THE BOUNDARIES OF PROTECTION IN THE CONTEXT OF THE ARMORICAN BLOCK

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Water resources in use; historically and at the present day.

Formerly, at a time when the need for water was small and scattered, the use of underground water was predominant. This was harnessed by means of wells and springs – individual or shared – and sometimes, for greater volumes of water, by a network of surface drains (eg. the drains constructed by the city of Rennes in the 19th. century, which are still in use.

These constructions, mainly gravity-fed, were seen to be inadequate given the increase in consumption and the development of water-distribution services. So surface water was called into use, drawn directly from watercourses or stored in reservoirs either already existent or purpose-built for the supply of drinking water.

This use of surface water, nowadays the most common (80% in Brittany) essential for the significant needs of urban areas, but sometimes less justified for rural areas, is linked to confusion between the output of the "traditional" structures and the actual potential for output of the underground waters of the block, largely unrecognised until the mid-seventies.

The development of this knowledge has only occurred since that time and is linked to 3 main causes: The increase in demand for water by cattle farms which is not met by the public supply network, (total volume and cost); the drought of 1976 which revealed local shortfalls; the arrival in the region of the percussion drilling technique which is cheap and well adapted to the Armorican block. Thus, from "haphazard" bores (certainly several tens of thousands in 20 years) carried out mainly by farmers, for the relatively small needs of their own animals, we have progressed to more organised prospecting, with more ambitious objectives, for the supply of drinking water to communities.

But this knowledge has come too late to make a noticeable change in the relationship between the use of underground water and surface water; having resorted to the latter necessitated the grouping together of rural 'communes' into water associations whose size (ten or so communes) is often unsuitable for the local output potential of underground water (several communes).

However, researches into underground water have nevertheless been undertaken because of the decline in the quality of water (an increase in the nitrate and pesticide content chiefly agricultural in origin) which has progressively become established. It has thus been necessary to call on new reserves of quality water, either to replace, or to mix with that in use (shallow underground reserves or surface water) and interest has been shown in these reserves, tapped nowadays by deep drilling, in better conditions than formerly.

Underground water

Main characteristics:

- **Types of aquifer.** Setting aside some special geological formations (tertiary basins, alluvial plains) the aquifers of the Armorican block have developed in two principal types of situation. The upper degraded metamorphic formations (altérites) and the fissured formations of the sub-stratum.
  - **ALTERITES.** These result from the continental history of the Armorican massif, marked by the significance of the processes of degradation which have caused a more or less

important transformation in the rocks, according to their nature (granites, schists, sandstone) and their . degree of fracturation. These processes lead to formations, some softer than others, differing in nature according to the mother-rock and with different hydro-geological results: sand in the case of granite and clay in the case of schists. Two superimposed levels of "established" altérites are generally recognised (cf. BRGM)

- **Allotérites,** characterised by the disappearance of the original rock structure with a loss of mass and volume; these form the upper layer (10-15 m thick).
- **Isaltérites,** in which the original structure is retained, with loss of mass, but not of volume; these form the lower layer (20-30 m thick)

These altérites are characterised by a porous structure which establishes the potential for a relatively significant reserve of water. Their permeability is generally poor, except in certain granitic sands and under certain conditions. They give rise to numerous springs, permanent or temporary, often with a feeble output. They correspond, for the most part, to the water-table tapped by "traditional methods."

- **THE FISSURED ROCKS OF THE SUBSTRATUM.** These are situated under the altérites, but may appear on the surface in special topographical conditions (slopes, watersheds). Their potential for production has only really been brought to light with the drilling of deep bores, although there were formerly, thanks to mining operations, numerous indications of the presence of water at great depth, in the heart of the "hard rocks".

The presence of water is linked to the discontinuities which affect the different geological situations: contact between formations, alternating layers of differing natures (schists and sandstone), stratification joints, schistose planes, joints, fractures and faults, veins (eg. pegmatites, dolerites). Contrary to what was "accepted" formerly, it appears that productivity does not diminish with depth; water has in fact been found to circulate at 250 m., in bore holes which are now being made deeper and deeper.

