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INNOVATIONS IN REGIONAL TASKS OF WATER PROTECTION AND UTILIZATION

The effects and impacts of human activities on hydrosphere components are in many countries the subject of scientific research activities mainly in those with developed economy. Mutual exchange and confrontations of findings, methodological approaches and especially application of scientific data in practical solutions are everywhere of great significance. This holds specially true in actions that in their conceptions and processing contain progressive innovation elements.

In this sense the presented contribution deals with those topics in which national efforts can bring the best results on international scale. It is based on the fact that the problem is of interdisciplinary character and essentially belongs into the field of geography; additional scientific disciplines and application fields act as supplementary components.

1. Initial stage

The first, mainly analytical stage of increased till harmful damage of the hydrosphere components can be characterized as the period of the recording of damages, evaluation of causes and sometimes also of withdrawing from them. One of the important results of research activities in this stage is the differentiation of three categories of effects and resulting disproportions:

1. Harmful impacts of components of the socioeconomic field on the hydrosphere and especially on utilized or effectively utilizable water resources.
2. Harmful impacts and unbalanced interactions inside the hydrosphere mainly in the interactions between water management sectors.
3. Harmful impacts manifesting themselves from the hydrosphere outside, especially by the activities of water management on other natural, economic and social sectors.

The first group includes impacts of objects or production complexes of the primary and secondary sphere and effects of residential agglomerations as well as of man as individual. They have a harmful impact on precipitation, soil, ground and surface waters.

Shortcomings in interactions (category 2) arise, on the one hand, from activities of water management on the hydric base of the watershed and concern e. g. exploitation exceeding the acceptable extent of natural resources, on the other hand they are connected with the neglecting of hydraulic linkages existing between the components of the hydrosphere; this holds especially true for the hydrodynamic relationships of surface and groundwater.

The third group includes, on the one hand, harmful impacts caused by water as element, on the other hand local and regional effects of hydrotechnical structures (dams and impounding reservoirs, bridges, drainage systems, etc.).

The analytical period brought also numerous findings for the solution of practical problems (Zajíček 1973), of which it is necessary to emphasize mainly the following ones:

— The majority of problems can be solved, some immedietely, others after a longer time. Hence these problems can be tackled with a not exaggerated optimism.

— In spite of the fact that of the three mentioned categories the first is the most important, the hydrological and water management sector must arrange the relationships indicated in items 2 and 3. Only then can it assert its interests belonging to category 1.

— The solution of practical tasks cannot be narrowed down to the protection of isolated water resources. It requires the application of a wider spatial strategy in the genesis, regime and utilization of the hydrosphere components, especially in regions with intensive economic development. This means that the solution must be based on the optimal arrangement of structures and processes in space. Technological solutions are supplementary measures.

— Every collision between hydrosphere and the economic field must be overcome in its potential stage and on the principle of global optimisation, taking into balanced account economic, technical and ecological aspects.

— From the analytical phase it is necessary to exploit the maximum for the qualitative improvement of the location theory principles and for the spatial organization of economic activities. From this arises also the requirement not to admit actions causing mistakes and disproportions for the future.

— One of the most important principles in this sense is to stop with the prevailing one-sided exploitation approach to the hydrosphere components and to respect their potential in the planning and management processes on the scale of continents, countries and localities.

Under Czechoslovak conditions, the primary analytical research stage was essentially concluded at the beginning of the 70 's. It has become the basis for the synthetical solutions, and mainly for the permanent conceptional activity on this subject.

2. Solution principles

In the present stage of work there exist already sets of findings from the solution of problems as well as from satisfactorily executed tasks of economic development. Generally, in a cultural region the hydrosphere components maintain the necessary quantitative and qualitative level only when three basic principles are consistently consident in research as well as implementation field:

a) Hydrology permanently supplements its fund of findings, being able to provide in all situations necessary data, arguments as well as complex data.

