss	31.48	17.35	31.39	18.14	39.90
P loss (in runoff)			0.13*		0.11
N-uptake			60.01*		101.11

*for all alternatives

conditions similar to that of the area of investigation. The losses in pesticides are not given, as there were no reliable observations, therefore, no comparison could be made. The loss of phosphorus in Table 24 applies to the runoff only, as these values were measured.

On the basis of the comparison of the measured and modeled values, the following conclusions can be made:

- loss of nitrogen in Alternative 3 (which simulates best the conditions in 1977) corresponds rather well with the measured values and it is very close to the average values for the six years of investigation (see Table 11);
- loss of phosphorus in the runoff is adequately modeled;
- N-uptake given by the model is about one half of the measured values. However, in the observed value, not only is the yield of small grain considered (as in the model), but also the crop which follows (clover), which cannot be taken into account in one run of the model. If the N-uptake is reduced to small grain only, then a relatively good agreement is obtained.

5.3 Conclusions on the Chemical Submodel

A comparison of the measured and modeled values characterizing the balance of nutrients (nitrogen and phosphorus) enable validation of the chemical submodel and the entire CREAMS model, for small catchment areas.

The values of input data were determined on the basis of individual conditions of the area investigated and the calibrated values from the Samsin area. In the model run, a relatively close relation of the nutrient runoff (N,P) and the water runoff was found in the annual value, and in the monthly distribution as well. Reduction of the losses of nutrient in Alternatives 2 and 4 to approximately one half was caused (in accordance with the conclusion of the erosion/sediment submodel) by erosion control function of the strip of perrenial meadows along the brook. For larger catchments, the computation of denitrification would be necessary, as the CREAMS model overestimated these values even for small catchments. A comparison of the measured and modeled values (total N-loss, P-loss in runoff, and plant N-uptake after reduction to small grain) seems to show good agreement in validating the chemical submodel for small catchments.

At a further stage in the case study, experiments for the determination of the values of coefficients and exponents for evaluation of the nitrogen and phosphorus balance will be necessary.

6. CONCLUSIONS

After verification of the CREAMS model for climatic, hydrological, soil and agricultural conditions in the Samsin locality of Czechoslovakia (Holy et al., 1981), this model was validated in the case study of Sedlicky brook. The data of precipitation, runoff, soil loss, nutrients application rate, concentrations of basic nutrients in the Cechticky brook, and nutrient losses and plant uptake by crops have been observed since 1975 in these and neighbouring areas. On the basis of these data, the input values of the CREAMS model have been assembled.

The results of calculation and their comparisons with the measured values seem to show that the CREAMS model can be applied for small catchments, when the facts stated in the next few paragraphs are considered and the following conditions are fulfilled:

(1) The CREAMS hydrology submodel computes the surface runoff only. Therefore, the values of measured total runoff and their distribution in the year are different from that given by CREAMS. However, when the base flow from groundwater is subtracted, then the measured values agree relatively well with the calculated values. This agreement is better in Option 2 (rainfall intensities) than in Option 1 (daily precipitation), and it is rather good in Option 1 when the calibrated values of parameters are used. For the conditions prevalent in Czechoslovakia, the CREAMS model overestimates the maximum values of runoff for small catchments.

(2) In the erosion/sediment submodel, the main problem that has to be resolved before application of the model is the choice of a typical slope which can represent the erosion conditions of the catchment. The conditions necessary for the application of the erosion/sediment submodel for a small catchment are: uniform land use, relatively homogeneous soil, spatially uniform rainfall, uniform management practice. Under these conditions the model can predict the soil loss for small catchments and the influence of some erosion control measures (e.g. strips of perennial meadows along the channel).

(3) In the chemical submodel, the balance of nutrients (phosphorus and nitrogen) was computed on the basis of the calibrated coefficients from the Samsin locality and the modified parameters for the different conditions in the area investigated. The CREAMS chemical submodel was thus validated in this section.

This computation has shown that the values of denitrification given by the model are overestimated for the level of a small catchment. The main cause was the hydrology input and the coarse method of estimation. Once more, the necessity to adapt the hydrology submodel for larger catchment areas was proved.