The rocks of the substratum are characterised by their porosity through fissures, whose water storage capacity is generally fairly insignificant. Some examples do, however exist, which contain large quantities; this is the case, for example, in the volcanic rocks of the Trégor (Côtes d'Armor) where vacuoles occur. On the other hand, permeability can be locally high, allowing instant heavy discharges.

These instant outflows obtained (au soufflage*) through percussion drilling, reflect the very great differences in the substratum and are very variable: from a few m³/h (an absolutely dry bore is rare) to occasionally more than 100 m³/h. (Exceptionally several hundred m³/h). Equally varied results are observed in all types of geological formations. A statistical study, carried out by the BRGM, of "random" drillings shows, however, that some geological situations are more favourable than others.

The combination of the two preceding contexts: altérite over a fissured substratum, is the dominant feature of the water-bearing systems of Armorica, with the altérites determining the capacity and the fissured substratum determining the flow. The hydrodynamic function most frequently corresponds to that of a two-layer system, with the intervention of an irregularity in the draining of the altérites by the underlying substratum (cf. the "S" – shaped curves in the trial pumping). The vertical connections may be downwards, in the zones where the water-table is replenished, or upwards in the zones where water emerges. We have noticed besides, in deep bores, a frequent artesian effect, linked to this phenomenon, which may be the cause of certain damp areas in particular topographical regions.

Compartmentalisation of the aquifers

The compartmentalisation of the armorican aquifers is a characteristic met with frequently. We have noticed it both in the altérites, and in this case, it means the disappearance of the "altered" levels according to the topography, and also in the fissured substratum, where it involves a limited extension of the fissured area, or real impermeable limits, which may be due to clay-filled fractures, or changes in the type of rock.

This can occur in all types of instantaneous outflow which have been observed (on the site of Kernevec at Tréguier, in the vacuolar volcanic rock, there is an impermeable barrier, within the formation, between two bore-holes 60 m apart, each with a flow of 300 m^3/h!)

This characteristic may reduce the possibilities for development on account of the deficiency it causes in the areas supplying water. It brings about considerable differences in production, according to the local conditions of replenishment by effective rainfall, which are very variable geographically.

Thus a feeder-area of 200 ha. (a common situation) can provide, in the Monts d'Arrée where rainfall is high, (1400 mm/p.a.) a volume of water in the order of 170,000 m^3/p.a., while the same area will only provide (for a regular evapo-transpiration (by plants, soils etc) of 550 mm/p.a.) a volume of 30,000 m^3/p.a. in the Rennes basin, which is markedly drier (700 mm/p.a.)

Another consequence of this characteristic is the necessity for pumping trials over a long period (one to three months) to ascertain the limits. One can quote the example of the site at Launay (Water authority of Kerjaulez) also in the, vacuolar volcanic rock of Trégor, where the potential, at this point, resulting from a trial extraction of one month is in excess of 300m^3/h (More than 7,000m^3/day). However when the feeder-area is taken into account (in the order of 200-300 ha., which is rare in the Armorican block, it suggests a reduced potential (confirmed by the work done over the years) of 550,000 m^3/p.a. or 1,500 m^3/day or 60 m^3/h.

The quality of the water

The "natural" quality of the armorican ground-water is the result of the geological characteristics of the formations which contain it (mainly schists, sandstone and granite). The water is lightly mineralised and not strong-tasting. One can notice the differences relative to the distance from the sea (chlorides) and to special geological conditions such as: raised levels of minerals under an alluvial layer in the north of Brittany, a raised calcium content in certain formations of volcanic origin, the presence of certain substances originating in veins, such as fluorine and arsenic.

The quality of the water varies in vertical zones, thus corresponding for the most part (but not always) to the two water-bearing layers already described. In the upper level, conditions are oxydising, with dissolved oxygen and nitrates present. In the lower level, conditions are reducing so dissolved oxygen and nitrates are absent, but iron and manganese are present in a weakened state, which necessitates a special treatment before the water can be used to provide drinking water.

