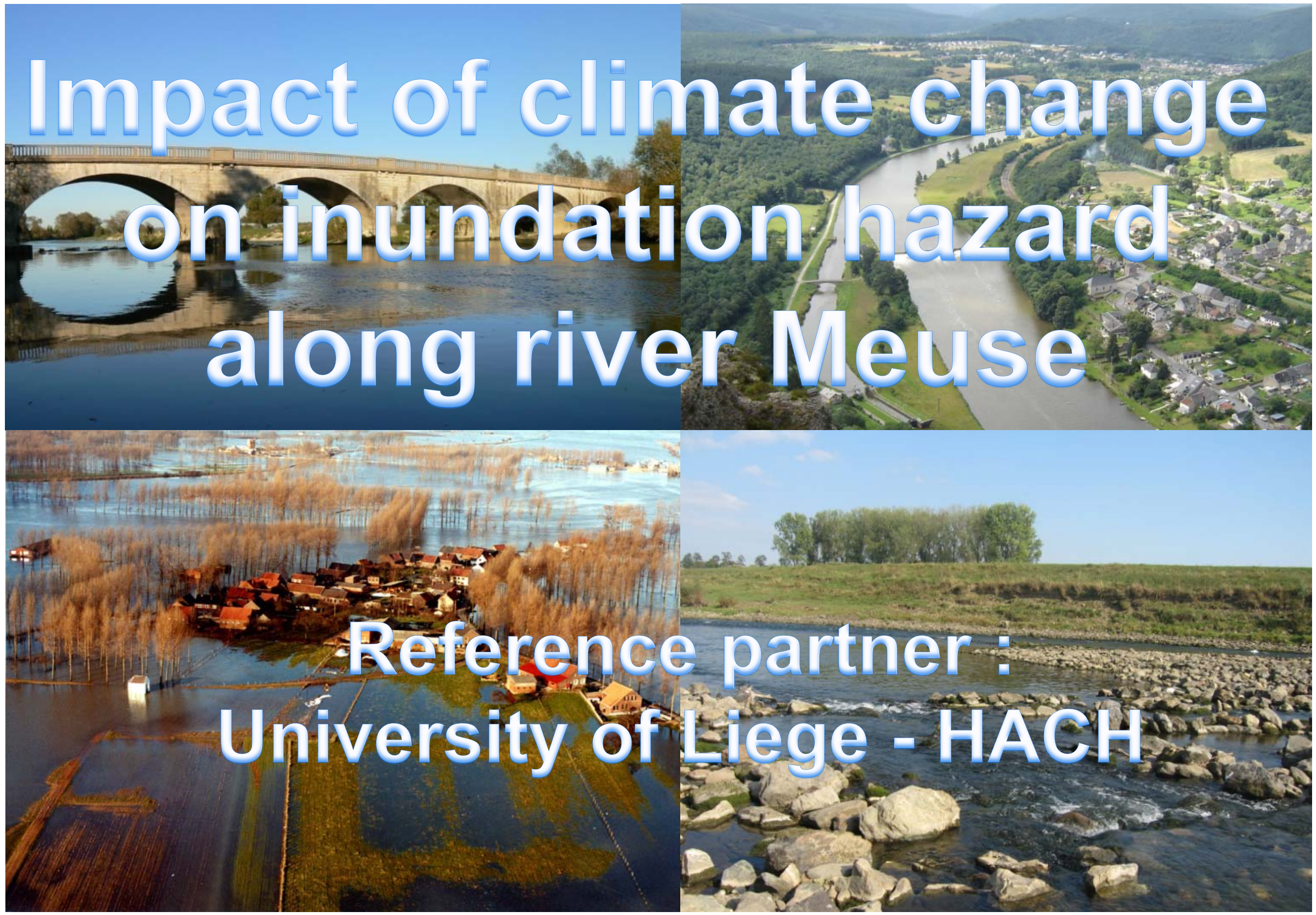
Adaptation of the Meuse to the Impacts of Climate Evolutions

This project has received European Regional Development Funding through INTERREG IV B.

INTERREG IVB



Impact of climate change on inundation hazard along river Meuse

Reference partner : University of Liege - HACH

Dr Benjamin Dewals, Ir Sylvain Detrembleur,
Dr P. Archambeau, Ir L. Gouverneur & Prof. M. Pirotton

Content

- Hydraulic modelling within AMICE
- Existing models and modelling procedures
- Transnational modelling methodology
- Preliminary results: consistency check at the borders
- Inundation characteristics for 2021-2050 and 2071-2100

Contributors	WP1 partners & **hydraulic modellers**: E. Guilmin, S. Detrembleur, S. Moeskops, B. Becker
Coordination	HACH-ULg: S. Detrembleur & B. Dewals

I - Hydraulic modelling within AMICE

Input:

Scenarios of climate change and hydrology

WP1: Impacts of future floods and low-flows: *an analysis of climate-change-induced floods and low-flows*

WP2: Natural Water retention, *an example of non-structural protection against future water-related risks*

WP3: Control of water quantities, *an example of structural protection against future water-related risks*

WP4: Crisis management software, *a preparedness measure against future water-related risks*

Output:

Common Strategy of Adaptation

Evaluation of measures based on cost-benefit analysis (CBA)

