River typologies and divisions

Basic concepts

What is a typology?

The term "typology" covers three fairly close concepts (Newson *et al.*, 1998).

- **Classification,** i.e. a general method used to group similar items (Bailey, 1994).
- **Taxonomy,** an objective, empirical procedure of assigning objects, animate and inanimate, to taxa (categories) on the basis of measured attributes. This procedure generally requires a differentiation system. It is then necessary to determine a number of discriminate variables, to create a hierarchy and to define precise thresholds for those variables.
- **Typology,** a conceptual approach based on a subjective division into classes. The typological method is similar to the discriminant form of multivariate analysis, where the researcher defines *ex ante* a set of types and the parameter thresholds used to discriminate between them. "Typical" facies, whether real or fictional, then constitute "standard formats" to which all other items may be assigned depending on their similarity.

On the basis of the above definitions, we consider the term "classification" to be generic. Methods used to formulate systems are either taxonomic or typological.

In accordance with current, common usage, the term **geomorphological typology** will be used here to designate the methods used to group types of rivers on the basis of their geomorphological similarities and the systems produced by those methods.

What is the purpose of a typology?

Generally speaking, there are **two main goals** of a typology, which depend on the degree of precision involved:

- **a basic typology,** organised around simple, easily accessible parameters, providing a general system for various approaches, notably for scientific purposes and for river management;
- **a more 'in-depth" typology,** based on more complex, less easily accessible parameters, in order to describe river operation as closely as possible and to improve both analysis and predictions.

■ A basic typology to establish a common basis for knowledge and analysis

One of the major objectives of creating a typology is to provide water managers, scientists and river users with a common basis for knowledge and analysis. This common basis may comprise a river classification in a limited number of standard types, to which all rivers may be assigned.

Given the difficulties in accessing some of the main control factors, this initial typology is based on a number of simple parameters that may be accessed via existing databases. However, even in its simplified form, this typology provides users with information on certain characteristics governing the overall operation of hydrosystems.

The basic typology is organised around the following parameters:

- valley slope;
- valley width;
- rank in the Strahler stream order;
- hydro-ecoregion.

■ An in-depth typology to address geodynamic processes

This second typological level calls on more descriptive parameters of river hydromorphological operation and notably those for geodynamic processes. This more in-depth approach is still in the process of being formulated and is limited by access to the necessary parameters, e.g. intensity of sediment input, unit stream power, bank cohesiveness.

NB Parameters on habitat, notably the various river facies and their proportion, may be linked to this typological level.

An in-depth typology has a number of advantages.

Weight the quality grade of a river physical-quality evaluation system

This goal is of interest primarily to the Water agencies. The typology must enable users to assign weights to a physical-quality grade produced by measurements and analysis of various river parameters (e.g. the SYRAH and QUALPHY methods). It is clear that the resulting value, always calculated in the same manner, cannot signify the same thing, in terms of the physical quality, for mountain and lowland rivers, for sand-bed and boulder-bed rivers. Similarly, a high density of slow and deep river facies is not indicative of a malfunction in a lowland river with a sand/silt bed, whereas it does signal a problem in a river having a steep slope and characterised, under natural conditions, by alternating rapids and running sections, etc.

Decision aid

Within a given management unit (river basin, sub-basin, river) and simply by studying a map with the explanatory data, managers can immediately determine the mode of operation of a river or section of river for which a decision is required, propose development strategies, decide whether to fund development or hydromorphological restoration work, etc.

Evaluate the impact of development work

It will be possible to evaluate *ex ante* the impact of proposed development work on a river by finding in the same basin or elsewhere a river of the same "type" that has already undergone the proposed development work and by quantifying the observed impacts.

Propose preservation and restoration work

Similarly, water managers will be in a position to propose preservation projects, notably on rivers exemplifying the typological categories (they will not exist for each category), or restoration work on degraded rivers that no longer function according to their natural "typology".

Pros and cons of a geomorphological typology

■ Pros include rapid access to operational information via the habitat

It is now widely acknowledged that the biological operation of most hydrosystems is closely linked to their physical operation, itself determined by sediment erosion, transport and deposition processes. These processes result in river landforms (planform, long profile, cross profile) that can now be correlated fairly well with ecological functions. The links most commonly used to establish these correlations are based on the concept of the **"habitat" of biological communities, notably via the river facies** that are seen as macro- or mesohabitats (see below the section on the river-facies typology).

■ Cons include the river continuum and adjustments

The river continuum

Many authors, both geomorphologists and ecologists, are of the opinion that rivers evolve from upstream to downstream along a **continuum** and that it is difficult to "extract" discrete units. Consequently, there are often real difficulties in clearly setting limits for morphological types and river divisions.

Adjustment processes and river metamorphoses

Most rivers in the temperate regions of Europe underwent a phase of major geomorphological adjustment during the great climate change at the end of the last glacial period, 15 000 years ago. The very wide alluvial valleys in glacial and periglacial Europe were choked with sand and rock deposits that were sculpted by vast braided rivers whose morphology and sediment may be observed even today in valley bottoms.

This "mega-adjustment" has been reworked and masked by "macro-adjustments" in response to hydro-climatic fluctuations during the period from 15 000 BP to now. It was these river metamorphoses that imposed alternating multi-secular adjustments caused by an excess or deficit of bedload (see the preceding chapters). Each of these phases left its geomorphological and sedimentary mark that continues to influence the current operation of rivers (type of riverbed and banks, original pattern and progressive filling of side channels, etc.).

For example, the most recent period (1900s) saw the gradual shift from braiding to meandering in rivers that had received large volumes of bedload during the Little Ice Age. This observation confirms that the assignment of a river to a morphological type is not necessarily definitive and may need to be changed in response to adjustments.

Similarly, it is difficult to define the concept of a **reference state** for rivers undergoing metamorphosis. For example, rivers that were braided during the 1900s cannot be considered an absolute reference if evaluation reveals an ineluctable shift toward single-channel rivers with downcut beds, in response to the control factors themselves evolving to a stable condition, to say nothing of the lack of bedload caused by factors impacted by human intervention (dams, extractions, dikes).

Other discriminant criteria

Finally, it should be noted that aquatic (or riparian) habitats are often influenced by morphodynamic processes that are themselves determined by various parameters (geological, climatic, tectonic, etc.). However, the "inhabitability" of these environments also depends on other criteria, e.g. hydrology (natural or impacted), the physical-chemistry of water and sediment, the amount of sunlight, temperature, the type and density of riparian vegetation, etc.

The issue at hand is therefore to determine if these parameters should be integrated in a typological approach and, if so, at what level in a typology or system of river divisions.

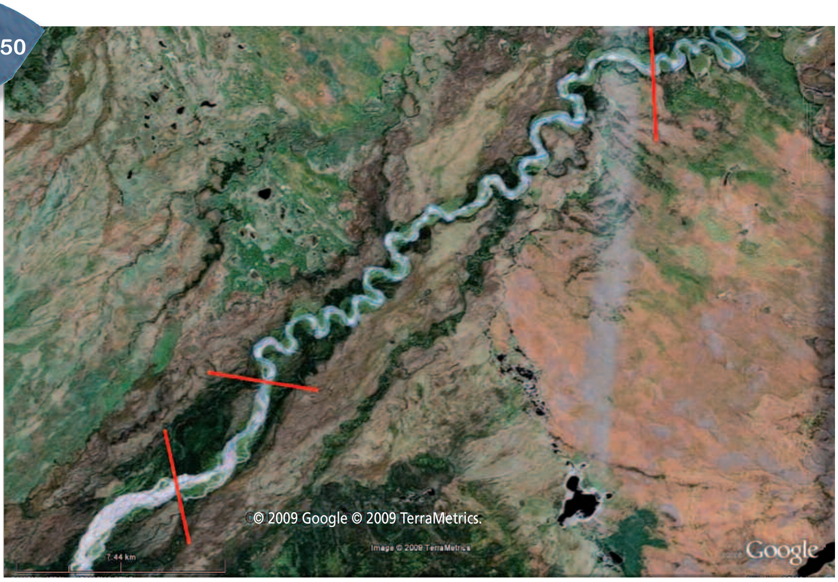
Typologies and river divisions, two very similar concepts

The purpose of the typological approach is to create a management and decision-aid tool for managers working on various spatial scales, which is why it must be possible to use the typology on those different scales.

The most simple method consists of mixing the **typological and river-division concepts.**

As noted above, the typological approach consists of creating a classification of rivers based on more or less objective criteria. **In fact, the goal is not to categorise rivers, but river reaches.** Though not neglecting the concept of the river upstream-downstream continuum, it is clear that rivers often have very different morphologies and operation at different points between the source and the confluence with a higher-order river or water body.

Figure 150



River evolution between upstream and downstream. It is clear that these different hydrological entities must be managed differently.