In further investigations when the application to larger catchments is considered, the reconstruction or use of a different hydrology submodel will be necessary. In the erosion/sediment submodel it will be necessary to stipulate the principles for division of the basin into subcatchments which can be typified by a representative slope, and then the problem of incorporating these subsystems into the system of the basin will have to be solved. In the chemical submodel, the relation of coefficients and exponents in principal equations to the spatial characteristics and the problem of denitrification overestimation have to be solved. Further, the problem of relations among the subsystems that have homogeneous input chemical parameters in the system has to be considered.

For these investigations, the CREAMS model proved to be a good basis and starting point as is evident in this case study validating the CREAMS model for small catchment areas.

APPENDIX A

Card	Manual Symbol	Cechticky Brook Catchment Alternative 1	2	3	4	Samsin Area
4	BDATE	77091	77091	77091	77091	77091
	FLGOUT	2	2	2	2	2
	FLGPAS	1	1	1	1	1
	FLGPRT	0	0	0	0	0
	FLGSEQ	1	1	3	3	1
5	KINVIS	0.0	0.0	0.0	0.0	0.0
	NBAROV	0.0	0.0	0.0	0.0	0.0
	WTDSOI	0.0	0.0	0.0	0.0	0.0
	KR	0.0	0.0	0.0	0.0	0.0
	NBARCH	0.0	0.0	0.0	0.0	0.0
	YALCON	0.0	0.0	0.0	0.0	0.0
6	SOLCLY	0.22	0.22	0.22	0.22	0.25
	SOLSLT	0.33	0.33	0.33	0.33	0.26
	SOLSND	0.45	0.45	0.45	0.45	0.49
	SOLORG	0.01	0.01	0.01	0.01	0.02
	SSCLY	45.0	45.0	45.0	45.0	45.0
	SSSLT	5.0	5.0	5.0	5.0	5.0
	SSSND	0.05	0.05	0.05	0.05	0.05
	SSORG	850.0	850.0	850.0	850.0	800.0

Card	Manual Symbol	Cechticky Brook Catchment Alternative 1	2	3	4	Samsin Area
9	DATOV	178.2	178.2	178.2	178.2	13.1
	SLNGTH	1967.0	1967.0	1967.0	1967.0	1213.0
	AVGSLP	0.065	0.065	0.065	0.065	0.072
	SB	0.077	0.077	0.077	0.077	0.068
	SM	0.055	0.055	0.055	0.055	0.072
	SE	0.063	0.063	0.063	0.063	0.080
	XIN(3)	639.3	639.3	639.3	639.3	361.0
	YIN(3)	82.0	82.0	82.0	82.0	62.8
	XIN(4)	934.4	934.4	934.4	934.4	1049.0
	YIN(4)	65.6	65.6	65.6	65.6	13.1
10	NK	1	1	1	1	1
11	XKIN(I)	1.0	1.0	1.0	1.0	1.0
	KIN(I)	0.32	0.32	0.32	0.32	0.30
12	NS			3	3	
	FLAGC			2	2	
	FLAGS			2	2	
	CONTL			2	2	
	SECTN			2	2	
13	SIDSLP			5.0	5.0	
	BOTWID			1.64	1.64	
	OUTMAN			0.030	0.030	
	OUTSLP			0.022	0.022	
	RA			0.0	0.0	
	RN			0.0	0.0	
	YBASE			0.0	0.0	
14	LNGTH			3606.0	3606.0	
	DATCH			178.2	178.2	
	DAUCH			1.0	1.0	
	Z			5.0	5.0	