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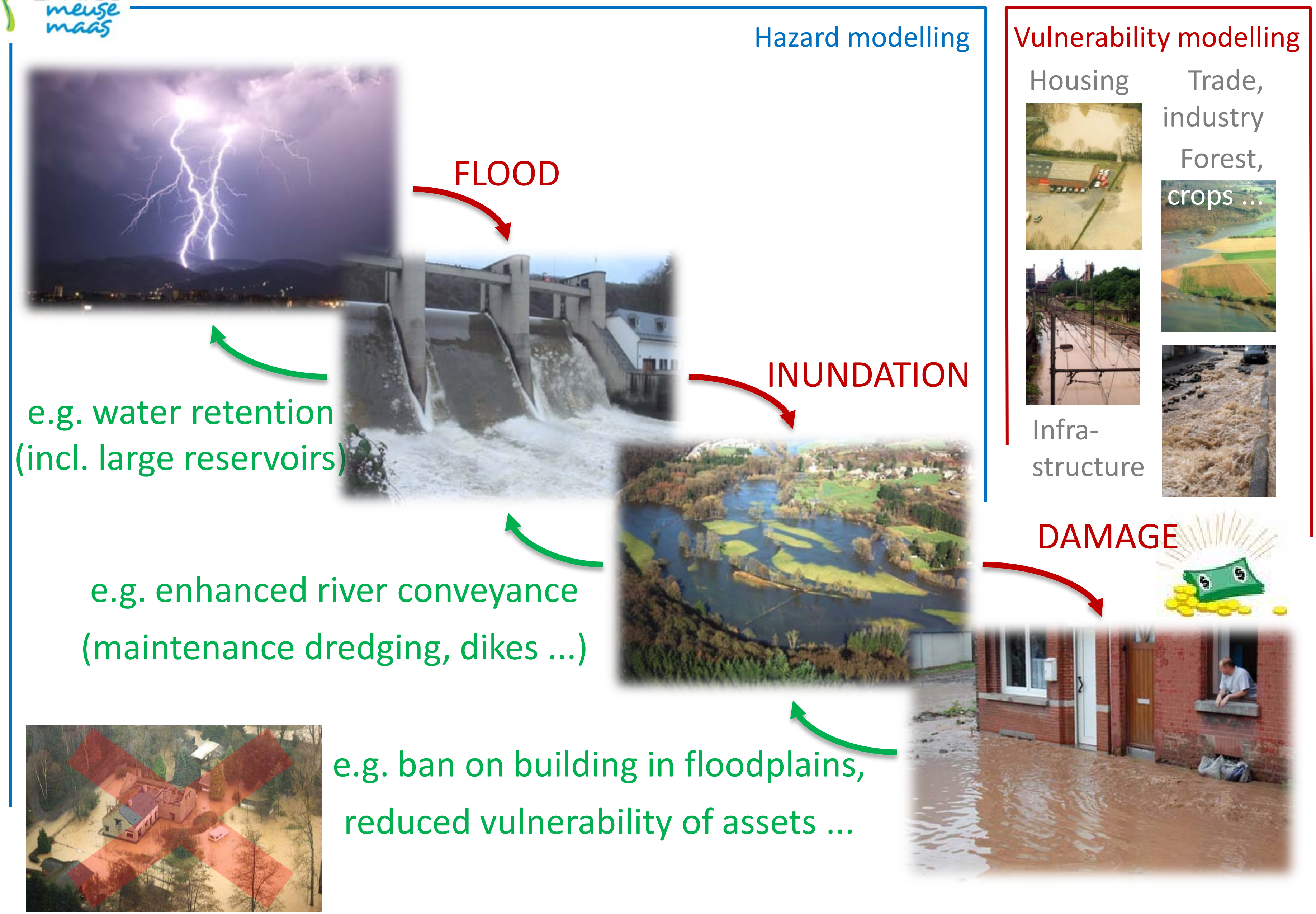
I - Hydraulic modelling within AMICE



I - Hydraulic modelling within AMICE

Hazard modelling

AC 3: Scenarios

FLOOD

AC 6: Hydraulics

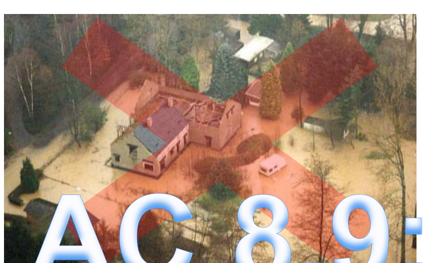
e.g. water retention
(incl. large reservoirs)

INUNDATION

AC 7: Risk

e.g. enhanced river conveyance
(maintenance dredging, dikes ...)

DAMAGE



e.g. ban on building in floodplains,
reduced vulnerability of assets ...

AC 8,9: Evaluation of measures

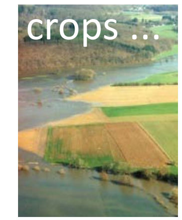
Vulnerability modelling

Housing

Infra-
structure

Trade,
industry

Forest,
crops ...