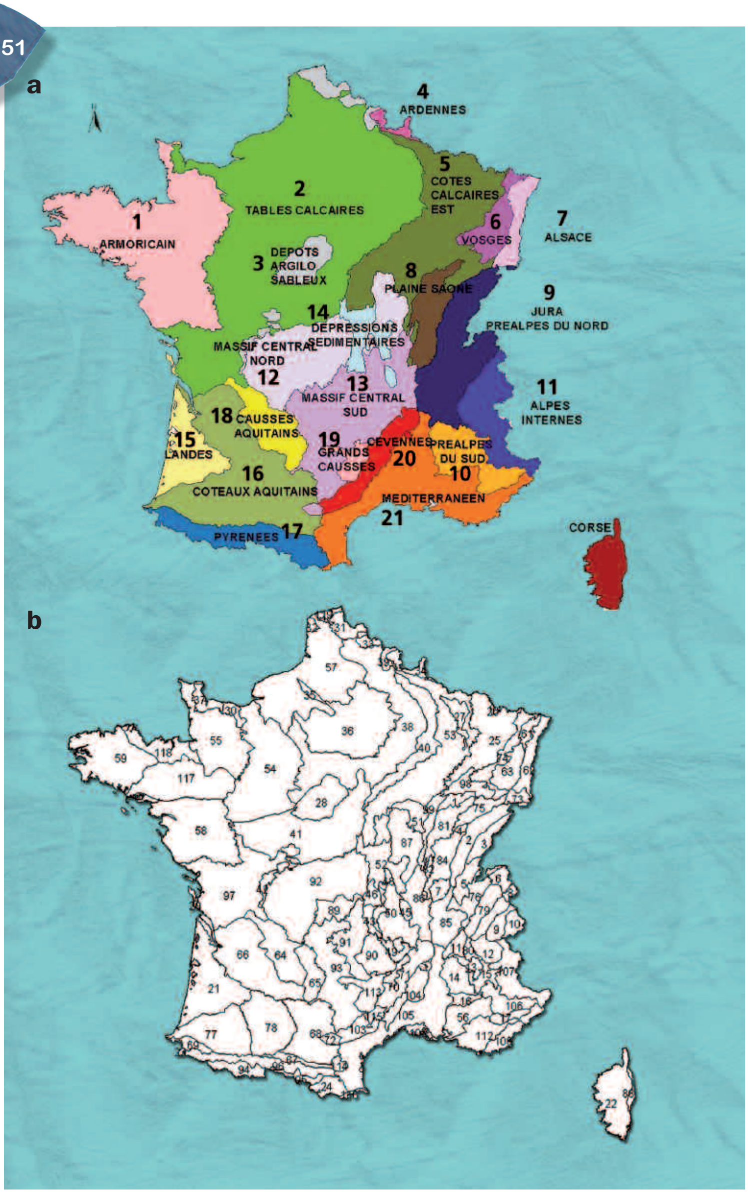
In theory, all rivers can be divided into a certain number of **nested entities,** similar to Russian dolls (see the image on page 135), each of which is of interest in understanding the overall operation of the river and as an element in overall management. Some of the hierarchical levels of these nested entities may also be categorised as **morphological types,** making it possible to **combine** the two concepts.

Examples of typologies

The national typology of surface waters

In compliance with the European Water framework directive (WFD, Annex II), a typology of **water bodies** was created. The purpose was to group consistent aquatic environments based on certain natural characteristics (relief, geology, climate, water geochemistry, discharge, etc.) that have a structural influence on the geographic distribution of biological organisms. The main issue concerned the definition of reference conditions on the basis of which the ecological status reports (i.e. any discrepancy with respect to the reference) are drafted.

Figure 151



1- ARMORICAN
2- LIMESTONE PLATEAUS
3- CLAY-SAND DEPOSITS
4- ARDENNES
5- EASTERN LIMESTONE CUESTAS
6- VOSGES
7- ALSACE
8- SAÔNE PLAIN
9- JURA, NORTHERN PRE-ALPS
10- SOUTHERN PRE-ALPS
11- CENTRAL ALPS
12- NORTHERN MASSIF CENTRAL
13- SOUTHERN MASSIF CENTRAL
14- SEDIMENTARY DEPRESSIONS
15- LANDES
16- AQUITAINE HILLS
17- PYRENEES
18- AQUITAINE LIMESTONE PLATEAU (CAUSSE)
19- LIMESTONE PLATEAU (GRANDS CAUSSES)
20- CÉVENNES
21- MEDITERRANEAN

HER1 (a) and HER2 (b) in continental France (Wasson et al.*, 2002).*

■ Regional criteria

The ecological operation of rivers is determined upstream by the relief as well as by the geological and climatic characteristics of the river basin. A regional division based on the homogeneity of these characteristics results in sets of rivers having similar physical and biological characteristics, over a similar longitudinal gradient (Wasson *et al.*, 2002). This division (Figure 151) of continental France produced **22 level-1 hydro-ecoregions** (HER1) exhibiting significant differences between the primary determinants. These high-order HERs can be divided into **112 level-2 hydro-ecoregions** (HER2).

■ River-size classes

The longitudinal evolution of rivers is expressed using the Strahler stream order, which takes into account significant differences in river size at each main confluence. Rivers are thus organised in size classes that are adapted and occasionally grouped together depending on the local characteristics of ecosystem longitudinal evolution.

■ Application

In each of the 22 level-1 hydro-ecoregions, a downstream classification, adjusted to the known characteristics of ecosystem operation, is applied. This first step results in proposing types of water bodies said to be "endogenous".

In some cases, for rivers crossing the various hydro-ecoregions, it is necessary to take into account the influence of the upstream hydro-ecoregion. This influence is expressed notably by the geochemical and hydrological characteristics of each river.

For example, a river travelling through a hydro-ecoregion with a predominantly limestone substratum, but that originates in a hydro-ecoregion with a siliceous or crystalline substratum (Pyrenees, Massif Central, etc.) and whose discharge accumulates primarily in the latter, will have a geochemical composition similar to rivers located in siliceous or crystalline regions. In this case, its code is more similar to that of the hydro-ecoregion with a predominantly siliceous or crystalline substratum (e.g. the lower sections of the Dordogne, Lot and Garonne Rivers). Depending on the position and relative surface area of the river basins upstream of the rivers influenced by another hydro-ecoregion, the typology of water bodies must be completed with the addition of "exogenous" types or information on local singularities.

The resulting national typology and its codes are presented in the table below. Some of the types are not particularly significant in terms of their surface area and linear distances. However, it is nonetheless important to present them in an international context in which they may be much more common.

Each code in the table corresponds to a type of water body having similar characteristics, comprising a size class, a geographic unit and any local particularities or the influence of an upstream hydro-ecoregion.

Tableau 8 *The WFD national typology of surface waters.*

			National types and codes				
		Ranks (Loire-Bretagne basin)	8, 7	6	5	4	3, 2, 1
		Ranks (other river basins)	8, 7, 6	5	4	3	2, 1
Level-1 hydro-ecoregions (HER)		General situation or rivers exiting a different level-1 HER or a level-2 HER	TG - Very large	G - Large	M - Medium	P - Small	TP - Very small
20	CLAY-SAND DEPOSITS	General situation		GM20		P20	TP20
		River exiting HER 9 (Limestone plateaus)		GM20/9			
		River exiting HER 21 (Northern Massif Central)		G21	M21		
21	NORTHERN MASSIF CENTRAL	General situation				P21	TP21
3	SOUTHERN MASSIF CENTRAL	General situation		G3	M3	P3	TP3
		River exiting HER 19 (Grands Causses)			M3/19		
		River exiting HER 8 (Cévennes)			M3/8		
		River exiting HER 19 or 8		G3/19-8			
17	SEDIMENTARY DEPRESSIONS	General situation			M17	P17	TP17
		River exiting HER 3 or 21 (S. or N. Massif Central)	TG17/3-21	G17/3-21	M15-17/3-21	P17/3-21	TP17/3-21
15	SAÔNE PLAIN	River exiting HER 3 or 21					
		River exiting HER 5 (Jura)		G15/5	MP15/5		
		General situation	TG15		MP15		TP15
		River exiting HER 10 (Eastern limestone cuestas)	TG10-15/4				
5	JURA, NORTHERN PRE-ALPS	General situation		G5	M5	P5	TP5
		iver exiting HER 2 (Central Alps)	TG5/2	GM5/2			
TTGA	ALPINE RIVERS	General situation	TTGA				
2	CENTRAL ALPS	General situation		G2	MP2		TP2
7	SOUTHERN PRE-ALPS	General situation		GMP7			TP7
		River exiting HER 2 (Central Alps)	TG6-7/2	GM7/2			
6	MEDITERRANEAN	River exiting HER 2 or 7		GM6/2-7			
		River exiting HER 7 (Southern pre-Alps)		GM6/2-7			
		River exiting HER 8 (Cévennes)	TG6/1-8	GM6/8			
		River exiting HER 1 (Pyrenees)		GM6/1			
		General situation		G6	MP6		TP6
8	CEVENNES	General situation		GM8		PTP8	
		A-her2 n°70			M8/A	PTP8/A	
16	CORSICA	A-her2 n°22		G16	M16/A	PTP16/A	
		B-her2 n°88			M16/B	PTP16/B	
19	LIMESTONE PLATEAU (GRANDS CAUSSES)	General situation				P19	
		River exiting HER 8 (Cévennes)		GM19/8			
11	AQUITAINE LIMESTONE PLATEAU (CAUSSE)	General situation				P11	TP11
		River exiting HER 3 (South. MC) or 21 (North. MC)	TG11/3-21	G11/3-21	M11/3-21	P11/3-21	
14	AQUITAINE HILLS	River exiting HER 3, 8, 11 or 19	TG14/3-11	G14/3	M14/3-11		
		River exiting HER 3 (South. MC) or 8 (Cévennes)			M14/3-8		
		General situation		GM14		P14	TP14
		River exiting HER 1 (Pyrenees)	TG14/1	G14/1	M14/1	P14/1	
13	LANDES	General situation			M13	P13	TP13
1	PYRENEES	General situation		G1	M1	P1	TP1
12	ARMORICAN	A-Central-South (her2 no. 58 and 117)		G12	M12/A	P12/A	TP12/A
		A-West-North East (her2 no. 55, 59 and 118)			M12/B	P12/B	TP12/B
TTGL	LOIRE RIVER	General situation	TTGL				
9	LIMESTONE PLATEAUS	A-her2 n°57			M9/A	P9/A	
		General situation	TG9	G9	M9	P9	TP9
		River exiting HER 10 (in her2 no. 40)		G9/10	M9/10		
		River exiting HER 21 (Northern Massif Central)	TG9/21	G9-10/21	M9-10/21		
10	EASTERN LIMESTONE CUESTAS	River exiting HER 21 (Northern Massif Central)					
		General situation	TG10-15/4	G10	M10	P10	TP10
		River exiting HER 4 (Vosges)		G10/4	M10/4		
4	VOSGES	General situation			M4	P4	TP4
22	ARDENNES	River exiting HER 10 (Eastern limestone cuestas)	TG22/10				
		Cas général		GM22		P22	TP22
18	ALSACE	Cas général			MP18		TP18
		River exiting HER 4 (Vosges)		G18/4	M18/4	P18/4	