Card	Manual Symbol	Cechticky Brook Catchment Alternative 1	2	3	4	Samsin Area
15	TX(I)			0.0	0.0	
	TS(I)			0.036	0.036	
				1180.0	1180.0	
				0.052	0.052	
				2098.0	2098.0	
				0.044	0.044	
18	PDATE	77091	77091	77091	77091	77091
	CDATE	77121	77121	77121	77121	77121
19	NC	1	2	1	2	1
	NP	1	1	1	1	1
	NM	1	2	1	2	1
20	XCIN(I)	1.0	0.95	1.0	0.95	1.0
	CIN(I)	0.65	0.65	0.65	0.65	0.30
			1.0		1.0	
			0.03		0.03	
21	XPIN(I)	1.0	1.0	1.0	1.0	1.0
	PIN(I)	1.0	1.0	1.0	1.0	1.0
22	XMIN(I)	1.0	0.95	1.0	0.95	1.0
	MIN(I)	0.014	0.014	0.014	0.014	0.025
			1.0		1.0	
			0.046		0.046	
23	NN			1	1	
	NCR			1	1	
	NCV			1	1	
	NDN			1	1	
	NDS			1	1	
	NW			1	1	
24	XN(I)			0.0	0.0	
	TN(I)			0.035	0.035	

Card	Manual Symbol	Cechticky Brook Catchment Alternative 1	2	3	4	Samsin Area
25	XCR(I)			0.0	0.0	
	TCR(I)			2.0	2.0	
26	XCV(I)			0.0	0.0	
	TCV(I)			100.0	100.0	
27	XDN(I)			0.0	0.0	
	TDN(I)			0.1	0.1	
28	XDS(I)			0.0	0.0	
	TDS(I)			0.1	0.1	
29	XW(I)			0.0	0.0	
	TW(I)			1.64	1.64	
18	PDATE	77121	77121	77121	77121	
	CDATE	77152	77152	77152	77152	
19	NC	1	2	1	2	
	NP	0	0	0	0	
	NM	1	2	1	2	
20	XCIN(I)	1.0	0.95	1.0	0.95	
	CIN(I)	0.4	0.4	0.4	0.4	
			1.0		1.0	
			0.03		0.03	
22	XMIN(I)	1.0	0.95	1.0	0.95	
		0.018	0.018	0.018	0.018	
			1.0		1.0	
			0.046		0.046	

Card	Manual Symbol	Cechticky Brook Catchment Alternative 1	2	3	4	Samsin Area
23	NN			0	0	
	NCR			0	0	
	NCV			0	0	
	NDN			0	0	
	NDS			0	0	
	NW			0	0	
18	PDATE	77153	77153	77153	77153	
	CDATE	77227	77227	77227	77227	
19	NC	1	2	1	2	
	NP	0	0	0	0	
	NM	0	0	0	0	
20	XCIN(I)	1.0	0.95	1.0	0.95	
	CIN(I)	0.06	0.06	0.06	0.06	
			1.0		1.0	
			0.03		0.03	
23	NN			0	0	
	NCR			0	0	
	NCV			0	0	
	NDN			0	0	
	NDS			0	0	
	NW			0	0	
18	PDATE	77228	77228	77228	77228	
	CDATE	77274	77274	77274	77274	
19	NC	1	2	1	2	
	NP	0	0	0	0	
	NM	1	2	1	2	

Card	Manual Symbol	Cechticky Brook Catchment Alternative 1	2	3	4	Samsin Area
20	XCIN(I)	1.0	0.95	1.0	0.95	
	CIN(I)	0.25	0.25	0.25	0.25	
			1.0		1.0	
			0.03		0.03	
22	XMIN(I)	1.0	0.95	1.0	0.95	
		0.023	0.023	0.023	0.023	
			1.0		1.0	
			0.046		0.046	
23	NN			0	0	
	NCR			0	0	
	NCV			0	0	
	NDN			0	0	
	NDS			0	0	
	NW			0	0	
18	PDATE	77275	77275	77275	77275	
	CDATE	77365	77365	77365	77365	
19	NC	1	2	1	2	
	NP	0	0	0	0	
	NM	1	1	1	1	
20	XCIN(I)	1.0	0.95	1.0	0.95	
	CIN(I)	0.6	0.6	0.6	0.6	
			1.0		1.0	
			0.03		0.03	
22	XMIN(I)	1.0	1.0	1.0	1.0	
	MIN(I)	0.046	0.046	0.046	0.046	

Card	Manual Symbol	Cechticky Brook Catchment Alternative 1	2	3	4	Samsin Area
23	NN			0	0	
	NCR			0	0	
	NCV			0	0	
	NDN			0	0	
	NDS			0	0	
	NW			0	0	
	Blank card					

