ABOUT THE HYDROGEOLOGICAL POTENTIAL OF THE URBAN AREAS
Structural aspects and aspects of the spatial distribution. Estimation possibilities

Irina Ungureanu[1]

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Résumé : *Souvent surévalué, le potentiel naturel est abordé généralement d'une manière utilitariste, comme réserve non-systémique, toujours exploitable, dans toutes conditions et dans des quantités imposées par le niveau de la demande, en désaccord avec les réserves réelles. Même les évaluations à formule consacrée, comme pour le cas des réserves phréatiques, sont fondées sur des calculs dans lesquels les éléments du bilan sont introduits d'une manière uniformisatrice, en dépit d'une variabilité et d'une complexité extrêmes, surtout dans les espaces très anthropisés des villes. Un schéma logique de la structure du bilan des aquifères phréatiques des aires urbaines met en évidence des éléments négligés ou ignorés dans les calculs courants, même si leur impact quantitatif et qualitatif est particulièrement fort. Parfois; ces éléments sont imposés au bilan hydrogéologique par l'infrastructure résidentielle urbaine de différents âges. D'autres fois ils agissent en qualité d'effets secondaires des travaux d'entretien des réseaux utilitaires transportant ou non de l'eau (potable ou usée) etc. Souvent ils ont un rôle alternatif – entrée-sortie. Une méthode d'expression graphique (la visualisation progressive) des intégrations successives qui donnent des unités spatiales à potentiel hydrogéologique différent ouvre la perspective d'une mise en valeur plus adéquate des réserves réelles, de leur protection, aussi que d'un contrôle plus efficace des conjonctures génératrices de risque hydrogéologique.*

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1. General conditions

The evolution of the notion of **potential** and of the term which expresses it outlined them along the time an anthropocentric, utilitarian, firmer and firmer acceptations. In parallels with the relatively precise meanings of some specific potential forms – electrical, chemical, hydro-energetic etc., the **natural potential** (as a generic notion) implies in fact segments/categories of natural **resources** situated in different, natural or administrative, spatial units towards whose use is

[1] „Alexandru Ioan Cuza" University of Iaşi, Faculty of Geography and Geology

orientated the general social and economic interest. Integrated in the concept of sustainable development, this interest towards the natural potential is more and more accentuated.

Having as an objective the continuous growth of the efficiency and a proper reply to the vast, strongly diversified and exacting to-day solicitations, the technologies conceived in order to obtain raw materials, to retrieve them secondary and to use them finally find their efficiency on a realistic estimation/evaluation of the natural potential. The conceptual level and the precision of this action constitute a *de jure* implicitly objective conditioning. But, *de facto*, correct evaluations and properly useful effects co-exist with frequently non-strategic approaches and with rapidly profitable tactics, weakly founded on extremely approximately appreciations of the many times overestimated natural potential. In a direct consequence, the efficiency of the investments made in order to identify the respective resources, the exploitation/processing technologies, the investments and the conservation/rehabili tation works/measures diminishes sometimes substantially. As a concrete effect, important material damages, human risks and risks over the natural live structures amend severely activities which have been projected as advantageous.

On the other side of the objective difficulties (an inaccessible position, difficult, indirect quantifications etc.) important evaluation errors may be generated by flatly subjective factors. We consider that, on the whole, the wrong evaluations have two main causes.

The first cause derives from the lack of objectivity of the anthropocentric, reductionist approach, according to which, the only ration of natural resources existence is their use – direct or indirect – for people. With a double loss, this approach induces, from a *quantitative* point of view, the almost integral consuming – often with great waste – of the resources. This happens before that, in the consumption structure evolution, and in the evolution of the entrance fluxes in the respective structures, a new alternative for the period when those resources will have exhausted, is offered. From a *qualitative* point of view, it is responsible for the diminution of the system functionality, strongly affected by the chain, progressive reduction of the active role of the exhausted resources, of other elements in direct relationship with them, of the specific interactions which cannot sustain the spontaneous regeneration.

