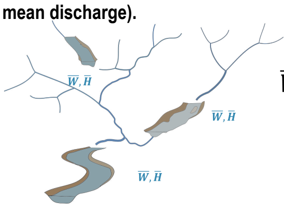
I.S.RIVERS LYON 2018

Modelling the hydraulics of river networks and management applications.

Introduction

Large-scale variations in river hydraulics are often represented by hydraulic geometry relationships (HG) introduced by Leopold and Maddock (1953).

"Downstream hydraulic geometry" describes the spatial variations of river hydraulics along river networks at a characteristic discharge (e.g., bankfull or mean discharge).

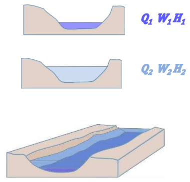


$$\overline{W} = a_{ds}\overline{Q}^{b_{ds}}$$

$$\overline{H} = c_{ds}\overline{Q}^{f_{ds}}$$

$\overline{W}$: mean wetted width
$\overline{H}$: mean water depth
$\overline{Q}$: mean discharge

"At-a-station hydraulic geometry" describes the temporal variations of hydraulic parameters with discharge at a given site.



$$W = aQ^b$$

$$H = cQ^f$$

W: wetted width
H: water depth
Q: instantaneous discharge

Values of parameters are generally around :

- At-a-station : 0.15 for b, 0.4 for f, a and c are related to downstream hydraulic geometry (Lamouroux, 2008).
- Downstream : 0.5 for b_{ds}, 0.36 for f_{ds}, 2,2 for a_{ds} and 0,38 for c_{ds}.

However considerable variations occur between sites.

➡ Implication of others factors (e.g. bank vegetation, geomorphic units, fluvial pattern, bank cohesion).
➡ Hydraulic geometry relationships across sites remain largely unexplained.

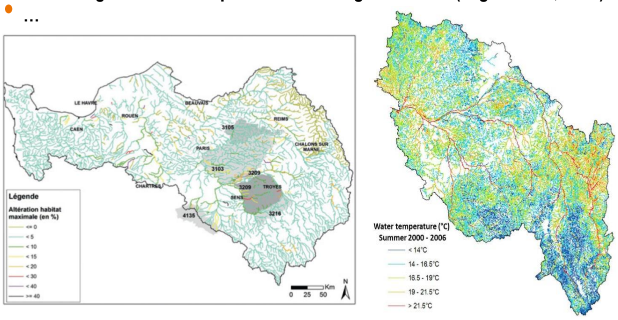
Most past studies on hydraulic geometry were made at the cross-section scale
➡ Our approach : analyse HG at the reach scale (10 X width or longer ➔ variations at individual cross-section are smoothed)

Interest of hydraulic geometry

HG are translators of discharge information to hydraulic characteristics at large scale.

Many applications at catchment scale :

- Modelling water temperature (Beaufort et al., 2015)
- Simulation of nitrogen fluxes (Dupas et al., 2013)
- Assessing fish habitat impact with discharge alteration (Miguel et al., 2016).
- …



Examples of applications : modelling river temperature on the Loire catchment (Beaufort *et al*., 2015), estimating habitat alteration due to water abstraction on the Seine catchment (Miguel *et al*., 2016),

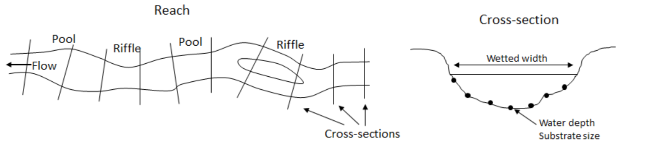
➡ **A better comprehension of hydraulic geometry variability between rivers will improve these types of simulation.**

Objectives of the project

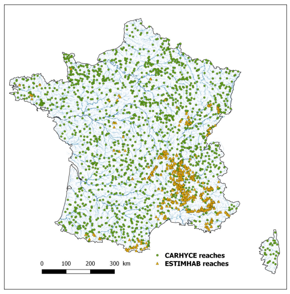
Collation of > 1000 stream reaches hydraulic characteristics at several flows rates from France, New-Zealand and elsewhere.

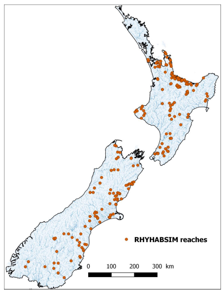
Data come mainly from :

- ESTIMHAB and RHYHABSIM habitat models (Lamouroux, 2002; Booker, 2016)
- Hydromorphological characterization national tool "CARHYCE" (Gob et al., 2014).



Scheme of reach survey: every reach comprises >10 cross-sections and includes several sequences of geomorphic units. On every cross-section, wetted width, water depths and substrates size are measured.





