Uncertainties on flow calculated from stage-discharge rating curves in small streams

François Birgand, Guillaume Lellouche and Timothy Appelboom

1. Introduction

- Discharge is now generally perceived to be a routine, an 'easy thing to measure' and is part of many temporary projects
- It is generally calculated using a stage-discharge rating curve developed on site over the course of the project
- The hypothesis for using the rating curves are a **unique and stable relationship** between stage and discharge, and generally a **simple mathematical function**

2. Objectives

- Evaluate the **magnitude and range of uncertainties** induced by the stage-derived discharge in low gradient and upland streams installed away from control structures

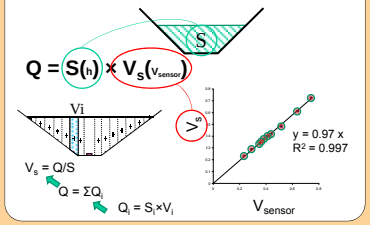
3. Method

- Use ***reference data*** obtained from **velocity and stage** measurements on **two low land and two upland stations**
- **Numerically simulate** manual gauging points and corresponding rating curves. Use a power and polynomial relationships.
- ***Compare*** the simulated annual cumulative flow volume and daily flow rates to the reference one

4. Reference data

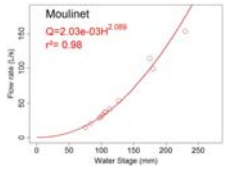
- Doppler velocimeters in Trapezoidal wooden flumes

e.g. Nozay, France
Upland stream: 1% slope, up to 10 m³/s

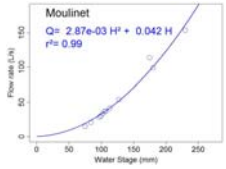


5. Types of rating curves tested

- Power and polynomial



Power relationship

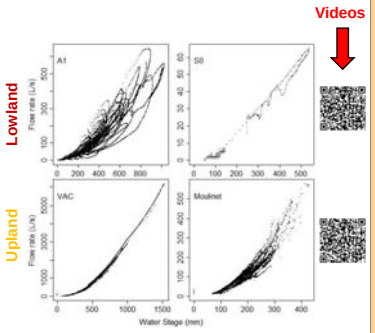


Polynomial relationship

No clear and definite difference

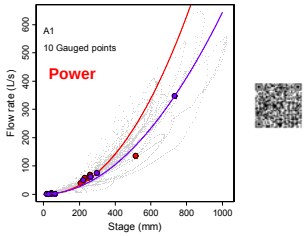
6. Results: hysteresis of the stage-discharge relationship

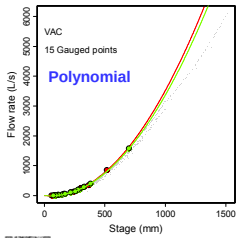
- Common in both upland and lowland watersheds

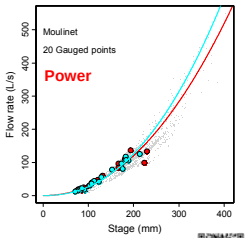


5. Results: Hysteresis and gauging times induce uncertainties

- Rating curves derived from sets of 6 to 30 gauged flows per year
- Numerical simulations generate an infinite number of possible sets and rating curves (see videos)

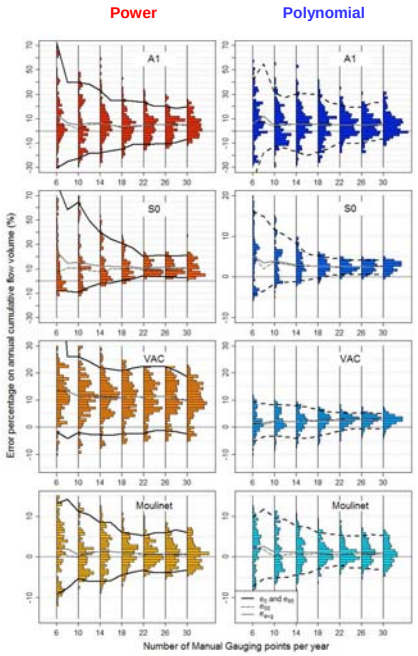






6. Results: Relative errors on annual cumulative flow

- 22 gauged flows per year optimum across all stations
- Uncertainties do not decrease with more gauged points
- General bias towards overestimating cumulative volumes
- Large hysteresis in lowland stream A1 induces largest uncertainties
- Better than ±8% for upland streams but for VAC using the power relationship for rating curve



7. Discussion and Conclusion

- Many short term projects involve flow measurements for e.g. water or nutrient balance
- Methods proposed in international norms (ISO 1100-2:2010) were followed here
- Hysteresis in lowland streams was expected, not in upland ones
- Use of rating curves in lowland streams may be very hazardous
- Significant hysteresis for Moulinet (upland) did not result into large uncertainties, however
- The recommended power relationship may be used but with caution (e.g. VAC)
- These results suggest that velocimeters installed in wooden flumes may be a good alternative

ISO 1100-2: 2010. Hydrometry - Measurement of liquid flow in open channels - Part 2: Determination of the stage-discharge relationship

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Abstract

Some of the uncertainties associated with stage derived flow rates in streams

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The vast majority of hydrological stations are set up such that discharge can be estimated from the measurement of the sole water height or stage above a local datum. Hydraulics laws show that in the right conditions there may be a unique and stable relationship between stage and discharge, which can be described by a rating curve. Because water stage can be quite easily measured on a continuous basis, the unique relationship between stage and discharge is at the basis of what is known in hydrology since the late 1800s. What if the rating curves were not as good as we might think? We propose to evaluate the uncertainties induced on instantaneous flow and cumulative annual flow volumes by the use of rating curves. For that we used reference data in upland and lowland watersheds where flow was calculated from stage and velocity data obtained by Doppler flow meters installed into trapezoidal wooden flumes. Rating curves were obtained by random sampling of the reference flow and stage data. Flow computed using the simulated rating curves were compared to the reference ones. For the four watersheds tested, errors did not decrease significantly when more than 20 manual gauging were performed. Significant under- and overestimations were found reaching -10 to +20% compared to the reference cumulative flow in a low land station.