The same anthropocentric approach induces the *second cause* of the incorrect evaluation. By ignoring (due to real incompetence) or deliberately neglecting the quality of each natural resource to be a systemic element, this is assimilated to a good that is accessible anytime and constantly and spontaneously preserves the quality parameters. The more and more visible and hard to detect limits of some natural possibilities (available drinking water, available wood quantity, water self-cleaning capacity, forest self-regeneration capacity etc) transformed the reality (which is totally different than the simplified explanation previously given) into something that is intelligible as well, in the present world that considered itself launched on a trajectory of unlimited growth. To the quantitative tough restrictions (constant reduction of useful substances and energy forms, in an absolute way, through consumption from finite reserves, or, relatively, through the same increase requirement, from sources considered to be very rich, but they are hardly accessible, with more expensive technologies) qualitative obstacles are added, starting with accessibility (which is very often conflicting) and ending with catastrophic quality parameters of different resources, frequently degraded by means of irrational use as well.

This second cause of incorrect evaluation – ignoring the systemic identity – implies also certain characteristics of the used resources, which are only rarely and selectively important in the current use process: *vulnerability* of these resources and *favourability* of their use. In reality, the former is very important, either objectively (the necessity of conservation for each resources), as well as subjectively (a higher profitability of the exploitation/capitalization forms which ensures the „health" and therefore the longevity of that resource). The latter characteristic expresses clearly the specific utility of the natural offer, which, if it is known correctly, can be used differetiatedly, in accordance with its spatial variability (structural and functional), therefore profitably.

The knowledge and respecting of both characteristics implies the following: in the approach of *estimation/evaluation of the natural potential,* the quantity/quantities necessary to the *„current metabolism"* of the respective resource, the things necessary to the *resistance* and then *recovery* on the duration and after the vulnerability intervals, as well as its *contribution part* to the functionality of the structure it belongs to, should be subtracted from what was considered usable. For example, from the total quantity of coarse alluvia deposited in different sectors of the thalweg and flood plain of the rivers, a part (variable according to the flow regime, current components, evolution stage of the river bed etc) is absolutely necessary for the balanced evolution of the longitudinal profile in the thalweg, and this reduces the exploitable quantity accordingly. The drawing of higher quantities causes forced deepening of the thalweg upstream, the change in the regime and location of the alluvia downstream, as well as a much longer interval for the recovery of the exploitable reserves. Furthermore, another resource – the phreatic water in the flood plain – is moving deeper, causing either exploitation from a greater depth, either the temporary cancelling of the sources.

Therefore, the natural available potential is much more reduced than shown by the analytical evaluations of one resource or another, which are exclusively quantitative and non-differentiated. More than that, the neutralization and attenuation of the negative impact of some of the exploitation/capitalization forms of the natural resources require investments which, normally, must be covered from the specific profit. As the recovery funding is transferred from the central budget (at least in the centralized economies or with remainders of centralization) the local responsibility for the genesis and management of the impact is weak or null, and the high prices of the expert examinations and consultancies stimulate fast and incorrect evaluations.

Finally, any estimation/evaluation form of the natural resources must take into consideration the intensifications/reductions caused by the *temporal dimension* of the natural and socio-economic processes and phenomena. In accordance with this, the *genesis* of the natural resources, their *regeneration*, diverse *changes*, the *evolution of capitalization technologies* and *spatial distribution* of these resources, are produced. For example (among many other confirmations of the legic role of time in defining the quality and real dimensions of some resources), even if the total sum of temperatures with role of biological limit can be realized on the duration of a year, if the temperature regime is not uniform and – especially – if it does not correspond to the seasonal biological cycles of the crop plants specific to the given area, then they cannot count as a thermal resource, but only with a lower value.

The problem of natural potential of the inhabited areas which are used in a complex way and for a long time, is more complicated than in the case of the spaces with other destinations or with an almost natural evolution. Among the mentioned areas, the urban usually uses integrally, even abusively quite often, the natural offer. The complex impact of the urban inhabiting, with all the infrastructure that is needed, with the dynamics, often extremely complicated and fast, of the urban functions, with the multiple polarizing capacity of the cities, produced important mutations of the natural support, either from a quantitative point of view (elements – resources) as well as from the point of view of their regime, evolutive rhythms and specific balances. This explains the originality of the natural potential in the urban areas, and this fact requires a spatially and structurally differentiated approach of the estimation.