APPENDIX B

Card	Manual Symbol	Input Data for the Cechticky Brook Catchment	Input Data for the Samsin Area
4	BDATE	77091	77091
	FLGOUT	2	2
	FLGIN	0	0
	FLGPST	1	1
	FLGNUT	1	1
5	SOLPOR	0.42	0.43
	FC	0.34	0.29
	OM	0.65	0.67
6	NPEST	1	1
	PBDATE	77091	77091
	PEDATE	77365	77365
7	PDATE	-	-
	CDATE	77365	77365
8	APDATE	77105	77105
9	PSTNAM	SIMAZINE	SIMAZINE

Card	Manual Symbol	Input Data for the Cechticky Brook Catchment	Input Data for the Samsin Area
10	APRATE	3.0	3.0
	DEPINC	1.0	1.0
	EFFINC	1.0	1.0
	FOLFRC	0.0	0.0
	SOLFRC	1.0	1.0
	FOLRES	0.0	0.0
	SOLRES	0.0	0.0
	WSHFRC	0.0	0.0
	WSHTHR	0.0	0.0
11	SOLH20	5.0	5.0
	HAFLIF	0.0	0.0
	EXTRCT	0.1	0.1
	DECAY	0.05	0.05
	KD	2.3	2.3
12	OPT	1	1
	NF	7	2
	DEMERG	105	105
	DHRWST	243	241
13	SOLN	0.25	0.25
	SOLP	0.18	0.20
	NO3	20.0	25.0
	SOILN	0.0005	0.0005
	SOILP	0.0002	0.0002
	EXKN	0.065	0.050
	EXKP	0.040	0.062
	AN	17.2	17.2
	AP	11.2	11.6
	BN	-0.16	-0.18
14	BP	-0.146	-0.146
	POTM	51.0	51.0
	RCN	4.51	1.71
	RZMAX	756.0	756.0

Card	Manual Symbol	Input Data for the Cechticky Brook Catchment	Input Data for the Samsin Area
15	YP	5200.0	4500.0
	PWU	552.0	480.0
16	C1	0.033	0.033
	C2	-0.134	-0.134
	C3	0.0134	0.0134
	C4	-0.750	-0.750
17	DF	77095	77125
18	FN	10.27	23.31
	FP	2.26	5.87
	FA	1.0	1.0
17	DF	77102	771162
18	FN	10.07	23.33
	FP	22.74	0.00
	FA	1.0	1.0
17	DF	77114	
18	FN	49.31	
	FP	0.87	
	FA	1.0	
17	DF	77128	
18	FN	34.03	
	FP	0.0	
	FA	1.0	
17	DF	77139	
18	FN	1.26	
	FP	0.0	
	FA	1.0	

Card	Manual Symbol	Input Data for the Cechticky Brook Catchment	Input Data for the Samsin Area
17	DF	77196	
18	FN	27.53	
	FP	0.0	
	FA	1.0	
17	DF	77275	
18	FN	6.41	
	FP	0.0	
	FA	0.2	

REFERENCES

Holy, M. 1980. Erosion and Environment. Pergamon Press, Oxford, U.K.

Holy, M., J. Mls, J. Pretl, J. Vaska, and K. Vrana. 1980 The Quantitative and Qualitative Balance of Water of the Sedlicky Brook Catchment (in Czech.) Research Report VI-4-1-4/10, Technical University of Prague, CSSR.

Holy, M., J. Mls, J. Pretl, J. Vaska, and K. Vrana. 1980. The Modelling of Erosion Processes in a Catchment and Influence of these Processes on Quality of Soil and Water Resources (in Czech.) Research Report P-16-329-059-01-01/5. Technical University of Prague, CSSR.

Holy, M., V. Svetlosanov, Z. Handova, Z. Kos, J. Vaska, and K. Vrana. 1981. Procedures, Numerical Parameters and Coefficients of the CREAMS Model: Application and Verification in Czechoslovakia. International Institute for Applied Systems Analysis, Collaborative Paper (forthcoming) Laxenburg, Austria.

Knisel, W.G. Jr. 1980. CREAMS: A Field Scale Model for Chemicals, Runoff and Erosion from Agricultural Management Systems. USDA Conservation Research Report No. 26.