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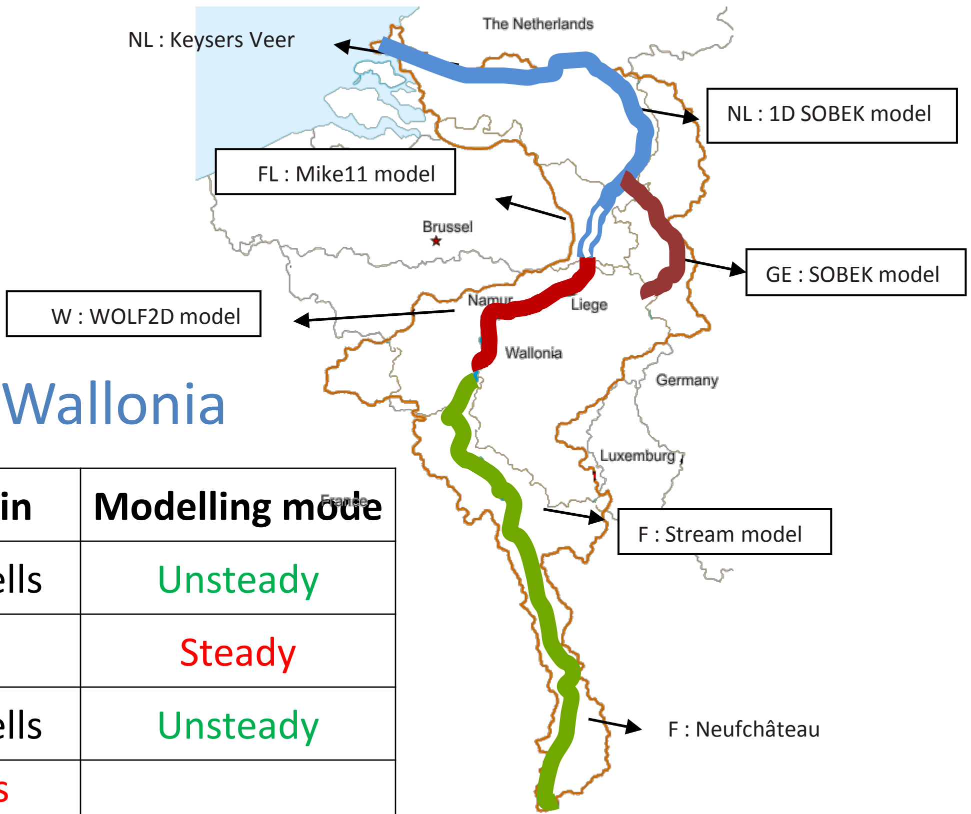
II - Existing models and procedures

in the perspective of elaborating a transnational modelling methodology

Questionnaire

Hydraulic models available from spring to mouth

Steady modelling in Wallonia

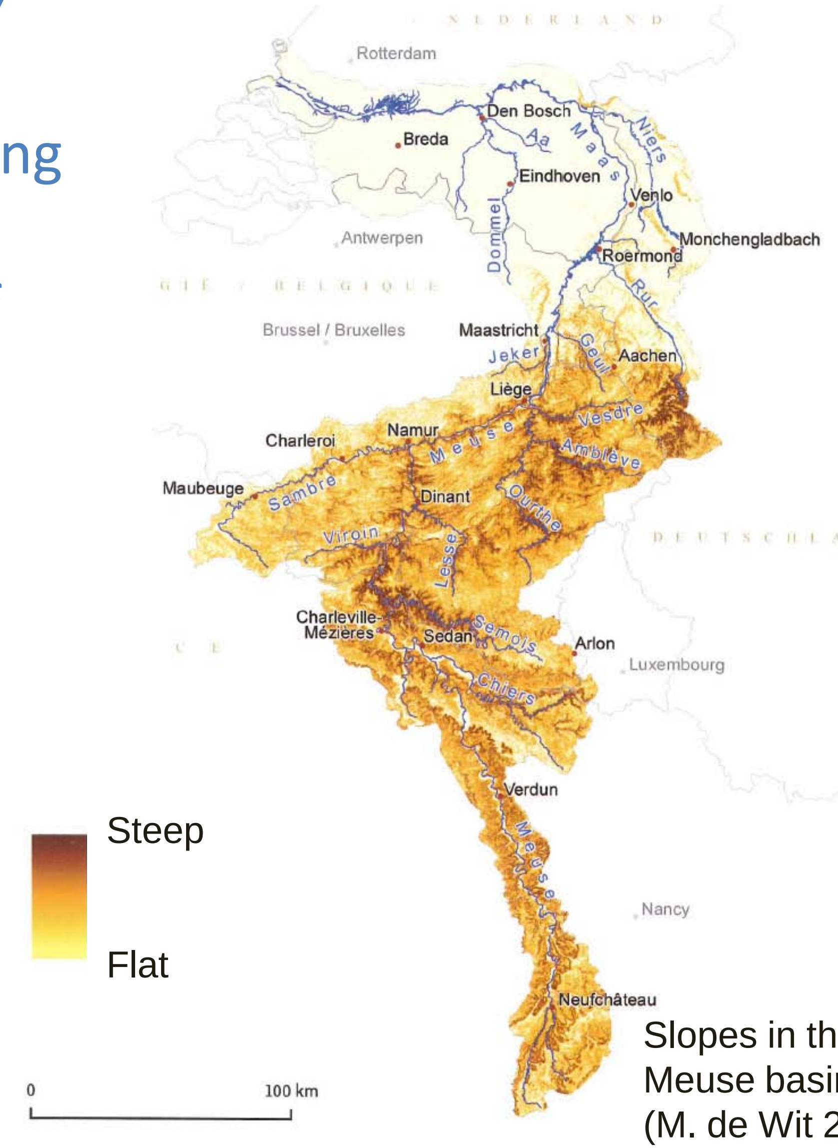


	Main stream	Flood plain	Modelling mode
F	1D	Storage cells	Unsteady
W	2D (Δx = max. 5 m)		Steady
FL	1D	Storage cells	Unsteady
NL	1D	1D Cross sections	Unsteady
	(2D Waqua / Not in AMICE)		
GE	1D	Storage cells	Unsteady