In the majority of cases, the water from the upper layer collected by traditional methods (wells etc) has a high concentration of nitrates corresponding to the agricultural activities carried out in the feeder-area. (The DDASS of Finistère has been able to match the observed nitrate content with the intensification of agriculture, maximal in vegetable-growing areas, minimal in areas devoted to animal husbandry. On the other hand the water from deep underground often has no nitrate content, even in areas of intensive agriculture. De-nitrification, at depth, of the water, is an almost general phenomenon in the Armorican block; it shows itself, during drilling, by a drop in the nitrate content at the same time as the appearance of iron. Whether this is a permanent phenomenon, which may be linked to the oxidisation of pyrites in the rock-matrix, is still unknown.

The presence of pesticides in underground water is only noted in a small number of cases; connected principally with carbonated substrata, alluvial deposits and sand. This occurrence may be due to the changing of rocks into clays and to the acidity of the land contributing to the fixation of certain molecules.

Methodology of protection.

Preliminary remarks.

It is advisable to remember than, generally speaking, the aims of the areas of protection of ground water, in the whole of the west, are to protect the points at which the water is extracted, as well as the resources which replenish them. (cf. report of the plenary session No.2). They also seek to control extensive pollution, especially of agricultural origin.

- **Defining the feeder-area.** The definition of the feeder-area of a borehole is one of the principal problems to be resolved. It includes the surface to be taken into account, and its situation.

  In the case of a new water supply point, installed following properly conducted searches for water, the results of the trial bores allow us to discover the distance between the lateral limits and also the dimensions of the aquifer, which, taking into account the effective local rainfall which percolates into it, allow us to work 'out the usable volume and the surface to be protected. It is as well to point out however, that although we can ascertain the amount of effective rainfall quite well locally, thanks to a close-knit pluviometric network, the respective proportions of run-off and percolation are not so well known, and we must often be content with approximations,, based on observations of the terrain (eg. presence or not of watercourses and of surface-water drainage in the rural sector). In certain cases this can lead us to consider that all the effective rainfall percolates through the surface.

  The creation of piezometers and long-term monitoring of levels during the trial, and during a hydrological cycle (high and low water) enable us to locate this surface accurately.

  On the other hand, in the case of "traditional" workings, already in production, the data are often less precise. At first, in view of the small radius affected by the wells etc. we take the feeder-area in with the topographical basin, which is usually justified in the case of the aquifers in the altérites. So, if we take into account the effective rainfall (with the preceding observation) this provides us with an order of magnitude for the volume of water which could pass through the water supply point (extractions and the eventual rate of overflow). Comparison with the "real outflow" (extractions) and outflows from which no water is taken often, unfortunately, leads us to accept or reject this preliminary step. In the latter case, complementary studies are necessary (piezometry especially). However, this preliminary step necessitates a certain number of precautions (the local hydro-geological situation, an inventory of the existing water-points, taking into account the quantity of water, the environment etc.) which may lead to its rejection even if the assessment appears to show a stable situation. Thus it is important that this basic method should be checked by a hydro-geologist who really knows the special conditions in the block.

- **Identifying vulnerability to pollution**
  (information from plenary sessions No.2 and No.4)

  Vulnerability refers to the ability of the physical environment to stop, delay, degrade or diminish pollution. This is particularly the case in a layer of impermeable terrain, a situation met with in the deep water-tables of sedimentary formations. In the Armorican block this arrangement is somewhat restricted, since the altered formations at the surface are not sufficiently impermeable.

We can, however, consider that two different areas of vulnerability exist in the Armorican block, corresponding to the divisions described above: altérites and fissured substratum.

Altérites must be considered very vulnerable to pollution coming from the surface, with particular reference to nitrates. Appropriate protective measures must accordingly be taken (elimination and/or restriction of polluting activities).