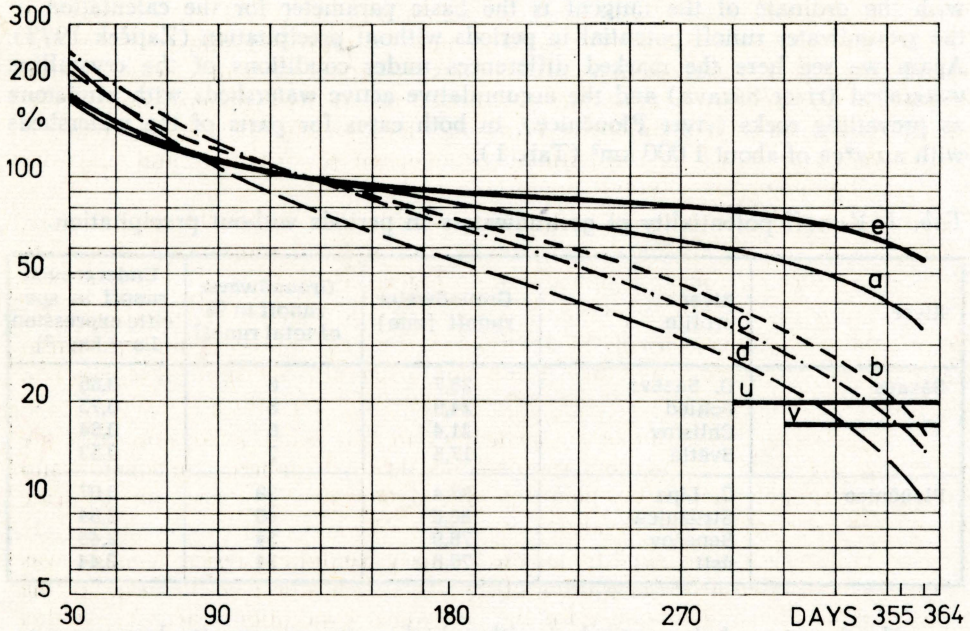
b) Research develops and practice implements hydrotechnical innovations, which already take a balanced account of water management as well as interests of other sectors in the given region.

c) The factor water is included on all levels of planning activities among the most important indicators; it serves mainly as location factor.

2.1 Supplementation of the fund of hydrological findings

Although this first principle concerns the advance in hydrology as such, it applies mainly for hydrological sectors effectively bound to the subject under discussion. Of greatest importance are problems of the discharge regime and problems of vulnerability of the different runoff components.

Water resources are mainly threatened under extreme runoff conditions, especially during drought periods. For their evaluation in watersheds of different size, dimensionless duration curves and additional characteristics arising from them are used satisfactorily. This holds true mainly for Central Europe having relatively small differences in the basic climatic parameters. As decisive factors in the distribution of runoff act categories of rock media in the different watersheds



1. Dimensionless duration curves of daily mean discharges for 30 to 364 days in the year: a — Svitava—Letovice, b — Labe State frontier, c — Morava — confluence, d — Svratka below Bystřice, e — Somme: u, v — parameters referring to 355 day water.

Selected duration curves in the Labe and Danube watersheds (Fig. 1) characterize thus on regional scale the poor capacity of rivers to overcome dry periods on a higher runoff level (Type d) in granite-gneiss regions; on the other hand they exhibit a high cumulative potential of the mighty layers of sedimentary rocks (Type a). With larger watersheds (Type b, c), the resultant characteristics correspond to the shares of the partial watersheds of the preceding types. The abscissae u, v in the range of low flows, e. g. in the ordinate of 355-day water (20 % Qa in the case of the river Labe and 17 % Qa in the case of the river Morava) determine for their tributaries the minimum limit of the necessary enrichment, reaching at least the runoff level of the main watersheds. In places where to the basic hydromechanical condition of the rock medium increased precipitation fre-

quency (in higher mountain positions or in seaside regions) must be added, the runoff characteristics in the range of 100 to 365-day waters are even more favourable. Under broader European conditions this can be seen in the case of the river Somme (Type e), which is a representant of a Cretaceous watershed in the French Atlantic zone. From this base we get further to the evaluation of runoff in the necessary intervals determined according to the m-day scale; in a similar way we process also floods in the n-day field.

Based on the duration curves of daily mean discharges, it is then possible for the chosen watersheds to evaluate the runoff phase of groundwater in periods without precipitation. In this case we define the duration curve analytically by means of an interpolation equation and we use the maximum of its derivation curve for the determination of the inflexion point of the tangent, which together with the ordinate of the tangent is the basic parameter for the calculation of the groundwater runoff potential in periods without precipitation (Zajíček 1973). Again we see here the marked differences under conditions of the crystalline watershed (river Sázava) and the accumulative active watersheds with sandstone as prevailing rocks (river Ploučnice), in both cases for parts of the watersheds with an area of about 1 000 km^2 (Tab. 1).