II - Existing models and procedures

in the perspective of elaborating a transnational modelling methodology

No significant damping of the flood waves in the central part of the basin

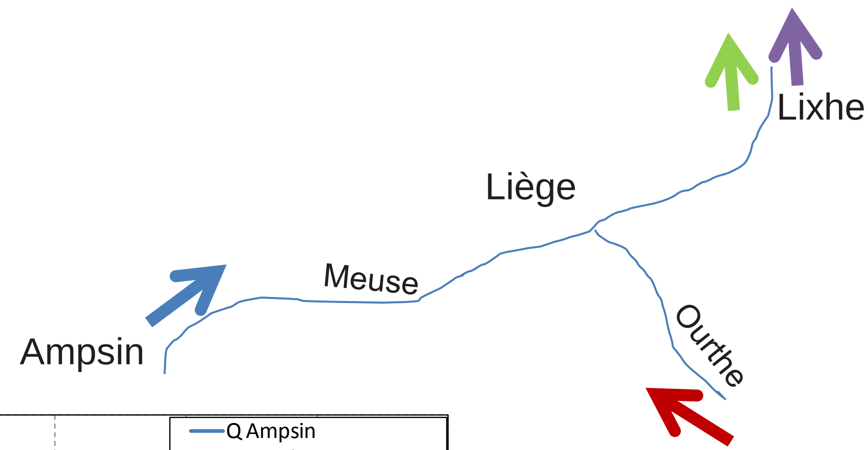


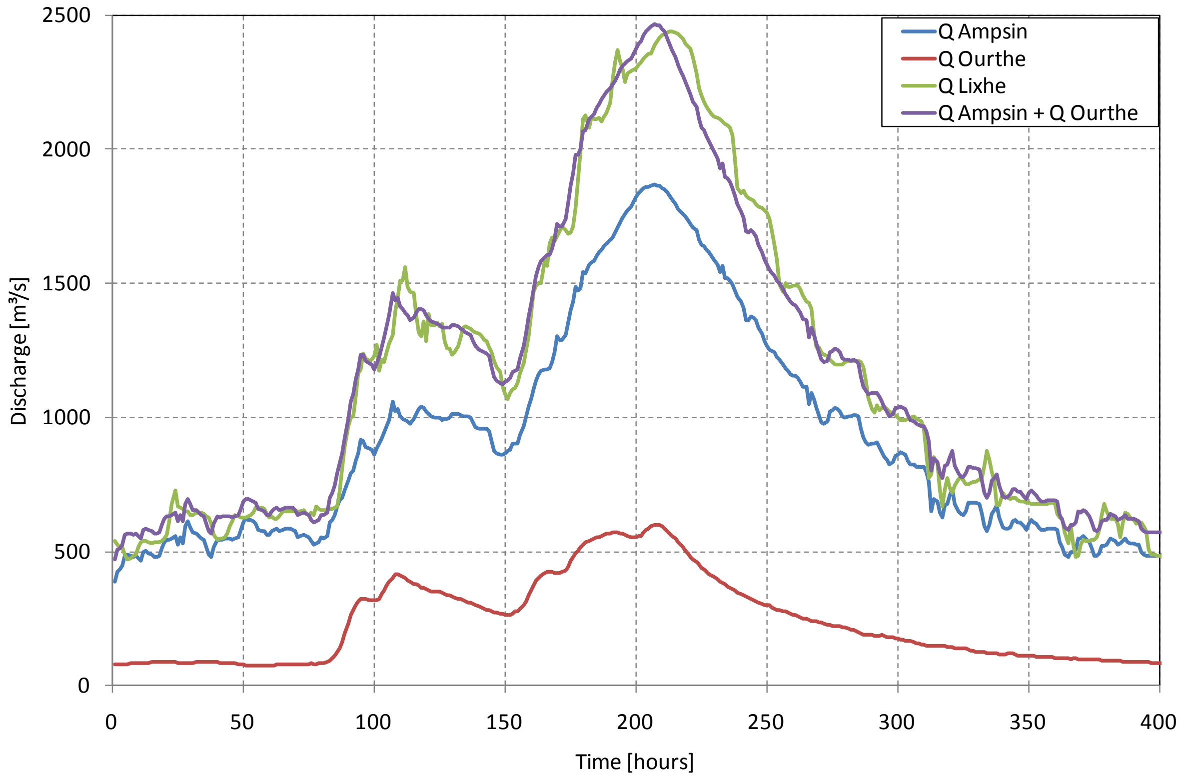
Slopes in the Meuse basin (M. de Wit 2008)

II - Existing models and procedures

in the perspective of elaborating a transnational modelling methodology

No significant damping of the flood waves





Measured hourly data at gauging stations

II - Existing models and procedures

in the perspective of elaborating a transnational modelling methodology

Outcomes of Ac3 Input data for AC6:

Common hydrological impact variable for high flows: Qhxa100 = annual maximum hourly discharge of 100 year return period (Q100)