The fissured substratum is better protected because of the presence of the altérites which, if sufficiently thick and of low permeability, can retard pollution, and also because of the existence of the phenomenon of denitrification. So it is particularly important to maintain the above precautions when starting to develop water-sources – (the need to line well-heads with concrete).

- **Study of the environment and the risks of pollution**

  This study comes after the previous ones leading to understanding of the aquifer. It is a case of making an inventory of, and describing all of the activities and situations which might lead to pollution of the well and the resources which have been tapped.

  It generally contains an important agricultural element (the so-called "agropedological" study) except when this activity is absent, which is rare. It contains firstly a description of the environment and the terrain included in the feeder-zone previously defined; run-offs, make-up of the landscape (banks, hedges, natural and cultivated areas); agricultural land-divisions, (crops & farmers). A pedological map (origins and evolution of soils) is usually produced. It is based on assessments of nitrogenous fertilisation, arrived at by the Corpen method. When agricultural buildings are present, a precise description is made of the installations. From this comes a result which can be compared with the quality of the water extracted (for nitrate content) and which leads to a diagnosis and to advice on the measures to be recommended.

  We can however see that this type of study is more suited to the waters in the upper stratum of altérites than to those of the deeper substratum. Moreover, it must supplement the examination of the risks of pollution, and not as is sometimes the case, replace the hydro-geological study necessary to find out the state of vulnerability of the aquifer.

Surface water

Principal characteristics

If we exclude the Loire, which flows across the Armorican platform for nearly 150 km., but whose catchment basin is largely outside it, the watercourses of this region are found chiefly in the interior of the massif. Apart from the Vilaine, much the largest, whose basin extends to 11,000 km², and a few other "big" water courses (the Aulne, Blavet, Mayenne etc.) the rivers are fairly modest; they are however, extensively exploited for the supply of drinking-water. We can classify them according to two principal features of their catchment areas, which influence their natural cycles.

- **The pluviometric situation**

  This differs widely, precipitation perhaps doubling according to distance from the sea and the relief (1400 mm in the Monts d'Arrées; less than 700 mm in the Angevin region). If we take into account adjacent conditions of evapo-transpiration, this gives widely differing annual averages from more than 800 mm/p.a. (25 litres/sec per km²) in central Finistère, to less than 200 mm/p.a. (6 litres/sec per km²) in the Rennes basin.

- **The geological situation**

Traditionally we have distinguished between catchment areas with a granite substratum, characterised by relatively constant minimum average water levels, and those with a schistose substratum, with very low, sometimes non-existent water in dry years.

The higher flow-rate in granite basins appears to be linked to the more significant presence of water reserves than in schistose basins. This distinction is worth discussing. In fact, the presence of underground water is noted especially following drilling work in these basins at times of especially low water-flow. So it is rather that the conditions of transfer of underground water towards the surface water seem to be different in the two cases discussed.

The contribution of underground water to the watercourses of Armorica was formerly largely under-estimated, since the underground water resources were also under-estimated. At the level of river-basins, computer models (Gardenia version) show the proportion to be 25-65% of underground water in the total annual discharge flow of rivers. Studies carried out at experimental sites (Naizin on schists; Maupertuis on granite) confirm these proportions and go even further in certain granitic situations. This should be taken into account in operations to restore the quality of water in the catchment areas, which have up to now been mainly directed towards controlling pollution linked to run-off.

A very important consequence of the hydrological characteristics of the Armorican watercourses is the relative lack of available resources for the production of drinking water "from the current" from surface water in periods of reduced flow, particularly in the schistose basins. This has led to the construction of reservoir dams, retaining the winter and spring water (often with high concentrations of nitrates and pesticides) for the needs of summer and autumn.

This availability is also, at present faced with the regulations concerning the use of water from such stocks, which impose on a water-supply, a reserve at least equal to 1/10 of its annual average flow, whilst natural supplies at low-water periods are often below this figure in dry years.