2. The hydro-geologic potential of the urban areas

The increase and diversification of water requirement are characteristics of the socio-economic and cultural evolution of the whole ecumene, manifested for a long time. Under the general demographic pressure, while permanent settlements (especially cities) network increased its density and functional diversity, the above mentioned requirement asked for more and more intense capitalization of the reserves from traditional sources, caused the use from sources situated at greater and greater distances, with lower quality in general, and, accordingly, with higher costs.

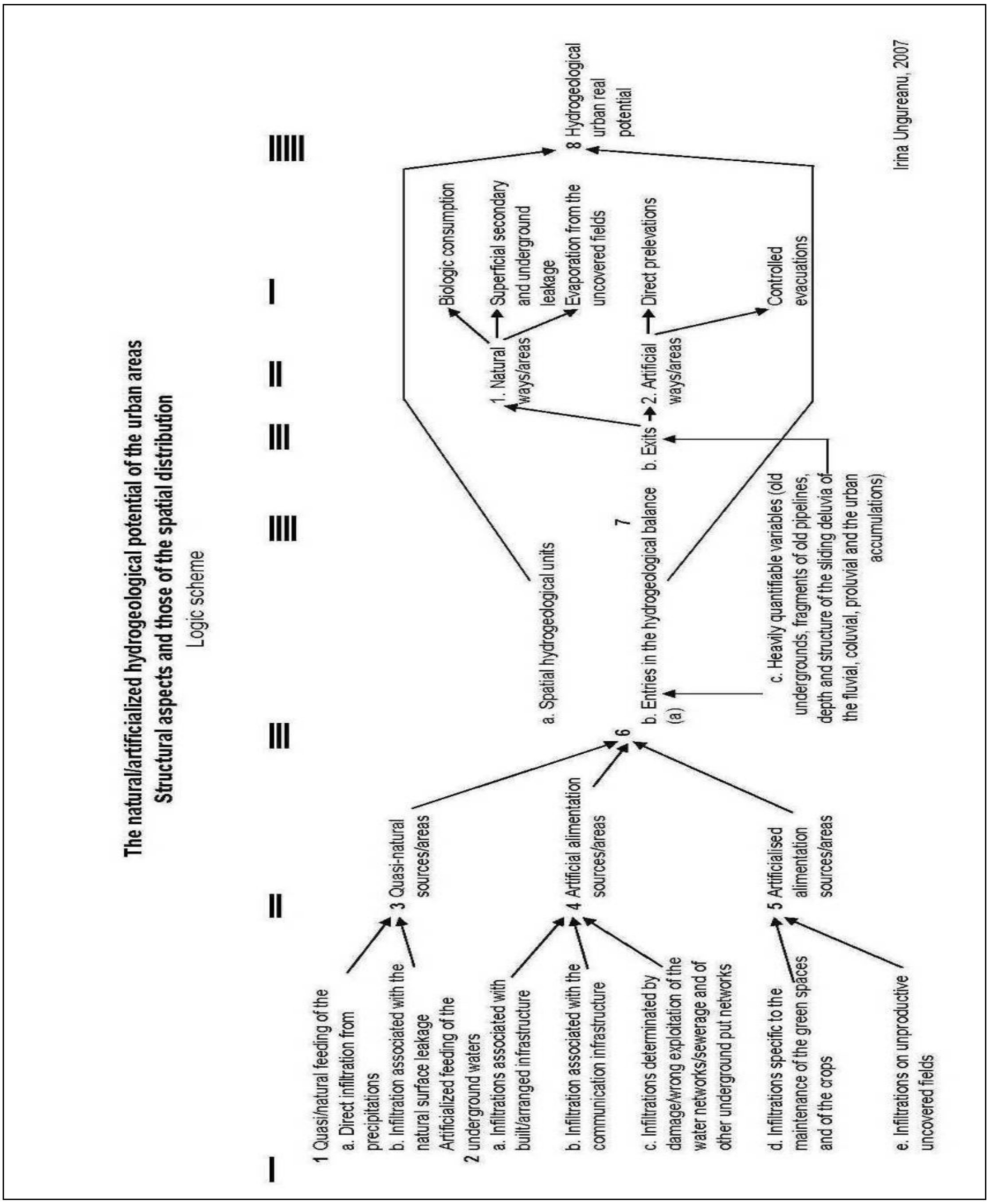
At the same time, the local sources were strongly changed by human interference, represented by the effective capitalization of the reserves as well as by the effect of vicinity with other segments of the utilitarian infrastructure, permanently exploited.