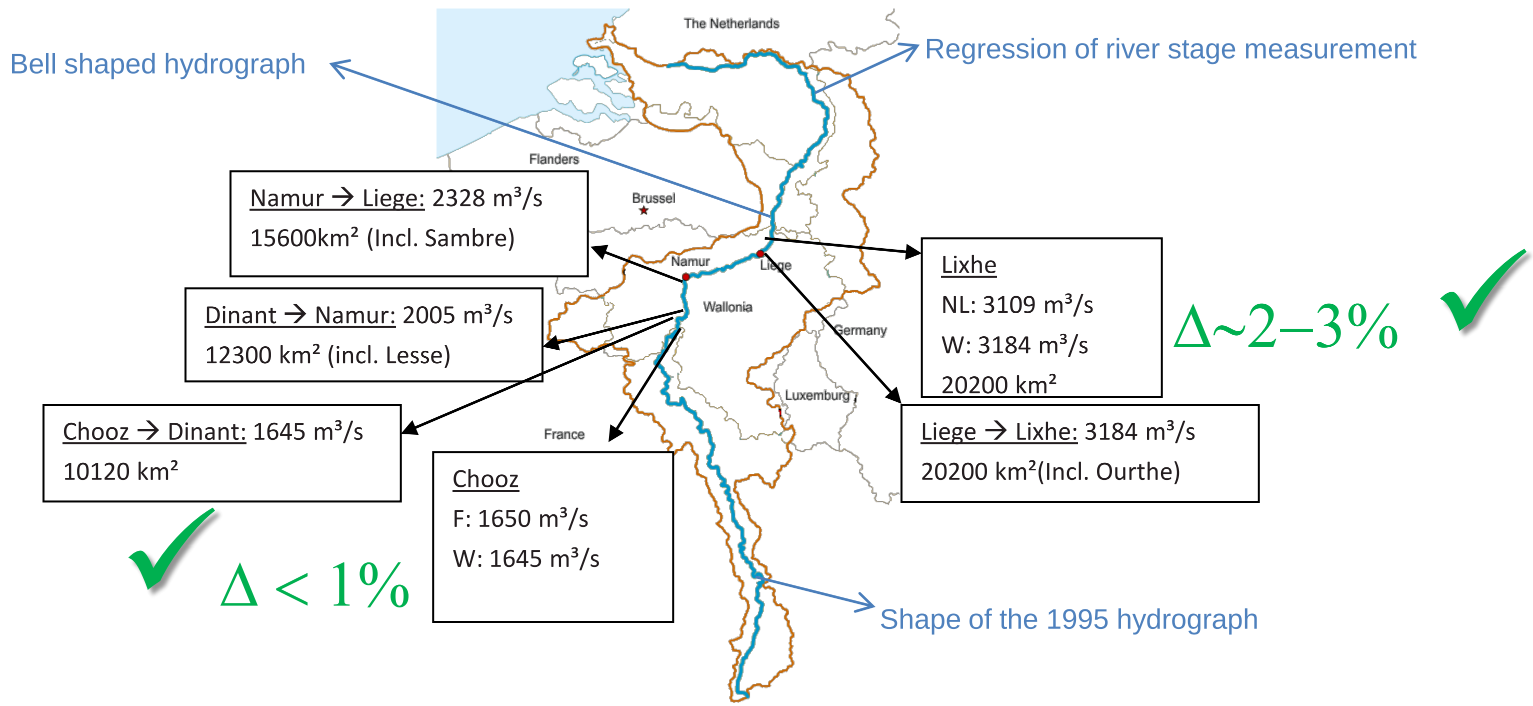
Hydrological scenarios:
increase in Q100 values of +15% for 2021-2050 and +30% for 2071-2100

[Meeting in Metz 3 September 2009, Ac3 report June 2010]

II - Existing models and procedures

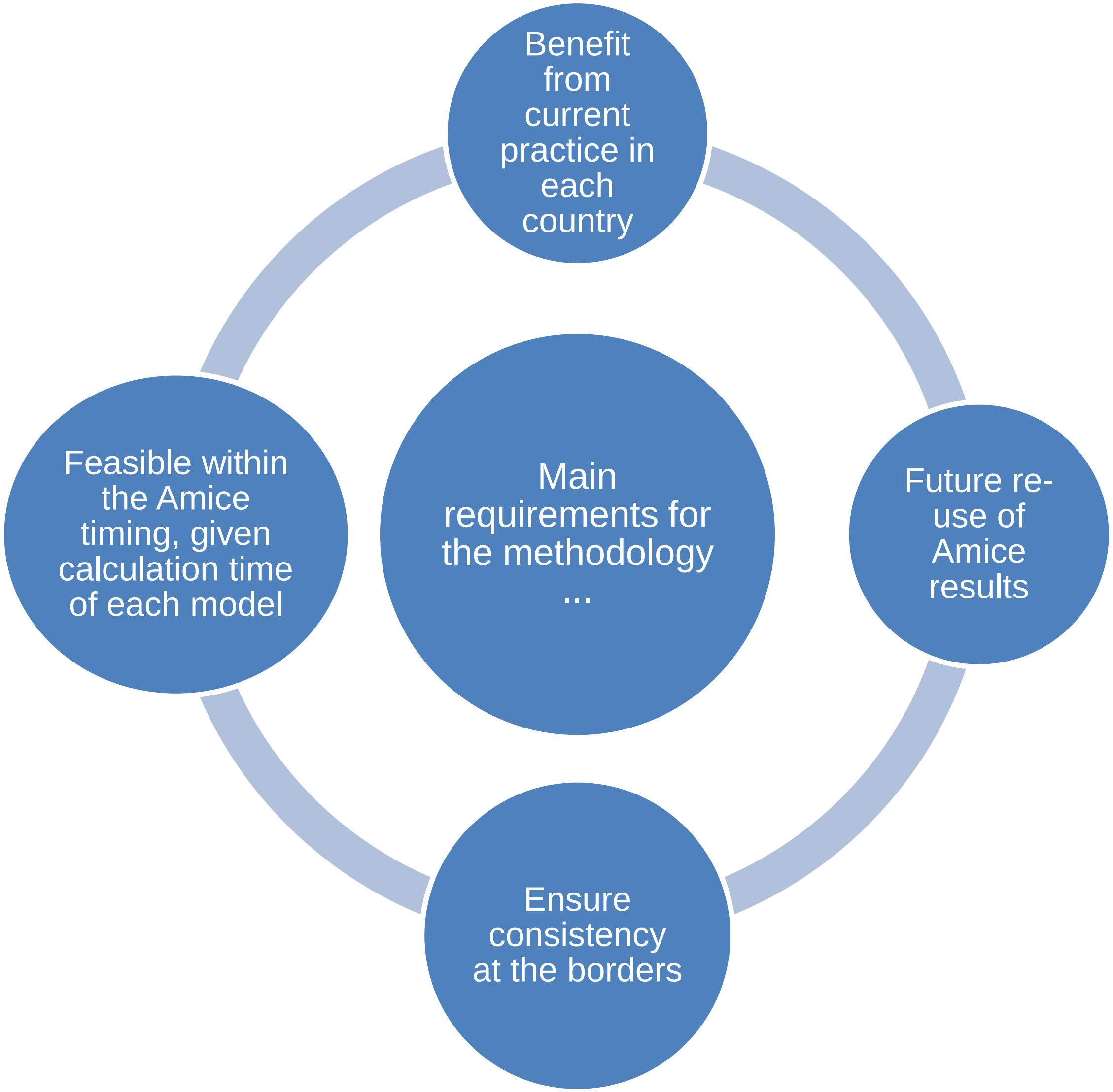
Main gauging stations have more then 30 years of measurements (100 years in Borgharen)