Key

■ *Column 1 indicates the number of the level-1 HER in which the river flows.*

■ *Column 2 indicates the name of the level-1 HER in which the river flows.*

■ *Column 3 indicates the situation of the river:*

- *general situation, rivers originating in the level-1 HER indicated;*
- *or rivers flowing in a specific level-2 HER having characteristics different than its level-1 HER;*
- *or rivers exiting an upstream HER.*

■ *Columns 4 to 8 indicate the size of the river.*

■ *Code. TTG = very, very large river ("A" for Alpine rivers and "L" for the Loire River), TG = very large river, G = large river, M = medium river, P = small river, TP = very small river.*

River types (no indication if the type does not exist)

1. *One or more letters indicating the size of the river.*
2. *One or more numbers indicating the level-1 HER in which the river (or river reach) flows.*
3. *If applicable, the letter A or B after a slash "/" indicating a specific level-2 HER.*
4. *If applicable, one or more numbers after a slash "/" indicating the level-1 HER influencing river characteristics (geochemistry, hydrology, etc.).*

Examples

■ *P22: small river in level-1 HER no. 22 (Ardennes).*

■ *GM22: large or medium-size river in level-1 HER no. 22 (Ardennes).*

■ *M10/4: medium-size river in level-1 HER no. 10 (Eastern limestone cuestas), exiting (influenced by) level-1 HER no. 4 (Vosges). Though located in the Eastern limestone cuestas, this type of river exhibits characteristics of rivers from the Vosges HER.*

■ *PTP16/B: small or very small river in level-2 HER no. 88 (Aléria plain), part of level-1 HER no. 16 (Corsica).*

■ *TG10-15/4: very large river in level-1 HER no. 10 (Eastern limestone cuestas) or no. 15 (Saône plain), exiting (influenced by) level-1 HER no. 4 (Vosges). Though located in the Eastern limestone cuestas or in the Saône plain, this type of river exhibits characteristics of rivers from the Vosges HER.*

■ Rivers in the overseas departments

The method employed is, in theory, identical to that used for continental France, but has been adapted to the natural conditions specific to the French overseas departments.

Regional criteria

Concerning the islands, the common predominant characteristics are the following:

- their small size (compared to continental France);
- their insular climate (tropical temperature regime with slight seasonal variations, major spatial heterogeneity in precipitation with maximum values far greater than in continental France and, in some cases, uneven distribution of precipitation between windward and leeward regions);
- a highly volcanic landscape reinforcing the uneven distribution.

As a result, the regions of each island are based on:

- elevations, distinguishing the lower regions where precipitation is limited;
- slope orientations in areas with high elevations (Reunion Island);
- the local geomorphology, where applicable.

Longitudinal zoning

Longitudinal zoning is a decisive element in structuring the ecosystems of continental water bodies, but is of limited usefulness in the islands. Upstream-downstream zoning is proposed only in the hydro-ecoregions with significant relief, where the differences in altitude and slope indicate probable differences in the structure and organisation of biological communities.

Consequently, "upstream" and "downstream" types exist for rivers in hydro-ecoregions with marked relief. The limit is generally located where major shifts in the slope of the long profile occur, at confluences with larger rivers (ranked 3 or higher) or at any other point that is easily identifiable locally and marks the transition between the two zones.

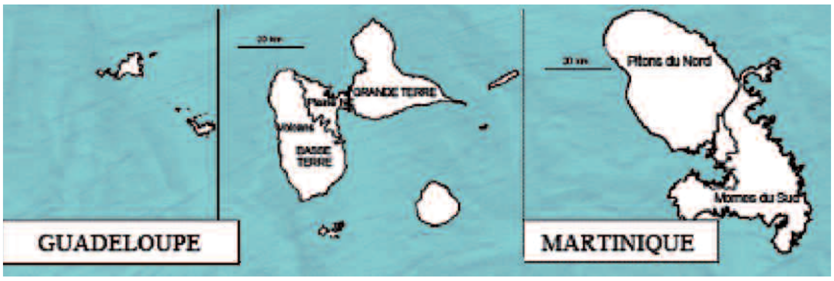
The proposed typology, structured using a similar basis for the various islands, still distinguishes between each island, even in the absence of sufficient data on aquatic fauna and ecosystem operation. The resulting typology and its codes are presented in the table below. Each code in the table corresponds to a type of water body with similar characteristics.

Tableau 9 *WFD typology for overseas rivers.*

Overseas-territorial types and codes			
		Longitudinal zoning	
Overseas territory	Hydro-ecoregion	Downstream	Upstream
GUADELOUPE	Basse Terre, North-East plain	MP31	
	Grande Terre and other islands	MP32	
	Basse Terre, volcanoes	M33	P33
MARTINIQUE	Northern peaks	M41	P41
	Southern hills	MP42	
REUNION	Windward cirques	M61	P61
	Leeward cirques	M62	P62
	Windward slopes	MP63	
	Leeward slopes	MP64	

Key

M = medium-sized rivers (downstream). P = small rivers (upstream). MP = river of undetermined size.
First digit: 3 for Guadeloupe, 4 for Martinique and 6 for Reunion.
Second digit: number of the hydro-ecoregion in each department (1 to 4, depending on the island).



NB The data on Guiana are still being processed.

The QAS typology (Aquascop, 1997)

This typology was produced as part of an overall effort by the Water agencies in the 1990s to formulate the QASs (quality-assessment systems) intended to assess the quality of the three major compartments in river ecosystems, i.e. water, biology and the physical environment, and serve as a decision-aid tool for development, maintenance and restoration work on river ecosystems and the quality of the compartments.

The first step was to set up a typology of rivers in France. Carried out by Aquascop in 1997, this work produced a proposal for a "simplified physical typology of French rivers" on the one to one million scale.
This simplified physical typology of French rivers was based on a hierarchy of five criteria:

- energy;
- sediment transport;
- geology;
- valley bottom (floodplain);
- water input.

It would appear, however, that these criteria were not systematically applied in the final typology. For example:
- geology in not a factor for high-energy rivers;
- sediment transport is assumed to be identical for all rivers with medium to low energy levels, which is clearly not the case. For example, in type 233, the Thouet River transports zero sediment whereas the Armançon River transports an abundant quantity of coarse alluvial bedload.
- etc.

In other cases, the hierarchy of criteria was not strictly observed. For example, in type 214, geology is a factor both before and after the valley bottom.

Criterion values

The various criteria, notably energy and sediment transport, the first two discriminant factors in the typology, are evaluated simply on the basis of "expert opinion", without any quantitative input.
- Energy is qualified as "very high to high", "medium to low" or "low to zero".
- Sediment transport is qualified as "high", "medium to low" or "low".

Practically speaking, the current division into a small number of classes based on "expert opinion" produces fairly good results, but raises two types of difficulties:
- concerning its accuracy, which would seem to vary from region to region (depending on the know-how of the experts involved in its formulation);
- concerning the possibilities of improving system application and refining the scale used.