If the process generating any underground water accumulation in the phreatic level (supply from precipitations followed by the remanence of the carrying deposit, after the evacuation imposed by the natural underground drainage and by the effect of evapo-transpiration) is the same everywhere where the natural water circuit is not marked by thermal and pluviometric extremes, in the cities, each of the elements of the hydro-geologic balance is more or less artificialized. Frequently, the urban condition of the phreatic waters requires also the use of artificially supply sources, control of the drainage, modification of the intensity and rhythm of the discharge through evapo-transpiration, causing a great variability of the spatial distribution of this process etc.

3. Logical scheme of the natural/artificial hydrologic balance of the urban areas

In order to realize an accurate approach of the urban specificity of the hydro-geologic potential, for a further estimation of an adequate capitalization, in the following logical scheme, the hydro-geologic balance has a different structure than the standard form, postulated in the scientific literature (Preda, I., Marosi P., 1971; Olaru, P., 2004 ş.a.) which is currently used in the application fields. The scheme we propose gives details, nuances and completes the general references at the „input" and „output", in and from the phreatic hydro-system. In this respect, quasi-natural supplying sources/conjunctures (normally neglected), supplying sources/areas with initialization natural components (but with a strong antropization of their current condition), artificial (and indesirable) supplying sources/areas (ignored deliberately, but with an important quantitative and qualitative hydro-geologic effect) are all mentioned. At the same time, in the structure of the „classical" output from the hydro-system are also registered: variables with their role consisting in reality by sequences of quasi-evacuations/quasi-supplying, hardly controllable (such as, for example, the direct drawings), as well as a series of variables of artificial or natural origin, hardly controllably or almost independent, with mixed role, aleatory from the point of view of the direction, flow, and rhythm of the manifestation.

In the proper scheme the supplying of the phreatic waters is introduced in a differentiated way, depending on the origin of the supply sources. Within quasi-


The natural/artificialized hydrogeological potential of the urban areas
Structural aspects and those of the spatial distribution
Logic scheme
I
II
III
IIII
III
II
I
IIIII
1 Quasi/natural feeding of the
a. Direct infiltration from precipitations
b. Infiltration associated with the natural surface leakage
Artificialized feeding of the
2 underground waters
a. Infiltrations associated with built/arranged infrastructure
b. Infiltration associated with the communication infrastructure
c. Infiltrations determinated by damage/wrong exploitation of the water networks/sewerage and of other underground put networks
d. Infiltrations specific to the maintenance of the green spaces and of the crops
e. Infiltrations on unproductive uncovered fields
3 Quasi-natural sources/areas
4 Artificial alimentation sources/areas
5 Artificialised alimentation sources/areas
6
a. Spatial hydrogeological units
b. Entries in the hydrogeological balance (a)
c. Heavily quantifiable variables (old undergrounds, fragments of old pipelines, depth and structure of the sliding deluvia of the fluvial, coluvial, proluvial and the urban accumulations)
7
b. Exits
1. Natural ways/areas
2. Artificial ways/areas
Biologic consumption
Superficial secondary and underground leakage
Evaporation from the uncovered fields
Direct prelevations
Controlled evacuations
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natural[2] supply, the infiltration from rainfall is considered on the first place *(1.a.)* (the calculation considering the total annual amount, on series of years and pluviometric tendencies, having results closer to the reality than those based on the average values). The infiltration associated to the superficial flow, absent from the classical calculations of the supply volume (being considered insignificant from a quantitative point of view) was still introduced in the scheme *(1.b.),* as in the sectors with low inclination, on a permeable layer – frequent situation in the urban areas where the lands are very precious, and they have artificial superficial recent and loose deposits – the

quantity of water can be quite significant, even if the superficial flow produces morphologic visible effects.