Applied statistical methods differ along the Meuse; Nevertheless reasonable agreement at the borders



III - Transnational modelling methodology

for consistent transnational modelling
and sound comparison of models outputs



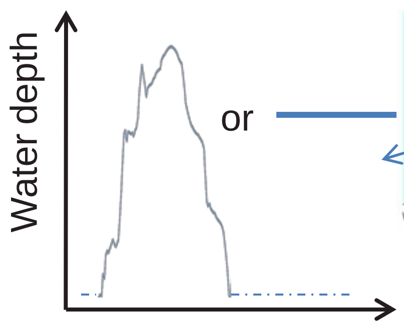
Sequential vs. parallel runs of the models

The Meuse remains subcritical even for high flows (Fr<1)

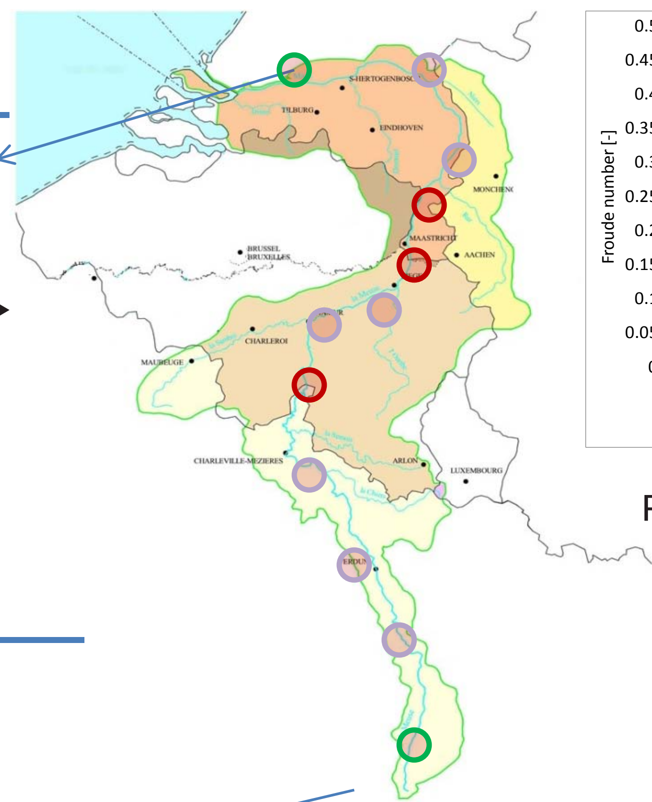
- *Downstream BC = water depth*
- Upstream BC = discharge

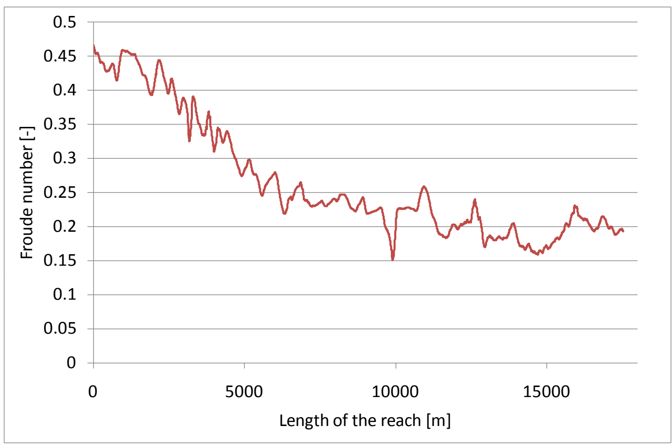
No sense to run models sequentially

Measured data or scenarios at the outer limits
Depends on the other models
Discharge input from tributaries

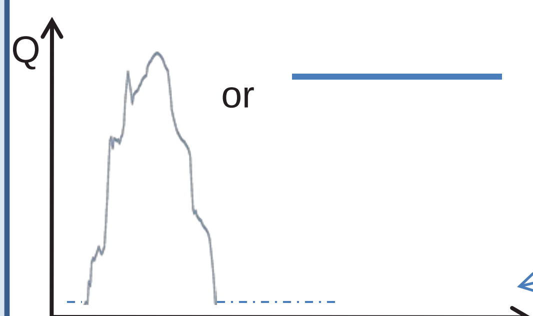


Time





Froude number along a reach of the Meuse in Wallonia for Q_{100}



Time

Steady vs. unsteady simulations ?

F, FL and NL models are unsteady, while the B model for inundation modelling is run in steady mode

The common methodology to be followed in AC6 should accommodate this difference in modelling procedures

Modelling from spring to mouth

Full unsteady	Full steady
Continuous exchange of BC	Sequential runs from NL to F
Models should be linked and run simultaneously	Exchange of water depth BC from downstream to upstream
Difficulty to couple all the models	Assumptions on flood damping
Unnecessary in W	Not suitable in F, NL and FL
• Not in the scope of Amice • Not in accordance with the current practice in W	• Such sequential runs not optimal/feasible in the timing of Amice • Not in accordance with the current practice in F, NL and FL