Areal nature of the typology

The proposed classification makes it very clear that in most cases, the river types are defined in areal terms and are highly similar to the hydro-ecoregions defined by Wasson *et al.* (HERs defined for the Loire River in 1993). For example:
- all rivers in Western Brittany are type "214 - Low plateau, hard rock", which corresponds to medium to low energy, medium to low transport, crystalline or sandstone terrain with the valley bottom in massive rock formations;
- the rivers in the limestone areas located north and south of the Loire River and in the Beauce region are almost all classed as type "233 - Limestone valley", which corresponds to medium to low energy, medium to low transport, limestone-plateau type sedimentary terrain with a floodplain and where there is little karstic influence.

Even though the typology is organised and presented differently (a hierarchy of criteria), rivers are still characterised by the ecoregional influences to which they are subjected (rivers of the same type, but located in different geographic regions, are in fact indicative of the high similarities between regions or sub-regions, depending on the degree of precision).

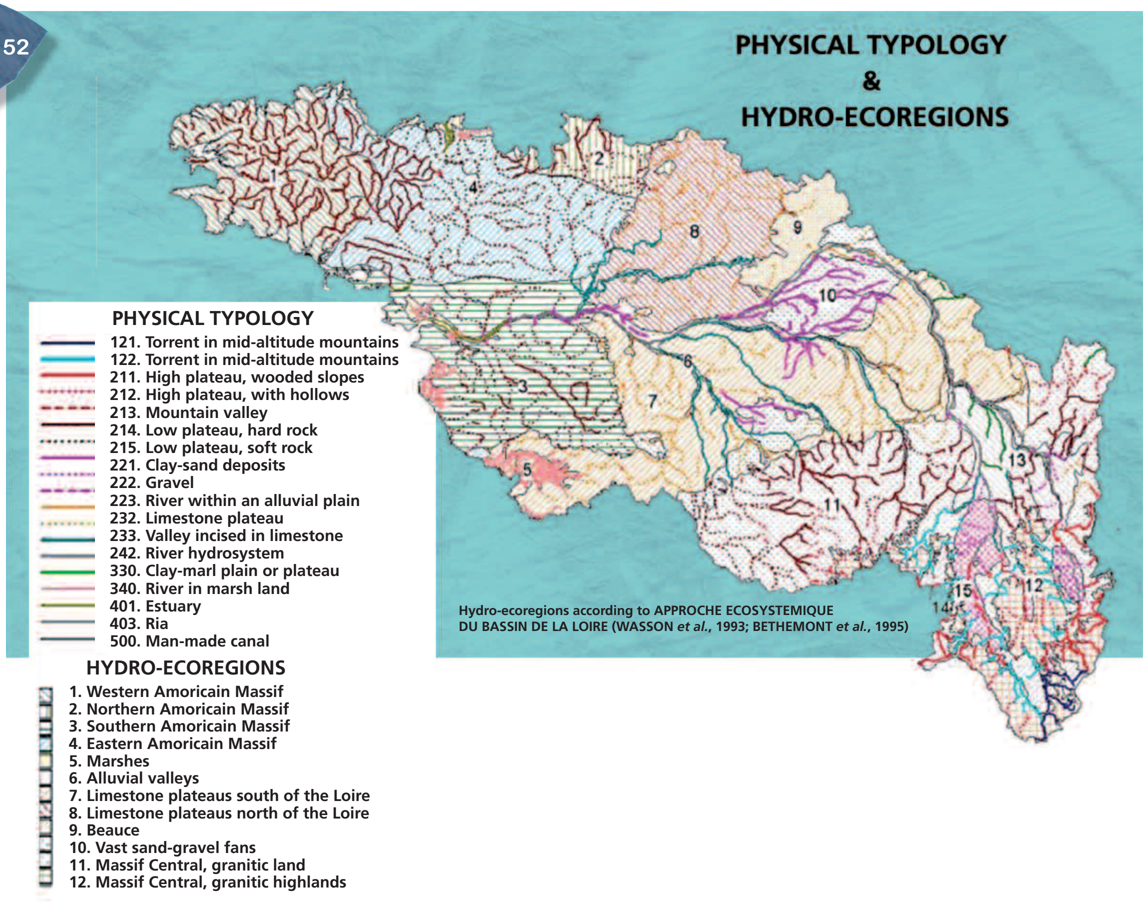
The influence of regions on their rivers is obvious, however the areal nature of the typology raises two questions:

■ does this typology produce significantly more relevant information than the simple division in hydro-ecoregions?

■ are the rivers in a region in fact more consistent in type (on the scale and with the objectives of this method), notably in terms of their size and their upstream course in other regions (if applicable)?

NB The latter point is covered partially by the notion of **allochthonous rivers.**

Figure 152



Example of the Aquascop typology (1997) applied to the Loire basin and correlation with the hydro-ecoregions (Malavoi, AREA, 2000).

In other words, this typology distinguishes rivers subject to the same influences (ecoregional context), but that exhibit various significant functional differences depending on geomorphological criteria, notably their size (position in the river network).

■ Conclusion

The "simplified physical typology" provides a basis for an ecoregional description of rivers, on a scale near that of the hydro-ecoregions. It may be seen as a **classification** of rivers in 30 types "arranged" according to certain criteria, rather than as an effort to formulate a "hierarchy-based classification". It is, however, of value, even though it has its weaknesses, some of which would seem to lie in the concept itself.

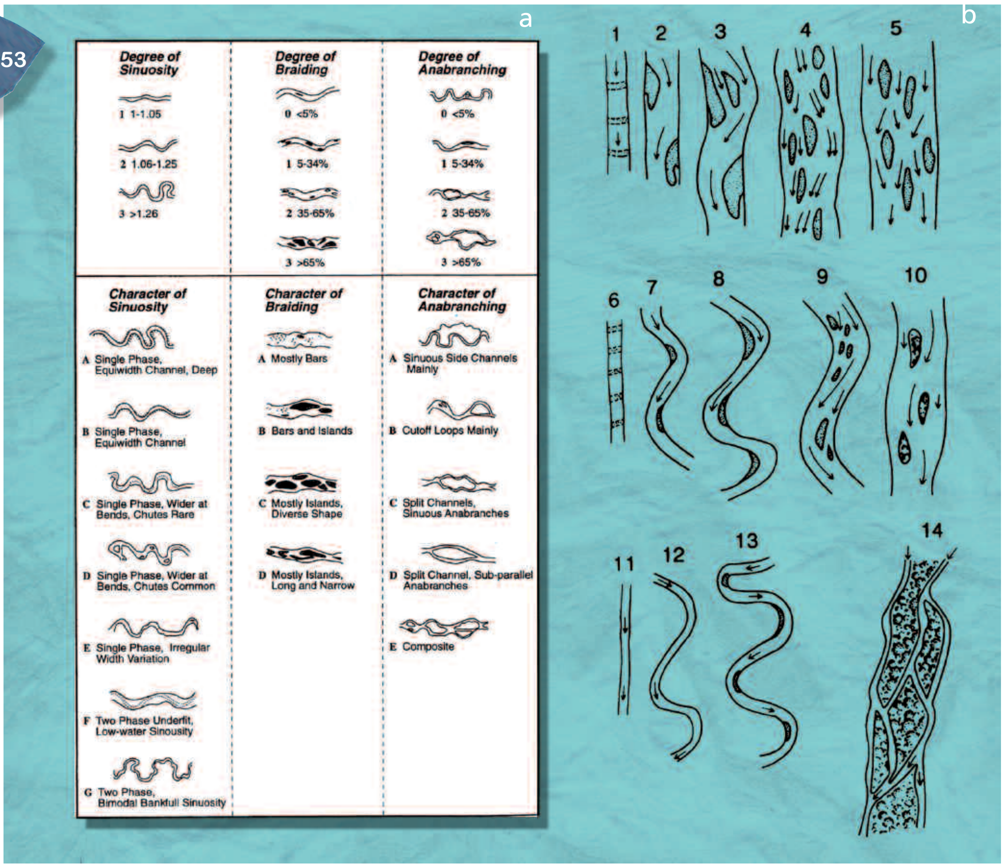
For a number of reasons, however, this approach strikes us as incapable of truly characterising the functional aspects of environments and, in addition, it deals only with 77 000 kilometres of river, generally ranked 4 or higher.

Some foreign typologies

■ "Simple" classifications

In the scientific literature, many attempts have been made to classify rivers, generally based exclusively on the river pattern, i.e. on a response factor. Two examples are presented below, without any comments.