Tab. 1. Runoff potentiality of groundwaters in periods without precipitation.

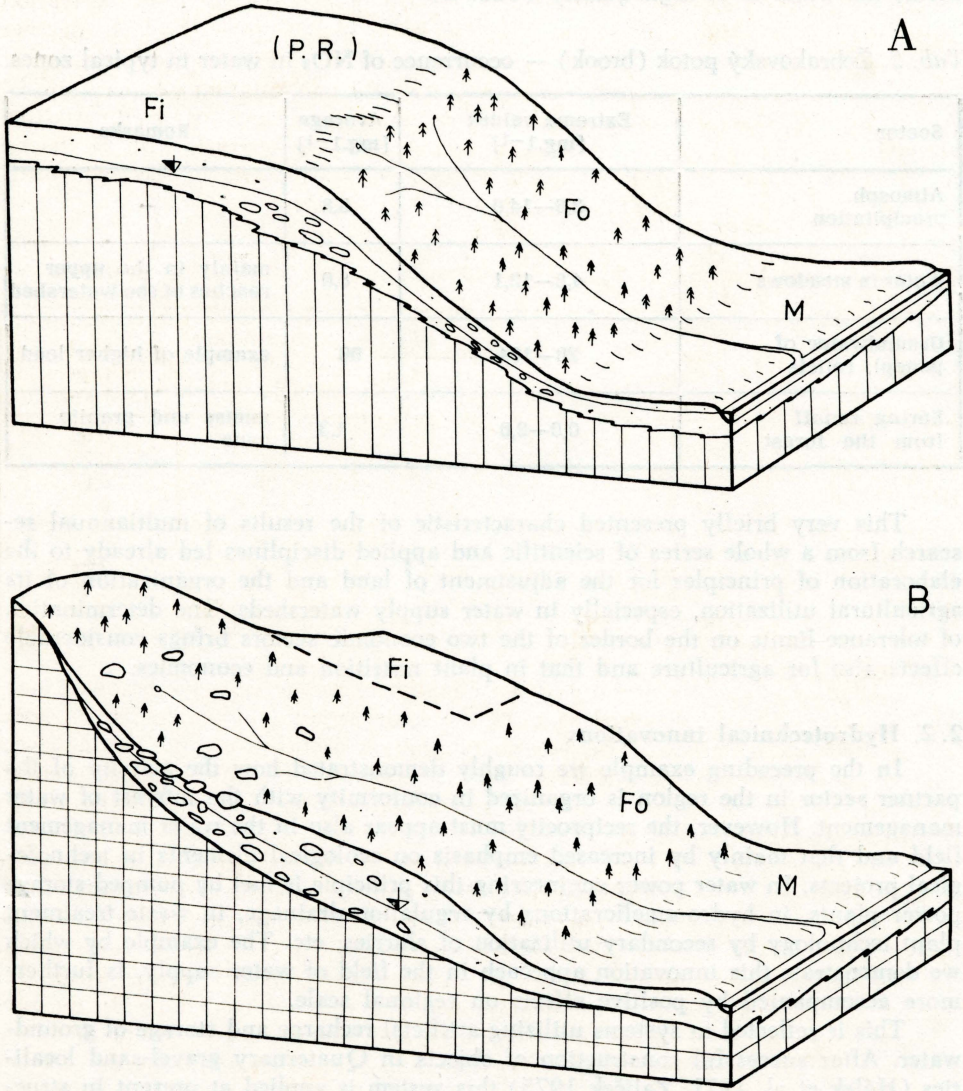
River	River profile	Groundwater runoff (mm)	Groundwater runoff in % of total runoff	Underground runoff in specific expression ($l.s^{-1}.km^{-2}$)
Sázava	D. Sázava	28,7	8	0,85
	Pohled	24,9	8	0,75
	Chlístov	21,4	8	0,64
	Světlá	17,5	7	0,53
Ploučnice	Č. Lípa	97,4	39	3,07
	Stružnice	88,8	40	2,84
	Benešov	76,9	34	2,45
	ústí	76,8	34	2,44

The function of the watershed with a higher storage capacity becomes markedly evident also in the evaluation of the underground component in the total runoff from the watershed. For these instances it is useful to use the original method of separation (Kliner, Kněžek 1974). Applying this method, the relation between the actual variations of the groundwater table and the discharges in a surface stream is used.