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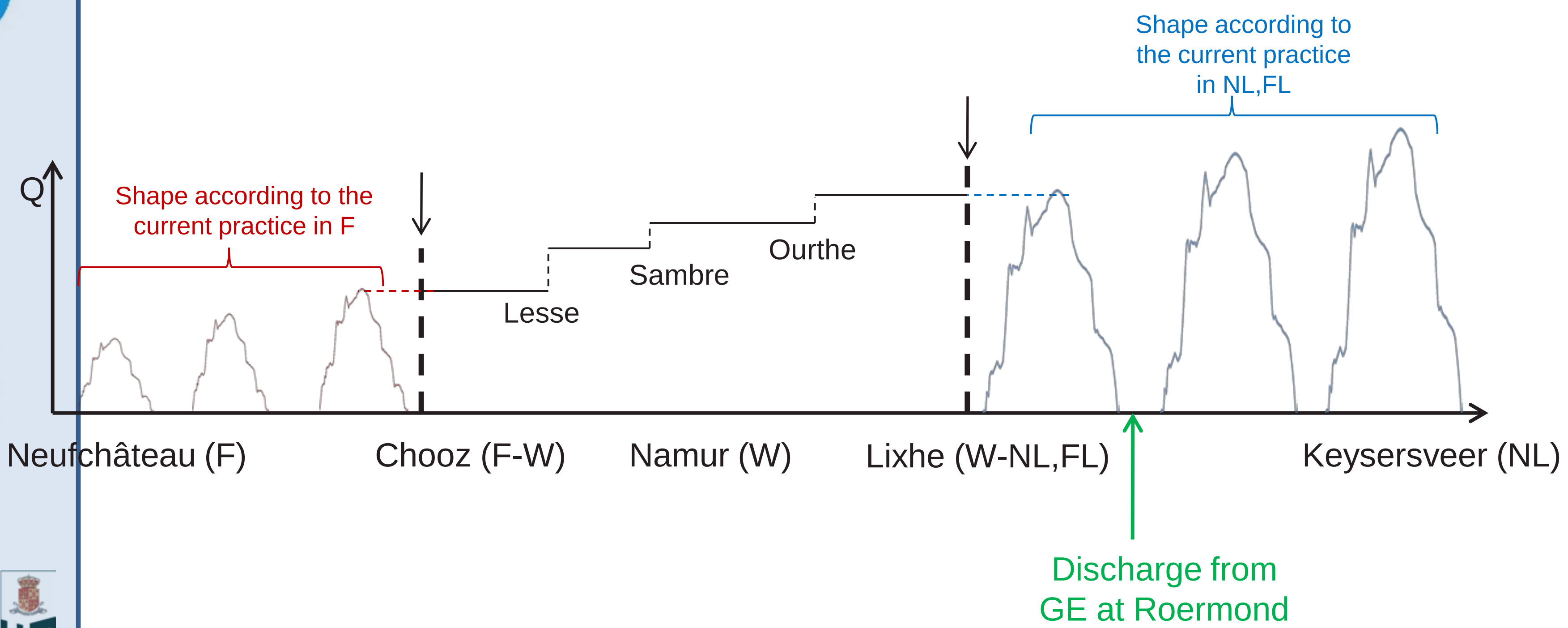
Overall procedure

➔ Trade-off methodology, combining unsteady and steady modelling, in accordance with

- existing practice in each region
- the storage capacity of the floodplains
- enabling parallel (instead of sequential) runs of the models
- ensuring reasonable continuity of the results at the borders



Overall procedure

➔ Trade-off methodology, combining unsteady and steady modelling, in accordance with

- existing practice in each region
- the storage capacity of the floodplains,
- enabling parallel (instead of sequential) runs of the models
- ensuring reasonable continuity of the results at the borders.

First step

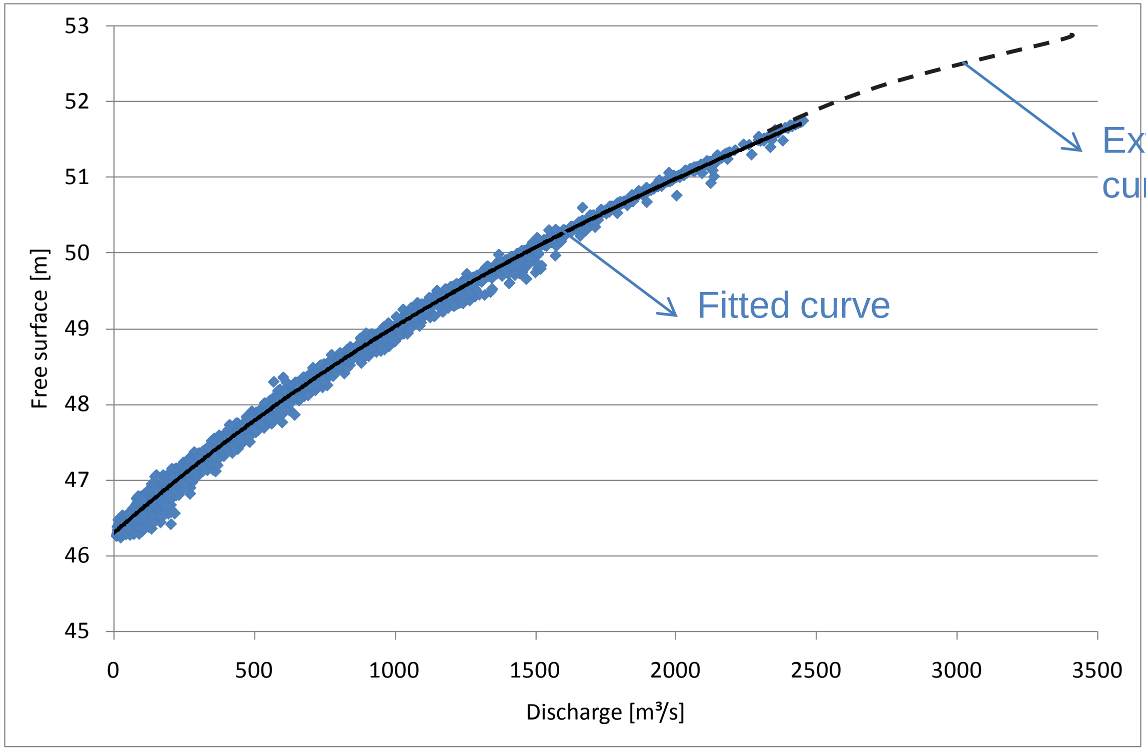
1st runs in parallel based on boundary conditions prescribed from extrapolated available measured data instead of transferred from one model to the next