Figure 153



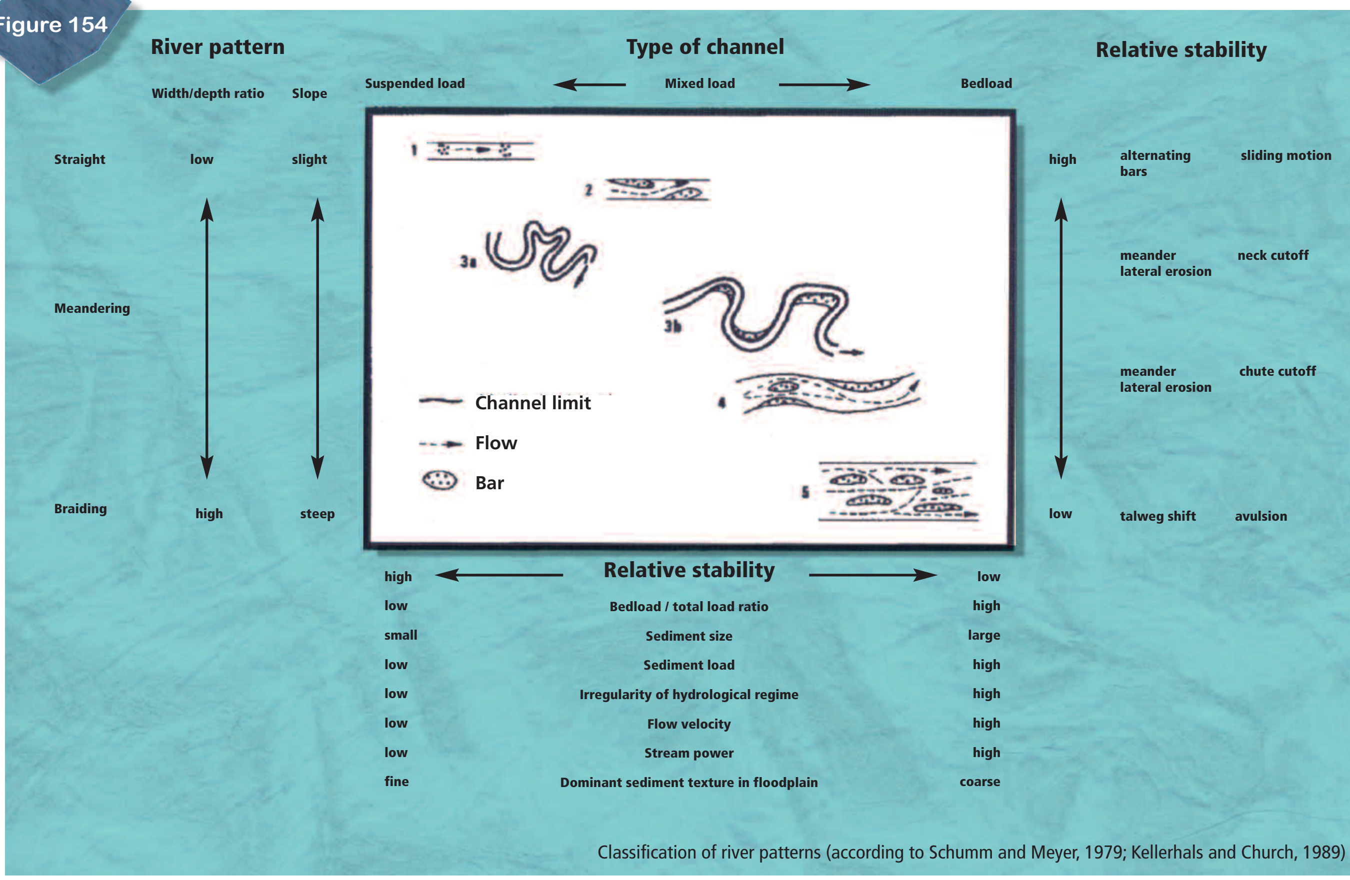
Examples of river classifications based on the pattern. (a) Brice (1975), (b) Schumm (1981).

■ Functional classifications

The "simple" classifications are occasionally coupled with more "dynamic" typologies. As noted above, river patterns can serve as good indicators for certain processes or certain degrees of intensity in hydromorphological processes.

For example, the simplified typology by Schumm and Meyer (1979, Figure 154) provides qualitative information on a number of functional characteristics of the river in question. Simply by determining the river pattern, it is possible to know if the river is dynamic or not, if the alluvial load is fine, coarse or mixed, if the stream power is high or low, etc.

Figure 154



Classification of river patterns (according to Schumm and Meyer, 1979; Kellerhals and Church, 1989)

The dynamic typology of Schumm and Meyer (1979) in Bravard and Petit (1997).

■ The Rosgen typology (1996)

The Rosgen typology merits particular attention because, though often criticised, it is the most commonly used typology in the United States.

It consists of a two-stage classification system producing results on two classification levels.

Level I comprising 9 types

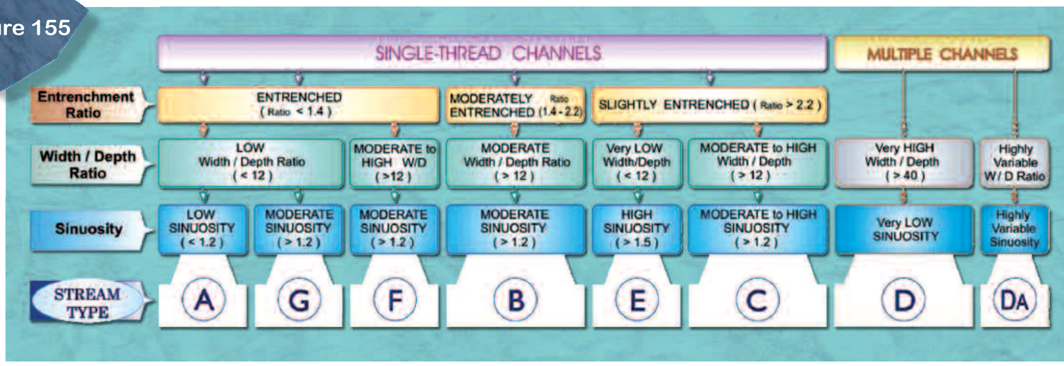
The first level is based on the following parameters:

- number of channels;
- entrenchment ratio (valley width measured at twice the bankfull depth. Must be measured in the field);
- width / depth ratio (bankfull). Must be measured in the field;
- sinuosity index.

This first level initially comprised eight types, but was completed with a ninth, type Aa+ specifically for mountain rivers (Figures 155 et 156).

Each type corresponds to functional geomorphological characteristics close to those proposed by Schumm and Meyer (1979), i.e. stream power, sediment input, lateral stability, etc.

Figure 155



First level in the Rosgen typology (1994).

Figure 156

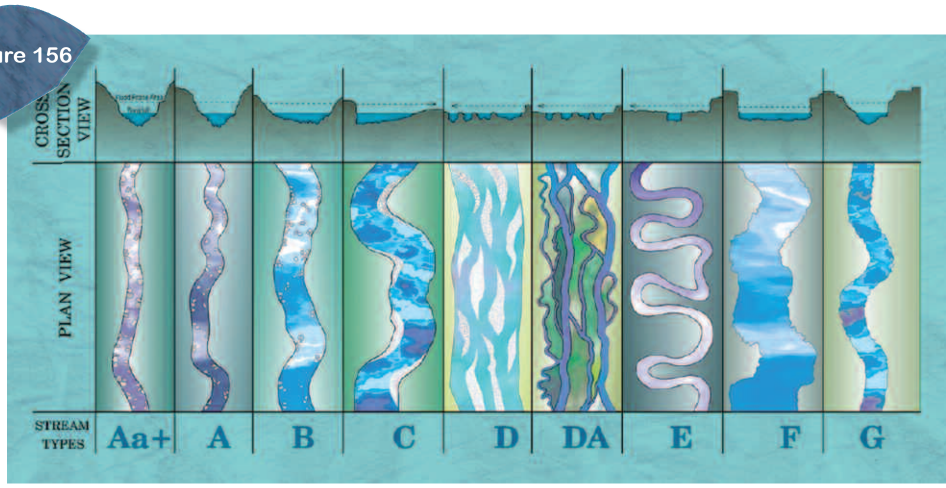
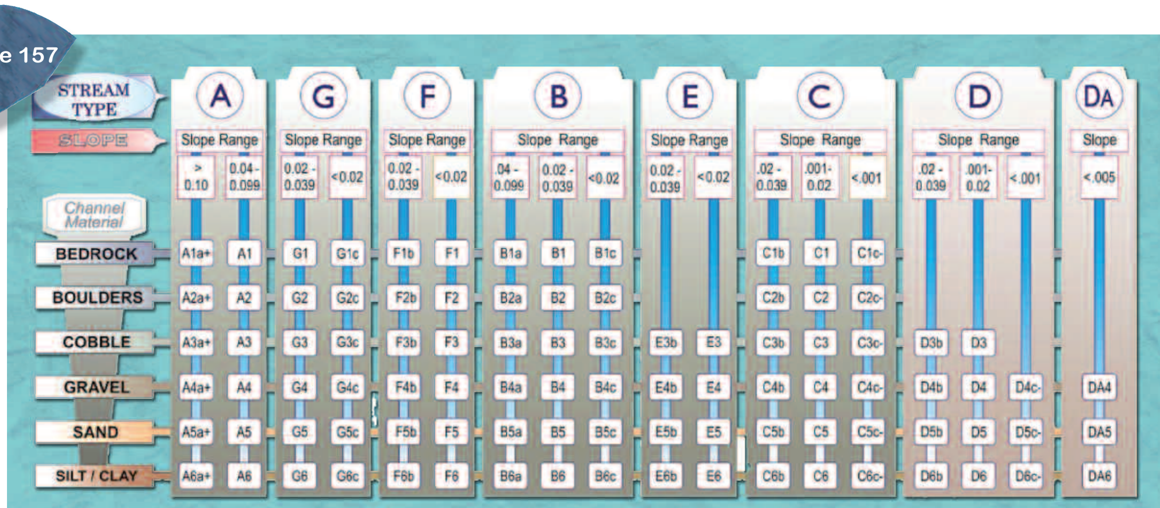


Illustration showing cross profiles and plan views of the first-level types in the Rosgen typology.