In watersheds with low retention capacity of the litho-and pedosphere, the results of these analyses belong among the arguments for the construction of impounding reservoirs, where contrariwise to the former practice, there exists the possibility to make use of additional innovation elements. So for instance, based on regionally treated characteristics of showers, we consider regions from this aspect extremely inclined to soil denudations and thus we contribute, in the predesign stage, to the selection of variants. In addition we devote attention to the problems of larger water abstractions from reservoirs to cover the needs of other watershed and especially to the problem of compensation measures for the initial watershed, which we process using diurnal hydrographical data from long-term observation series (Malíšek et al. 1977). Numerical methods and suitable programs

for large computers permit to overcome even problems of complicated water management systems. Thus we reach an incomparably more exact evalution than when using methods based on monthly parameters.

All mentioned work procedures are based on data of hydrographical services. In tasks requiring a more detailed knowledge of interactions (specially when interconnecting quantitative and qualitative problems) we use also the results of purposive research in small model watersheds. As example of a whole series of similar studies we present briefly the conclusions from a study of principles of nitrate load in waters. These results were obtained in the experimental water-



2. Žebrakovský Brook. A — predominant type, B — exceptional type, Fi — field, Fo — — forest, M — meadow; (P. R.) — peneplain and etchplain relicts.

shed of the Žebrakovský Brook near Světlá nad Sázavou, a typical representative of a peneplain region type, in which impounding reservoirs are situated in Czechoslovakia as well as in neighbouring countries.

Peneplain relicts are due to previous development in the Tertiary and Quaternary covered by relatively permeable soils and are utilized by agriculture (Fig. 2). Residual nutrients escape into groundwaters and springs and also into surface streams. Even relatively large percentages of forests on the slopes under the peneplain relicts have only a slight ameliorating function. On the contrary, where the forest reaches as far as the watershed divide (Type B) and the whole process of infiltration and groundwater flow to the springs takes place in forest areas, the water is of high quality (Tab. 2).

Tab. 2. Žebrakovský potok (brook) — occurrence of NO_3 in water in typical zones.

Sector	Extreme values ($mg.l^{-1}$)	Average ($mg.l^{-1}$)	Remarks
Atmosph. precipitation	2,6—14,0	5,8	—
Water in meadows	4,8—12,1	8,0	mainly in the upper reaches of the watershed
Groundwater of penepl. relicts	26—104	60	example of higher load
Spring runoff from the forest	0,0—2,6	1,3	gneiss and granite zone

This very briefly presented characteristic of the results of multiannual research from a whole series of scientific and applied disciplines led already to the elaboration of principles for the adjustment of land and the organization of its agricultural utilization, especially in water supply watersheds. The determination of tolerance limits on the border of the two economic sectors brings considerable effects also for agriculture and that in plant nutrition and economics.

2. 2. Hydrotechnical innovations

In the preceding example we roughly demonstrated how the activity of the partner sector in the region is organized in conformity with the interest of water management. However, the reciprocity must appear also in the water management field and that mainly by increased emphasis on ecological elements in technological projects. In water power engineering this principle is met by pumped-storage power plants, in hydro-ameliorations by regulation drainage, in waste treatment plant technology by secondary utilization of slurries, etc. The example by which we demonstrate this innovation approach in the field of water supply, is furthermore accompanied by positive effects on regional scale.

This is reflected in systems utilizing artificial recharge and storage of groundwater. After successful construction of objects in Quaternary gravel-sand localities (Hálek et al. 1971, Zajíček 1975) this system is applied at present in structures made up of mighty sandstones layers. Following field surveys — similar as in normal water supply actions — in the preparatory stage of these projects,

model simulation and preliminary evaluation is applied, which in turn leads to the basic design of the system and its size category.