- **Quality of the water**

The quality of the surface-water in Armorican rocks results from the geological conditions of the catchment areas. Thus the water has, in the main, a low mineral content. The types of flow (rapidly-flowing watercourses, well-oxygenated, the presence of dams) have an important influence. To those conditions must be added the effects of direct or indirect, limited or wide-spread spillages of substances which could change the quality. This depends on the nature of these substances, their quantity and rates of transfer (Immediate run-off; a few hours; underground flow – a few months to a few years) as well as on the situation regarding dilution and degradation (self-purification). Some developments (eg. the levelling of embankments, drainage networks) can also help to increase or decrease the impact of these spillages.

The chief problems which affect the quality of surface water, besides those relating to accidental pollution are: the amount of organic matter contained therein, pesticides and nitrates, as well as eutrophation (excessive accumulation of nutrients) of lakes. The substances involved are eliminated by appropriate treatments, but there are statutory limits, before treatment, in the use of water for human consumption. Where these are constantly exceeded, special dispensations are necessary. This is the case with nitrates above 50 mg/litre. This level is often exceeded in Brittany. (cf. the legal proceedings entered into by the consumers, which followed from it).

- **Vulnerability of the underground water**

The vulnerability of the surface water is much greater than that of the undergound water, and besides, regulations specify that the use of the former in the place of underground water must be justified. In the Armorican context, this vulnerability is increased by low flow-rates, which do not allow significant dilution, and by the velocity of run-off which brings a rapid transfer of pollutants. This is why it is advisable to respect the general safety-measures for the provision of water, such as: appropriate methods of treatment, warning stations, inter-connections and plans for the prevention of accidental pollution.

Methodology of protection

Preliminary remarks.

Unlike underground water, the protection of surface water, destined for the provision of drinking water, by the establishment of protective zones, will be chiefly intended to control localised accidental pollution near the point of extraction. Thus it is only a part of the feeder-zone which will be affected. The rest of the catchment area, together with the control of more widespread pollution, notably of agricultural origin, will eventually be the object of operations of a different kind, within the scope of "programmes of action in catchment areas" (eg. Bretagne Eau Pure)

- **Establishing the protection-zone to be considered**

The establishment of the zone studied with a view to protection, up-stream of the water-extraction point, is often difficult. Its limits are based on certain criteria: 1. hydrographic (presence of tributaries and/or lakes) 2. topographical (slopes) 3. environmental (presence of humid areas and natural uncultivated areas) and take into account any activities present. In the case of dams, we consider the whole of the lake and its margins as far as the change of gradient.

Markers intended to measure the run-off when the rivers are high and when they are low can prove helpful in setting these limits.

- **Study of the environment**

Within the study-area previously described a survey is carried out documenting all the elements of the environment which are susceptible to positive or negative influences on the quality of the water, as well as a description of any activities which could pollute the water. In certain cases, the survey of polluting activities can justify the removal of the water-extraction point uphill from these activities.

A final observation

It is somewhat paradoxical to note that the methodology of protection of the underground water resources, perfected over the years, is today more exact and more effective, at least in the short term (cf. report of plenary session No.4) than that used for the surface water resources, although the latter provide the majority of the water output (80% in Brittany). This ought to reinforce their importance for the provision of drinking water.

However, supplying drinking water is the 'driving force' of the measures for improvement in the quality of the water in catchment areas. These measures involve greater risks and it is feared, no doubt rightly, that abandoning the extraction of surface water of mediocre quality will bring about diminished financial support for them. So it is another paradox to note that today, the quality of underground water can put a brake on its wider use.

The expression "au soufflage" on page 31 of the original report has proved almost impossible to translate. The term "soufflage" normally relates to glass-blowing, but none of the dictionaries which have been used show any relevance of the term to the extraction of water. A geologist consulted for an opinion went to the web sites of several French universities without finding a relevant translation. The only opinion which can be offered is that the term refers to an artesian effect, or perhaps to the facilitation of water extraction by compressed air.

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INVOICE. To the translation from French to English of a report entitled "Les Périmètres de Protection dans le contrexte du socle Armoricain".

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