The artificial/artificialized supplying is mentioned in accordance with the main forms of human presence and activity in the urban areas, starting with the infiltrations associated to the built up/equipped infrastructure *(2.a.).* The water loss from the installations and from the coupling sectors to the networks of the residential, administrative, industrial buildings etc are well known. Other important quantities of water reach the phreatic aquifer along and on the surface of the communication arteries *(2.b.)*, since the construction phase when the cover with natural vegetation, buildings or other type of artery is temporarily removed, and the precipitation or the water from artificial sources penetrate rapidly underground. The same source activates also after the exploitation starts, either as a result of the permeability of the cover (river stone, cubic stone), or of the quality of the material used and of the equipping works (porous asphalt, thin covers rapidly degraded), or the careless in the maintenance works (delays, superficial interventions, with low quality materials etc). Through the spaces remained uncovered (in the carriage road, fissured gutters, on the degraded pavement, on the former grassy bands separating the traffic lanes etc) infiltrations are produced and they are important from a quantitative point of view due to the long duration of certain works and the longevity and repetitive character of the damages.

The most important infiltrations from the artificial sources come from the urban infrastructure of the networks that use water *(2.c.).* Either drinking or used water, besides the volumes lost in the network and installations belonging to the buildings, the water that circulates in the distribution or evacuation networks reaches, in incredibly[3] large quantities in the phreatic, during the

[2] Considering the specific urban artificialization of the genesis, frequency, intensity and quantity, atmospheric precipitations constitute only a quasinatural infiltration (and supply) forms for the phreatic waters.

[3] Considering the generic use of great, longer lasting underground water reserves, apparently any supply source is welcome. But in this case the use is illusory as the energetic cost for processing the raw water in order to become drinking water is too high as compared to the quantified

extension/densification works of the networks, during the works of maintenance/rehabilitation, and especially during damages. Even if, theoretically, the profile documentations remind, non-differentiatedly, the „human influence” in the hydro-geologic balance calculation, this type of supplying is never considered. Aggressive through the negative consequences for the quality of drinking water, it only presents an interest at the level of the indesirable transfer of used water in the distribution network, and this happens only in the cases when the negative severe effects on the human health have already occurred. In smaller quantities, water from different sources infiltrates in the phreatic, and on the occasion of the works related to other networks situated underground – electricity, thermal services, gas, especially in the social-economic systems which do not regulates the legal frame of the mutual responsibilities.

The next supplying source is in a quantitative-qualitative relationship with the phreatic waters, and it cannot be considered an artificial source, but rather an artificialized source. This is explained by the fact that, if the maintenance of the green spaces and of the crops (with different destinations) implies watering/irrigating, the quantity of water which is applied is mostly metabolized by plants, or hold back by them, and introduced in the evaporation process. As a result of a series of natural processes, only a modest quantity ends up in infiltrating in the phreatic (*2.d.)*.

At the end of the references to the supply of the urban phreatic from the same type of sources, the infiltration from uncovered, non-productive fields are included in the scheme (*2.e.)*. Very variable in space, from multiple causes (historical, socio-economic, political etc), the urban texture oscillates a lot, between extreme densities and lax forms. Even if the uncovered spaces have only a temporary existence usually, on that duration they function as areas/sources of supply for the phreatic, very often with quick effects, due to the permeability of the specific deposits. When the fields remain uncovered for a long time, the supply can be temporized through the effect of the specific ruderal vegetation. But sometimes, because they are hardly solificable or even aggressive due to the nature of the mentioned deposits, they are not covered with grass and they remain areas of free water access from different sources.

In the structure of the *hydro-geologic balance* (7), all the presented sources have the qualities of *inputs* (*7.a.*)[4].

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advantages of this phreatic contribution and the « supply » of the phreatic with used waters drastically reduces the range of uses.

4. In the proposed scheme, this essential element of the hydrogeologic balance is, concomitently, the integrated effect of all the supplying types and sources presented (*6.b.*).