On the other hand, the solution proper of hydraulic processes in the groundwater reservoir must include innovation elements, beginning already with the determination of the necessary filtration and storage parameters exceeding the extent of current hydrogeological investigations. In the storage space and in the zone between infiltration objects and the well recovery line, substancially non-stationary groundwater flow processes are encountered; this can be described by partial differential equations including the mentioned parameters. In concrete cases it has been shown to be suitable to aproximate partial derivations by differential expressions for a rectangular network (Stránský 1975) and to obtain thus systems of differential equations, easily processable on a digital computer. Formally these equations can be written in the form

$$A_{i-1,j} \cdot h_{i-1,j,n} + A_{i,j-1} \cdot h_{i,j-1,n} + A_{i+1,j} \cdot h_{i+1,j,n} + A_{i,j+1} \cdot$$

$$\cdot h_{i,j+1,n} - A_{i,j} \cdot h_{i,j,n} = n_e \frac{h_{i,j.n} - h_{i,j,n-1}}{\Delta t} - W'(x,y,t),$$

where coefficients

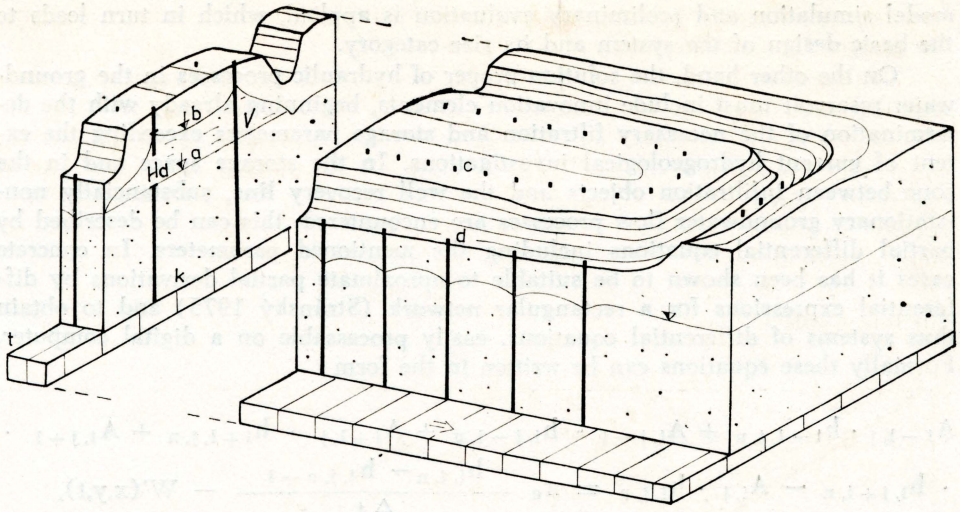
$A_{i,j}$ — are expressions including the coordinates of transmissivity tensors in the area studied,
h — groundwater table level in the nodes of the system (i,j),
n_e — effective porosity,
W' — value expressing summarily outflow and inflow of groundwater in the area studied,
Δt — time increment,
n — number of the solved time level n . Δt.

This simplified characteristic of the working procedure indicates that after the preliminary evaluation of each locality, it is necessary to incorporate as innovation link of the working procedure sectorial pilot-plant infiltration. Results obtained from this process correspond to the physical characteristics of permeability coefficients that, under conditions of sedimentary rocks, are decisive for very important transmissivity parameters.

In the locality of Černý důl near Mladá Boleslav with sandstone layers about 100 m thick, this infiltration test led to the determination of the values of the coefficient of permeability in the interval of the first half of the order of 10^{-1}m.s^{-1}. For the underground reservoir (Fig. 3) we derived the acceptable rising of the water table H_d by up to 40 m as well as the specific values of the recoverable quantity of q (l . s^{-1}) in characteristical points between the original (a) and raised level (b). The obtained graphical relation is defined analyticaliy as an exponential function

$$q = 31{,}0069\ H_d^{1{,}07933}.$$

From the given range of raised levels and possible drops below the natural level is the optimal operational range in the interval H_d = 20 to 25 m. In such a case the system capacity reaches 1 000 l . s^{-1}, similarly as in the existing water supply base at Káraný. Another interconnecting link of the two systems is the water source for artificial recharge — pretreated water from the river Jizera.



3. Conditions for artificial recharge and storage of groundwaters in the locality of Černý důl: a, b — original and raised groundwater table; c, d — infiltration and well recovery line.
k — sandstone; t — marlstone; Hd — raised groundwater table; V — newly obtained water volume. Illustration not to scale.

Water supply bases of this type provide water of better quality than surface water reservoirs and, in comparison with them, they have very low space requirements. Capital investments mostly do not reach even 50 % of the costs required by reservoirs on surface streams.