Levels II and IIa comprising 41 or 94 types

Level II first divides rivers according to their slope, then according to the channel material. The result is a classification with 94 types.

Figure 157



Second level in the Rosgen typology (1994).

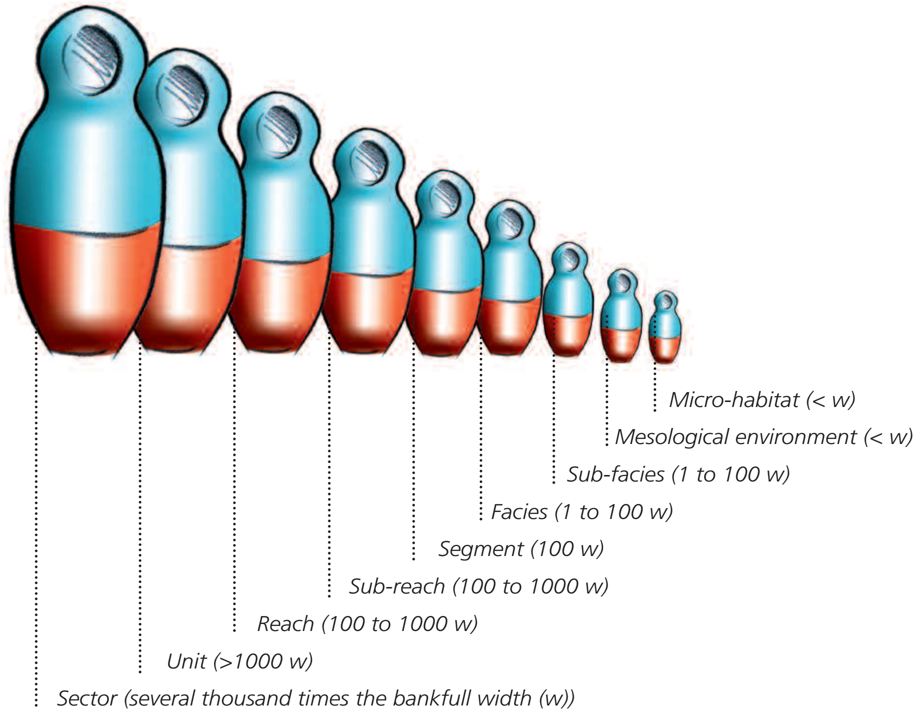
An intermediate level with 41 types (slope is no longer a factor) has been proposed but would not seem to be widely used.
This typology (levels I and II) has been adopted by many river-management services in the U.S. and references to Rosgen types (e.g. B3, E5b) are frequent in scientific and technical publications.
However, two aspects compel us to question its applicability in France:

- the typology is not easy to use because two of the main dichotomous variables (entrenchment ratio and width/depth ratio) theoretically require measurements in the field;
- it uses both control factors (bedrock in the riverbed) and response factors (river pattern, width/depth ratio, etc.), which, from the theoretical point of view, is far from ideal.

Proposed methods for river typologies and divisions

River divisions

The proposed river divisions are presented below, in decreasing size and with their length (order of magnitude) expressed in multiples of the bankfull width.



NB The last two divisions are of more ecological than geomorphological significance in that the size of these habitats depends on that of their inhabitants.

■ Which divisions are best suited to management purposes?

At least two levels would appear to be necessary for management purposes.

Level 1, consisting of geomorphologically uniform reaches

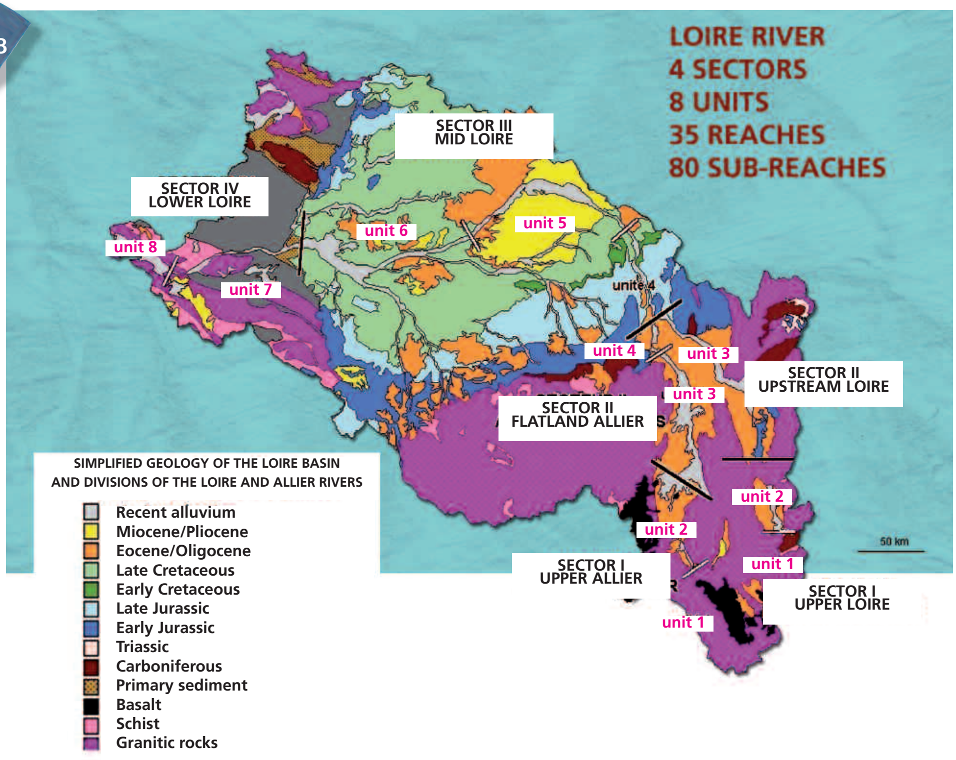
This division strikes us as the most relevant for overall, integrated river management. It can be used by all stakeholders and managers, in all sectors and fields. Reaches can be determined simply on the basis of geomorphological and hydrological control factors.

Level 2, consisting of sub-reaches

For this level, each scientific discipline and each river manager can select the relevant set of discriminant parameters. For example, geomorphologists can distinguish meandering sub-reaches in an otherwise braided reach or embanked sub-reaches in a reach traversing a wide valley bottom. Phytosociologists can divide reaches depending on whether there is riparian vegetation, an alluvial forest, etc. Biologists can use criteria such as water quality, the frequency of river facies, etc.

NB The two top divisions (sectors and units) are of interest primarily for managers working on the regional and national levels. The discriminant factors are essentially their presence in a level-1 hydro-ecoregion (HER1) or a level-2 hydro-ecoregion (HER2), given that these hydro-ecoregions (Wasson *et al.*, 2002) are determined by the major geomorphological control factors (geology, relief, climate).

Figure 158



The Loire River divided into sectors, units, reaches and sub-reaches (Malavoi, 2002).

Method selected for division into uniform reaches

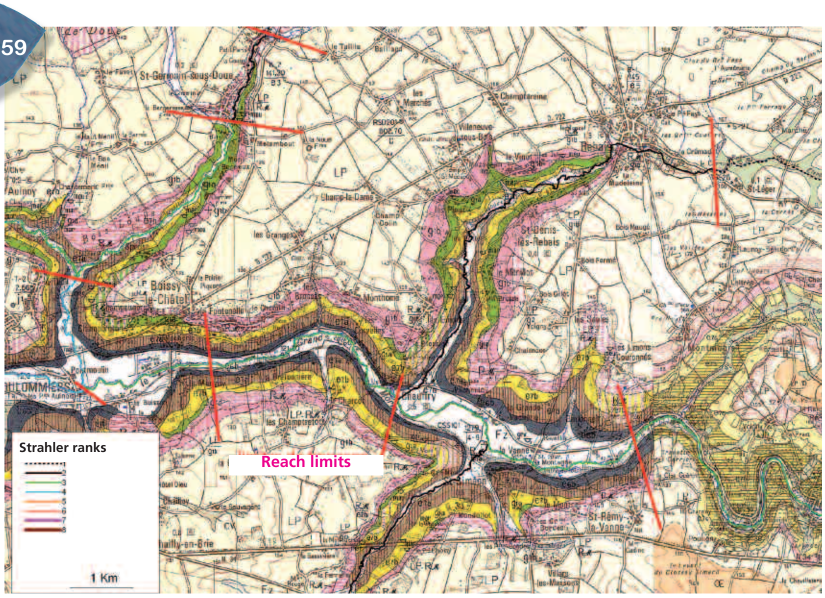
The division of 225 000 kilometres of French rivers (from a total of approximately 500 000 kilometres) into uniform reaches was carried out by Cemagref in 2008 (Valette *et al.*) using three control factors that are easily accessible in existing databases:

- width of the valley bottom;
- valley slope;
- confluence with large rivers (this "hydrological" parameter is used as a substitute for actual discharge values that are currently difficult to access on a uniform basis).