The outputs from the phreatic system (*7.b.*) have also compounds generally quoted through balance calculations. Some of them are natural (biologic consumptions, in which the human one is frequently present with large quantities, the discharge through springs, evaporation from uncovered fields. Other ones are artificial (direct drawings with other destinations than biological consumption, controlled evacuations).

Very important for urban hydro-geological potential (not only for balance calculations) are also a series of variables hardly identifiable and quantifiable (*7.c.*), with an extremely different[5] distribution and – mainly – with a very aleatory mobility of the role they have in the phreatic water balance. In this respect, very old basements, often disposed on several levels, displaced old ceramic segments (capable to conduct) sometimes water fluxes, but also enough permeable to take waters from infiltration, important variations – on a small distance – of the thickness and structure of the natural superficial deposits (alluvial, colluvial, deluvial, proluvial), as well as variations of the position and texture of the artificial (urban) deposits, surely intervene (most of the times in an uncontrollable way) to the spatial differentiation of the supply of some aquifers or their discharge.

Besides the above mentioned difficulties, the great mobility of the hydrologic balance elements is added. This is induced by the advanced artificialization of the complex of hydro-genetic factors: urban microclimate, with great impact of the natural climato-genetic factors, with strong attenuation or stimulation of the specific processes, the spatial evolution of the habitat (sometimes explosive), mutations (rapid sometimes) in the urban functions

With the recognition and quantification (as much as possible) of the mentioned variables, even difficult, the estimation/evaluation approach of the urban *hydro-geologic potential* can be finalized with a result close to the reality.

The spatial manifestation of the variability of the hydro-geologic balance is mentioned in the scheme by means of hydro-geological spatial units, differentiated in accordance with the sources/areas of supply (*3;4;5*) and with the ways/areas of getting out from the phreatic hydro-system (*7.b.1. ; 7.b.2*).

The proposed scheme also signals in its structure, successive levels of integrating the information (from 2 to 5), emphasizing not only the existence of reports with logic position between the different components of the hydro-geologic balance, but also the necessity of a spatial expression of these reports, in order to give the integration levels mentioned above (possible approach by progressive visualization - Irina Ungureanu, 1994-1995). In this way a more complete and clear

[5] In some cases, hundreds of years old urban infrastructures, under the form of underground holes with totally unknown disposal, strongly involved in the phreatic accumulation and in the dynamics of the respective aquifers, are covered by artificial deposits with a thickness greater than the depth of the foundation works.

reference support can be ensured for any public utility work, avoiding hasty evaluations, incorrect notices, preventing errors with tough consequences. The hydro-geologic spatial units from a final map will be therefore more truthful than the usual natural hydro-geological units which have deposits favourable to the phreatic accumulations and for which the calculations of the reserves are done on the basis of supply surfaces considered to be isomorphic, isotropic etc.

Finally, the large scale graphical image of the urban hydro-geologic potential, with spatial units outlined on the basis of a complete balance, can ensure a more correct basis to the spatial distribution of the control networks (drills, drains), can present the position of the richest aquifers and of the most oscillating aquifers from the point of view of their available volume (risky as a useful base, either because they disappear during severe droughts, or they have catastrophic discharges during extreme pluviometric episodes, of the areas with vulnerable phreatic due to the artificialized supply of the most required areas through direct (and sometimes abusive) consumption etc.

4. Conclusions

By comparing it with the former system used in the evaluation of the phreatic aquifers, the systemic approach we propose, in accordance with the specific integrating image in geography, creates the possibility of an approach which is more complete, with more nuances and analytical valences, especially concerning the reports of the piezometric surface with the real supply surface, such diverse and changing in the urban areas.

Logically, the systemic character of the geographic approach does not cancel – by replacement – the specialized one, but it can ensure a higher precision level, opening real interdisciplinary or maybe even trans-disciplinary perspectives. The cooperation between hydrologists and geographers, but also with historians, archaeologists, practitioners in other fields (etc) can emphasize the importance of associated approaches as well as stimulating the emergence of new fields or application areas. In this case, as well as in other specific conjunctures of the applicative and fundamental scientific research, the geographic vision acts like a revealer of the interactive complexity of different sectors of the terrestrial system, inducing the diverse attention of other fields to this system.

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