2. 3. The greater importance of the factor „water" in planning activities

The main principle for meeting this thesis, which is based on the results of the preceding chapters, is the shift of water resources from the category of affected factors to that of affecting factors. In this sense it is naturally necessary to abandon the one-sided concept of the water management potential of the watershed as source for drinking water supply and in all development tasks to consider it in three basic functions:

— in the primary supply sense for the residential and production sector,

— in the role of a sound receiving body, capable up to the critical loading level of the river to deal with the permissible pollution load from the residential and production sphere, predominantly in the form of waste treatment plant effluents;

— in the role of an positive urbanization factor with the composition function of a large water surface in residential surroundings.

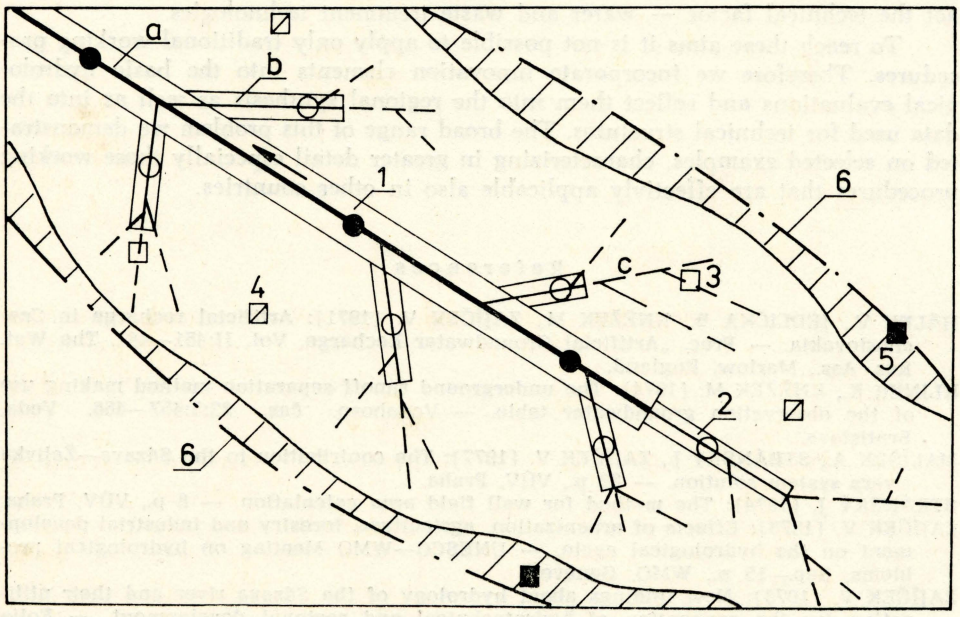
The main development regulative is unequivocally represented by the second function, be it in the form of offer or limits for economic sectors. It is characterized as representing the reserve of the stream capacity arising from the difference between the natural quantitative and qualitative base of the stream and the tolerance limit for the acception of substances which are added as residual pollution. This reserve is thus dependent on the sanitary, biological and chemical limits given by the water laws in different countries and on the discharge value in a given place or river reach. This concerns naturally mainly discharges warran

ted even in dry periods. For this reason we dealt with them and their evaluation in greater detail in the introductory chapter.

From this two basic conclusions can be reached for the application of the innovation elements as well as in the managing and decision-making field:

1. National economic planning as well as lower planning categories must bind their activities and presumed consequences of the differnt actions to the territory limited by hydrographical borders; this kind of procedure must be maintained even when the focus of the economic processes lies in otherwise bordered territorial entities.

2. With a view to the safeguording of a healthy environment, it is necessary in this connection to meet the principle of the critical loading level of rivers.



4. Water management conditions for the development of towns and industry — diagram of watershed section. River zones of offer and corresponding watersheds: 1 — most suitable, 2 — suitable. Other areas and corresponding towns: 3 — little suitable (with rivers of low order), 4 — unsuitable — spaces distant from rivers, 5 — fundamentally conflicting (infiltration and headwater areas), 6 — divide.

In a certain watershed (Fig. 4) we can thus differentiate zones of „offers", where conditions exist also for placing of more demanding users (territorial stripes 1, 2), and other localities up to infiltration and headwater areals (zone 5) where aspects of water resources protection should dominate. These principles can be naturally applied in various countries, mainly in developed or intensively developing countries. In Czechoslovakia, we have treated in this way mainly zones of offers (Zajíček 1977) for the main watersheds. This was done in the interest of their utilization for location greater economic activities and to elimit disproportions, which occur in infiltration and headwater zones.