Width of the valley bottom

The **width of the alluvial valley bottom** is an **essential control factor** for geodynamic processes, flooding, ecological processes within the river corridor and even socio-economic pressures. It is marked Fz and Fyz on geological maps and served as the primary factor in composing uniform reaches.

Figure 159



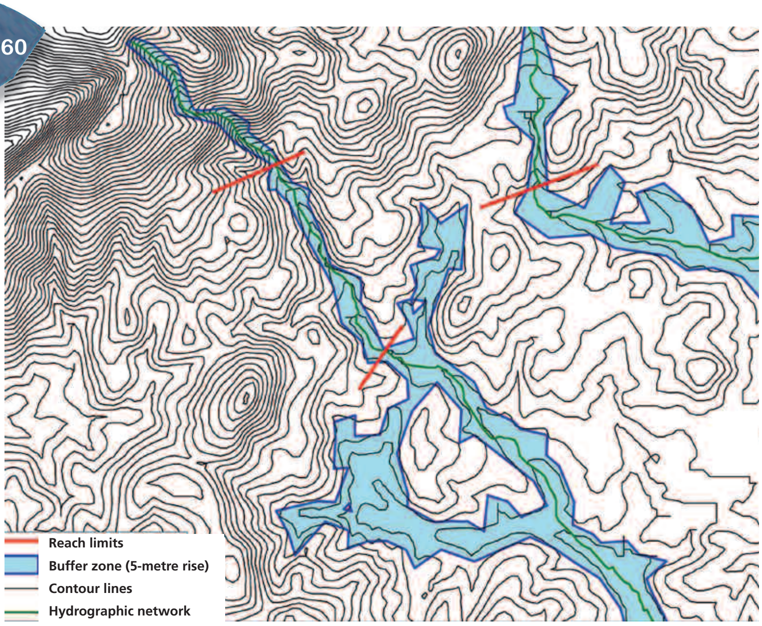
© BRGM

Example of a division into uniform reaches based on the width of the valley bottom (BRGM map).

Valley slope

Another important factor is the valley slope, which contributes to the potential stream power and notably its capacity to entrain and transport sediment. This factor is determined visually using the 50-metre DTM (digital terrain model) developed by IGN (French National Geographic Institute, BDalti), which served to generate a layer showing slope values and 5 or 10-metre contour lines.

Figure 160



Example of a division into uniform reaches based on the valley slope.

Hydrology (Strahler ranks)

The third factor is the Strahler rank (1957). This hierarchical numbering system is well suited to quantifying hydrographic networks and has the additional advantage of taking the longitudinal evolution of rivers into account. In this method, reach limits were positioned at each:

- change in the Strahler rank for ranks 1 to 3;
- confluence of a river ranked 4 with a river ranked 3 or 4;
- confluence of a river ranked 5 or higher with a river of the same rank or up to two ranks lower (for example, confluence of a river ranked 6 with a river ranked 4, 5 or 6).

Typology

■ Basic typology

Using the national system of uniform reaches, that is available as a GIS database, it is possible to create a "basic" typology employing the following parameters:

- Strahler rank and the relevant hydro-ecoregion (see the WFD national typology above);
- valley slope;
- valley width.

Work on this typology is now in the final stages.

■ More precise typology

This second-level typology is based on the parameters used to calculate the geodynamic rank (see chapter 3 for the discussion on the usefulness of this concept in understanding and predicting hydromorphological processes):

- unit stream power (ω);
- potential natural bank erodibility (B);
- sediment inputs (A).

Unit stream power (ω)	< 10 W/m²	10 - 30 W/m²	30 - 100 W/m²	> 100 W/m²
Bank erodibility (B)	Zero	Low	Medium	High
Sediment inputs (A)	Zero	Low	Medium	High

Work on this typology continues because it is more difficult to obtain the parameter data. There are 64 potential types, however some combinations are not realistic, e.g. low stream power and high sediment transport.

■ Additional information

In addition to the typological characteristics listed above, the plan is to add other descriptive parameters (response factors) to the data on each uniform reach:

- river pattern;
- grain size of the coarse bedload being transported;
- mean bankfull width and depth;
- the river facies present in the reach.

NB Acquisition of the data for these characteristics is not currently planned for the entire country, but will depend on the studies and investigations carried out on each river.

■ In conclusion, a postulate on interpreting river typologies/divisions

We postulate that if the division parameters and linked typology factors have been astutely selected (and the data correctly collected), they should make it possible to delimit uniform reaches within which, according to the laws of river geodynamics, the response factors should also be uniform.

Ideally, on the basis of the control factors, it should be possible to determine the precise characteristics of the response factors, e.g. river pattern, width, depth, slope, intensity of the geodynamic processes, etc. Unfortunately, that is still not possible, given the high level of uncertainty concerning the relationships between hydraulic geometry and river morphometrics (see the previous chapters), however current research should gradually improve the situation.

A particular typology, the river-facies typology

Usefulness of a river-facies typology

This typology addresses a much smaller scale than the preceding typologies because the goal is to identify river sub-sections using hydromorphological characteristics that are seen as good indicators of the **types of habitat available for the aquatic fauna,** i.e. macrohabitats and even **mesohabitats.**

The river facies are short river lengths (between 1 and 10 times the bankfull width approximately) that have consistent flow features, notably flow velocities, depth, sediment grain size, riverbed slope, hydraulic gradient and cross profile, spanning a few square metres to a few hundred square metres.

Hydromorphologists see facies, notably alternating riffles and pools, as the fundamental units in rivers whose physical function lies in the optimal dissipation of energy. They are also the long-term manifestations of the constraints exerted by geology, terrestrial morphology, plant cover and climate.

Hydrobiologists also use these morphological units to describe habitat use by fish and to establish their sampling units, e.g. sampling of benthic macroinvertebrates, fish inventories or selection of representative facies sequences in a reach (stations) for methods based on microhabitats.

It is often difficult to identify river facies because in real life, there are few "clear-cut" cases. The identification criteria have suffered from subjective implementation where some authors focus on the substratum, others on the hydraulic gradient, the distribution of water depths and velocities, the Froude number (a dimensionless ratio of the mean velocity to the water depth) or the characteristics of the water surface.

Malavoi (1989) and Malavoi and Souchon (2002) proposed an approach which, though comprising imperfections resulting in operator bias, nonetheless attempts to produce a more objective description based on a **system of discriminant criteria.**

Selecting discriminant criteria for facies

Two classification levels are proposed.

■ Level 1

Two level-1 criteria were selected:

- mean water depth;
- mean flow velocity.

These two factors must be measured for a mean low flow close to the interannual mean discharge of low month.

It is then possible to propose an initial classification level for river facies on the basis of their depth:

- **deep facies,** i.e. depths greater than 60 cm including lotic channels (LOTC), lentic channels (LENC), concavity pools (CCVP) and dissipation pools (DISP);
- **shallow facies,** i.e. depths less than 60 cm including runs (RUNS), glides (GLID), riffles (RIFF), rapids (RAPI) and cascades (CASC);

or on the basis of the flow velocity:

- **lentic facies,** i.e. flow velocities less than 30 cm/s, e.g. pools, lentic channels, glides;
- **lotic facies,** i.e. flow velocities greater than 30 cm/s, e.g. riffles, runs, rapids, lotic channels.

NB One possibility would be to propose a typology based on dimensionless values making it possible to identify riffles 5 mm deep in a scale model and 50 cm deep in a river 100 metres wide. However, in response to requests for a classification system coming primarily from biologists, it was decided to develop a typology based on raw data that can be linked to the types of communities.