Locations of the studied reaches

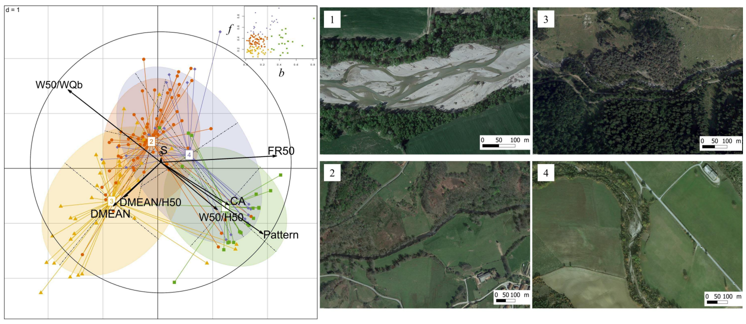
➡ Analyse and model variability of hydraulic characteristics
➡ Generalisation at international scale of these models (prediction at unvisited sites)

Progress

Exploration of relations between at-a-station exponents b and f of 560 French reaches and reach- and catchment- characteristics derived from :

- GIS (e.g. topography, catchment area, climate, geology)
- Aerial imagery (e.g. fluvial pattern, bankfull width)
- Field survey (e.g. riparian vegetation, grain size, riffle proportion)
- Empirical estimations (e.g. Froude number at median flow)

➡ Change of width: lateral and longitudinal channel shape, sediment delivery and fluvial pattern.
➡ Change of depth: longitudinal channel shape and flow resistance.
➡ Predictions of at-a-station HG are possible across river networks



Factorial map of a linear discriminant analysis on 4 distinct groups of reaches grouped by their b and f exponents values and related to explanatory variables such as fluvial pattern ("Pattern") stream mean grain size ("DMEAN"). Black arrows show the main correlations between axes and explanatory variables. Images illustrates examples of rivers for these 4 groups.

Comparisons of different models combining at-a-station and downstream hydraulic geometry and depending of explanatory variables availability (i.e. GIS variables or empirical estimation at characteristic discharge) are currently analysed in France and New-Zealand.

The resulting hydraulic geometry models of the project will be used for environmental applications. In particular, this project will focus on the impacts on aquatic habitats of large-scale flow alterations.

Acknowledgments

Many thanks to staff from Bay of Plenty and Northland regional councils and from NIWA for collecting RHYHABSIM input files. Many thanks also to the staff from the AFB (Agence Française pour la Biodiversité, ex-ONEMA) for supplying database of CARHYCE surveys. Thanks also to the Water Agency Rhône-Méditerranée-Corse and the many catchment stakeholders who contributed to gather ESTIMHAB row data.

References

Beaufort, A., F. Moatar, F. Curie, A. Ducharne, V. Bustillo, D. Thiéry (2015) River temperature modelling by Strahler order at the regional scale in the Loire River basin, France. *River Research and Applications*.
Booker, D.J. 2016. Generalized models of riverine fish hydraulic habitat. The Journal of Ecohydraulics, 1, 31-49.
Dupas, R., F. Curie, C. Gascuel-Odoux, F. Moatar, M. Delmas, V. Parnaudeau, P. Durand (2013) Assessing N emissions in surface water at the national level: Comparison of country-wide vs. regionalized models. *Science of the Total Environment,* 443, 152-162.
Gob, F., C. Bilodeau, N. Thommeret, J. Belliard, M.-B. Albert, V. Tamisier, J.-M. Baudoin, K. Kreutzenberger (2014) A tool for the characterisation of the hydromorphology of rivers in line with the application of the European Water Framework Directive in France (CARHYCE). *Geomorphologie-Relief Processus Environnement*, 57-72.
Lamouroux, N., 2008. Hydraulic geometry of stream reaches and ecological implications. In: Habersack H., Piégay H., Rinaldi M. (Eds.), Gravel Bed Rivers 6: From Process Understanding to the Restoration of Mountain Rivers. Developments in Earth Surface Processes, pp. 661-675.
Lamouroux, N. 2002. Estimhab: estimating instream habitat quality changes associated with hydraulic river management. Shareware & User's guide. Cemagref Lyon - Onema.
Leopold, L.B., Maddock , T., 1953. The hydraulic geometry of stream channels and some physiographic implications. 252.
Miguel, C., N. Lamouroux, H. Pella, B. Labarthe, N. Flipo, M. Akopian, J. Belliard (2016) Altération d'habitat hydraulique à l'échelle des bassins versants: impacts des prélèvements en nappe du bassin Seine-Normandie. *La Houille Blanche*, 65-74.

Authors : Morel M.[1], Booker D.[2], Stewardson M.[3], Vivier A.[4], Piégay H.[5], Gob F.[6], Tamisier V.[6], Lamouroux N.[1]

[1] Irstea UR RIVERLY, Villeurbanne, France; [2] NIWA, Christchurch, New Zealand; [3] University of Melbourne, Melbourne, Australia; [4] Agence française pour la biodiversité, Vincennes, France; [5] CNRS -UMR 500 ENS Lyon, Université de Lyon, France; [6] Université Paris 1, UMR 8591 LGP; Paris, France.

AGENCE FRANÇAISE POUR LA BIODIVERSITÉ
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irstea

maxime.morel@irstea.fr