3. Conclusion

The necessity to protect and suitably utilize water resources is an acknowledged postulate in all countries all over the world. A problem, however, is the use of rational and effective methods.

Good results can be obtained only when the protection of water and water management is a part of complex tasks of environmental control in which the natural base and its economic function are maintained in a balanced state. Principles of protection must be reflected in national economic plans. This aspect places in the foreground the condition of tolerance limits of rivers and their respecting in the development of the region. This actually decides about the future function of both running and standing waters in watersheds, regions and the whole country. In a balanced state with this regional arrangement must also act the technical factor — water and waste treatment technologies.

To reach these aims it is not possible to apply only traditional working procedures. Therefore we incorporate innovation elements into the basic hydrological evaluations and reflect them into the regional synthesis as well as into the data used for technical structures. The broad range of this problem we demonstrated on selected examples, characterizing in greater detail especially those working procedures that are effectivly applicable also in other countries.

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Résumé

INOVACE V REGIONÁLNÍCH ÚLOHÁCH OCHRANY A VYUŽITÍ VOD

Referát je začleněn do tematiky nazvané „Důsledky lidské činnosti v prostředí hydrosféry". Je v něm snaha o aktivní řešitelský přístup, jehož cílem je v rozhodující problémové oblasti přispět k docílení souladu mezi hospodářským rozvojem a vodními zdroji. Rozumíme jimi vodohospodářský potenciál povodí, který se uplatňuje ve třech základních funkcích, totiž jako primární vodárenské zdroje, dále jako recipienty, v nichž se odpadní látky ze sídelní a výrobní sféry projevují jen po mez únosnosti toků, a posléze jako kompoziční městotvorné prvky, zvláště ve formě velkých vodních ploch uvnitř zástavby.

Základní podmínkou pro dosažení uvedeného cíle je rozpracování a postupné uplatňování potřebných koncepčních principů pro styčnou oblast sociálně-ekonomických systémů a vodohospodářského sektoru. První princip spatřujeme v *posilování fondu hydrologických poznatků a ukazatelů* inovačního charakteru, účelově zaměřených k regionálním úlohám. Mezi ně patří např. charakteristiky retenčních potenciálů jednotlivých povodí (obr. 1) anebo ukazatele odtokové potenciality podzemních vod v bezsrážkových obdobích (tab. 1). Z kombinace detailně studovaných procesů v modelových povodích (obr. 2) vyplývají poznatky o příčinách zatížení vodních zdrojů některými nežádoucími látkami, např. dusičnany (tab. 2). Tím je i ukázána cesta k zvládnutí problematiky.

Druhý princip spočívá v *rozvoji a aplikaci hydrotechnických inovací* usměrněných hledisky krajinné ekologie. Jejich typickým zástupcem jsou podzemní nádrže doplňované umělou infiltrací (obr. 3), kterou v našich podmínkách aplikujeme především v říčních terasách a v křídových pískovcových strukturách.

Třetí zásadou je podstatné *zvýšení role vodních zdrojů v plánovací činnosti*, především jejich přesun z kategorie ovlivňovaných složek mezi faktory ovlivňující. Hlavní rozvojový regulativ přitom představuje únosnost toků, která je rezervou (nebo deficitem) mezi průtokovou a kvalitativní základnou toku a tolerančním limitem pro příjem látek přicházejících ve formě reziduálního znečištění. Umožňuje ochranu pramenných a dalších zranitelných území, ale i využití zón s dostatečnými rezervami (obr. 4) pro situování větších hospodářských aktivit.

Uvedené zásady a jejich aplikace jsou podány jako příspěvek k racionální organizaci a rozvoji společenských a výrobních aktivit v souladu s principy prostorové ekonomiky. Účinně se uplatňují ve stadiu příprav rozvojových úkolů a tak umožňují přenesení střetů mezi hydrosférou a hospodářskými sektory do oblasti jejich potenciálního výskytu. Technologické prvky v systémech (zvláště čistírny odpadních vod a úpravny) jsou kvalifikovány jako průvodní články doplňující primární regionální řešení. Zásady i dokumentované pracovní postupy jsou analogicky použitelné i v jiných rozvinutých zemích.