Level 2

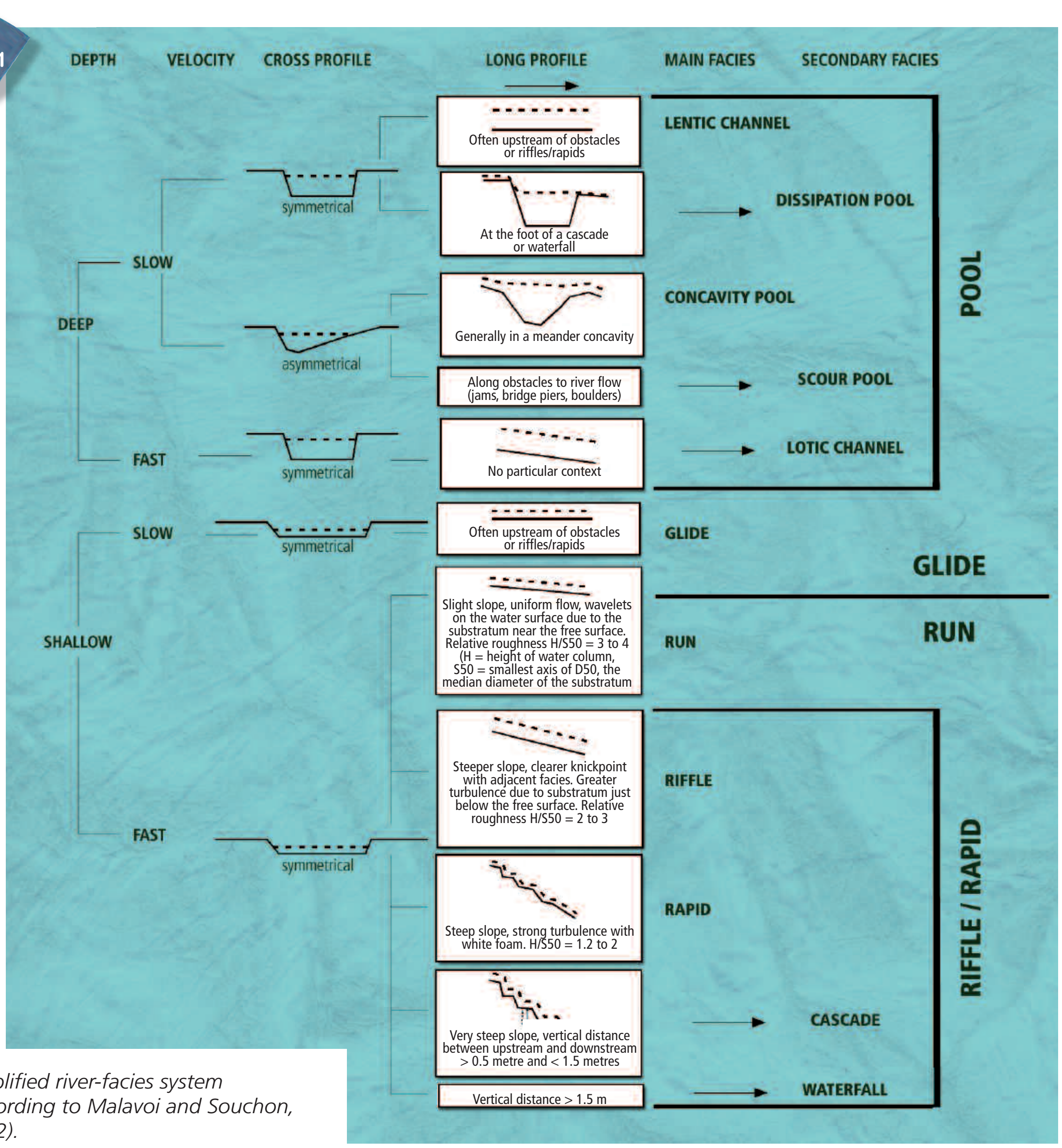
The level-2 criteria used to refine the level-1 results are the following:

- cross profile;
- long profile and water-surface characteristics.

A third level, not included here in the differentiation system, can be used to refine the classification even further. The criterion is the grain size of the substratum.

The dichotomous system currently used (see the figure below) results in 11 facies types, including six major and five secondary types. If a simplified system is required, the 11 types may be grouped into four mega-types (on the right in the figure).

Figure 161



Simplified river-facies system (according to Malavoi and Souchon, 2002).

We will see below that these river facies, the result of geodynamic erosion and sediment-transport processes, are one of the main means to establish links between the hydromorphological operation and the ecological operation of rivers.

Examples

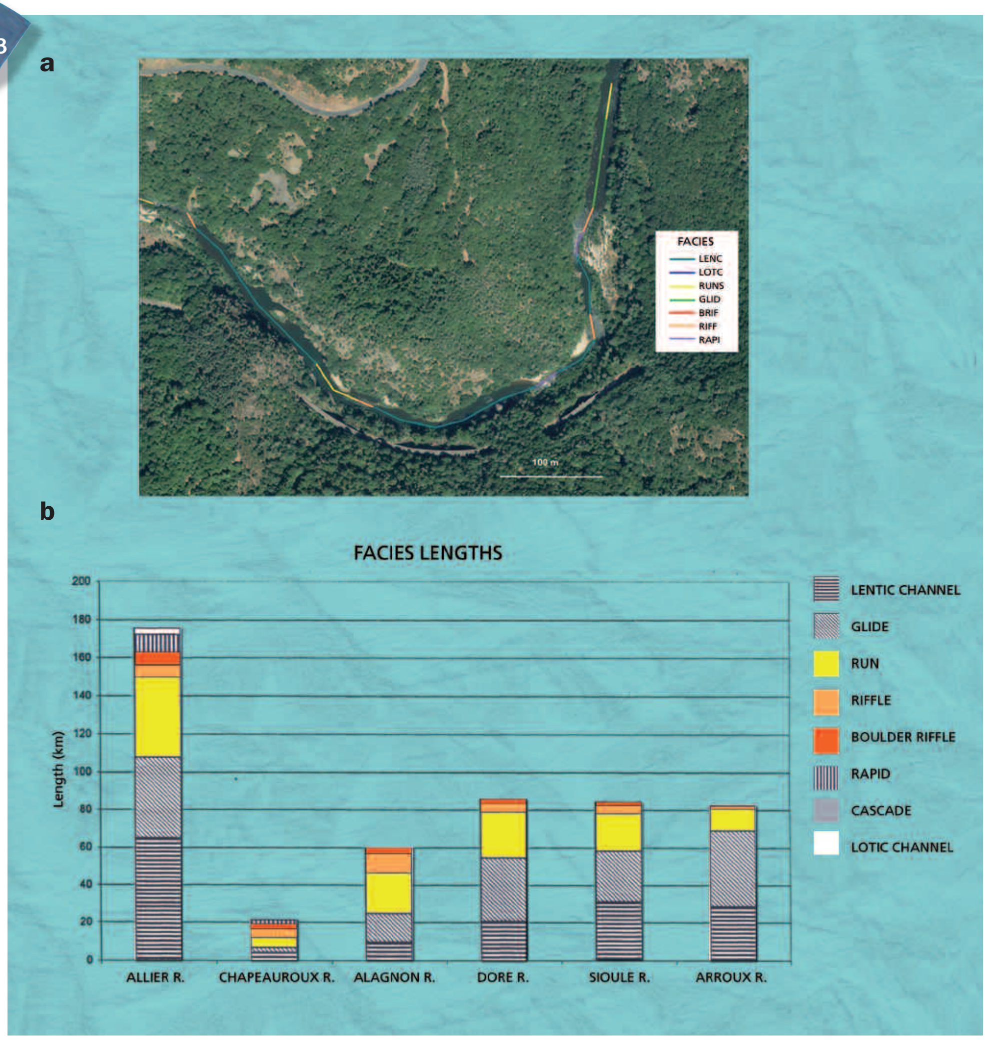
Figure 162

a- b- c- d- e- f- © J.R. Malavoi

Some examples of river facies.

An example of the facies typology and mapping applied to a river is presented in the figure below. The purpose of the study (Malavoi, 1999) was to map the potential zones for the reproduction and growth of Atlantic salmon in the Allier River basin. These zones were detectable directly via the typology because several facies (runs, riffles and particularly boulder riffles that could be distinguished) corresponded to the type of habitat for the spawning and growth of juvenile salmon.

Figure 163



a- © fond IGN

(a) Map of river facies on the upper Allier River (IGN base map). (b) Summary of the map data for six "salmon" rivers in the Allier River basin (Malavoi, 1999). The best facies for salmon spawning and growth are shown in colour.

The table below lists some facies lengths expressed in multiples of the bankfull width, based on data acquired during the study. The measurements were carried out on high-power rivers in the Allier River basin and cannot be extrapolated to all types of rivers in France, however the results provide a consistent set of indicative values.

Note that the length of riffles is approximately the same as the bankfull width, whereas on the opposite end of the spectrum, lentic channels and glides are generally 8 to 10 times longer than the bankfull width. Note also that only the Chapeauroux River has cascades.

Tableau 10 *Examples of facies lengths expressed in multiples of the bankfull width.*

	LENC	GLID	RUNS	RIFF	BRIF	RAPI	CASC	LOTC
ALLIER R.	8.57	6.63	3.12	1.36	1.76	2.46		2.19
ALLAGNON R.	7.53	5.81	4.80	2.21	3.16	1.57		1.08
ARROUX R.	11.41	8.40	2.59	0.89	2.04			
CHAPEAUROUX R.	7.03	6.07	4.96	4.39	5.33	6.45	3.50	
DORE R.	8.72	9.83	4.61	1.16	2.20	0.54		1.48