Second step

High values of historical discharges available

in the recorded data at the gauging stations
(Chooz, Lixhe, Linne, Roermond)

➔ Only limited extrapolation of the corresponding stage-discharge relationships will be needed



State-discharge relation at Lixhe from 2002 to 2004

Overall procedure

First step

1^{st} runs in parallel based on boundary conditions prescribed from extrapolated available measured data instead of transferred from one model to the next

Second step

Consistency of the simulation results at the borders between models has been checked

A second run (limited in space) of models has been undertaken accounting for boundary conditions transferred from the adjacent models

Handling boundary conditions

Downstream

The Netherlands

Run 1 : Extrapolation of the Sobek-RE model →BC for NL model

Run 2: not necessary

Flanders

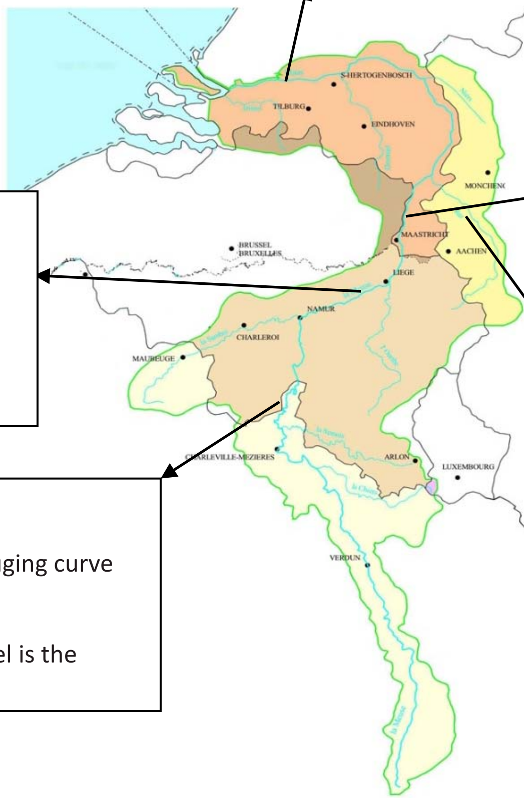
Run 1 : Extrapolation of the gauging curve at Linne →BC for FL model

Run 2 (optional) : BC for FL model is the result of NL model

Wallonia

Run 1 : Extrapolation of the gauging curve at Lixhe→BC for W model

Run 2 (optional) : BC for W model is the result of NL, FL models



Germany

Run 1 : Extrapolation of the gauging curve at Roermond →BC for GE model

Run 2 (optional) : BC for GE model is the result of NL, FL models

France

Run 1 : Extrapolation of the gauging curve at Chooz →BC for F model

Run 2 (optional) : BC for F model is the result of W model

Summary of the methodology

1. Working with a mixed unsteady and steady approach
2. Run the models in parallel to save time
3. Optional second run (with limited spatial extension) to ensure consistency at borders
4. Modelling Q_{100} discharge with the 2 *perturbation factors* obtained from Ac3 (based on the transnational WET climate scenario)

IV - Consistency check at the borders

Coordinates of upstream and downstream boundaries of each model

Providing location of the comparisons points

- expressed in relevant projection systems
- translated into a common coordinate system WGS84: Lat/Long

Points are available in a .kml file (easily loaded by Google Earth)

	Chooz - FR		Chooz - W		Lixhe - W		Lixhe - NL		Borgharen - FL - NL		Roermond - GE		Roermond - NL		Linne -FL - NL	
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
Lambert 1 [m]	777786	277445	777771	277428												
Lambert 72 [m]	182638	95515	182620	95500	243000	160930	242663	161676	243441	174107					258594	207578
Rijksdriehoek [m]					176103	306783	175810	307627	176724	319953	196687	356608	196687	356608	192331	353211
German coord system ?											2498735	5673585	2498735	5673585		
Long/Lat [°]	4.826	50.170	4.825	50.170	5.687	50.751	5.682	50.758	5.696	50.870	5.985	51.198	5.985	51.198	5.921	51.168

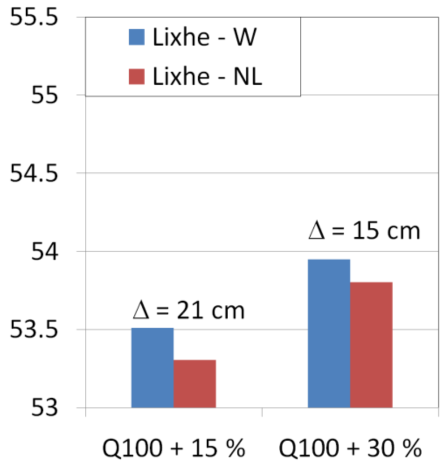
Offsets in altitude due to different system of reference :

$Z_W = Z_F + 1.794$ [m] → Topographic measurement of the gauging station in Chooz

$Z_{W,FL} = Z_{NL} + 2.32$ [m] → Confirmed by both W and NL partners, as well as historical documents

http://nl.wikipedia.org/wiki/Tweede_Algemene_Waterpassing

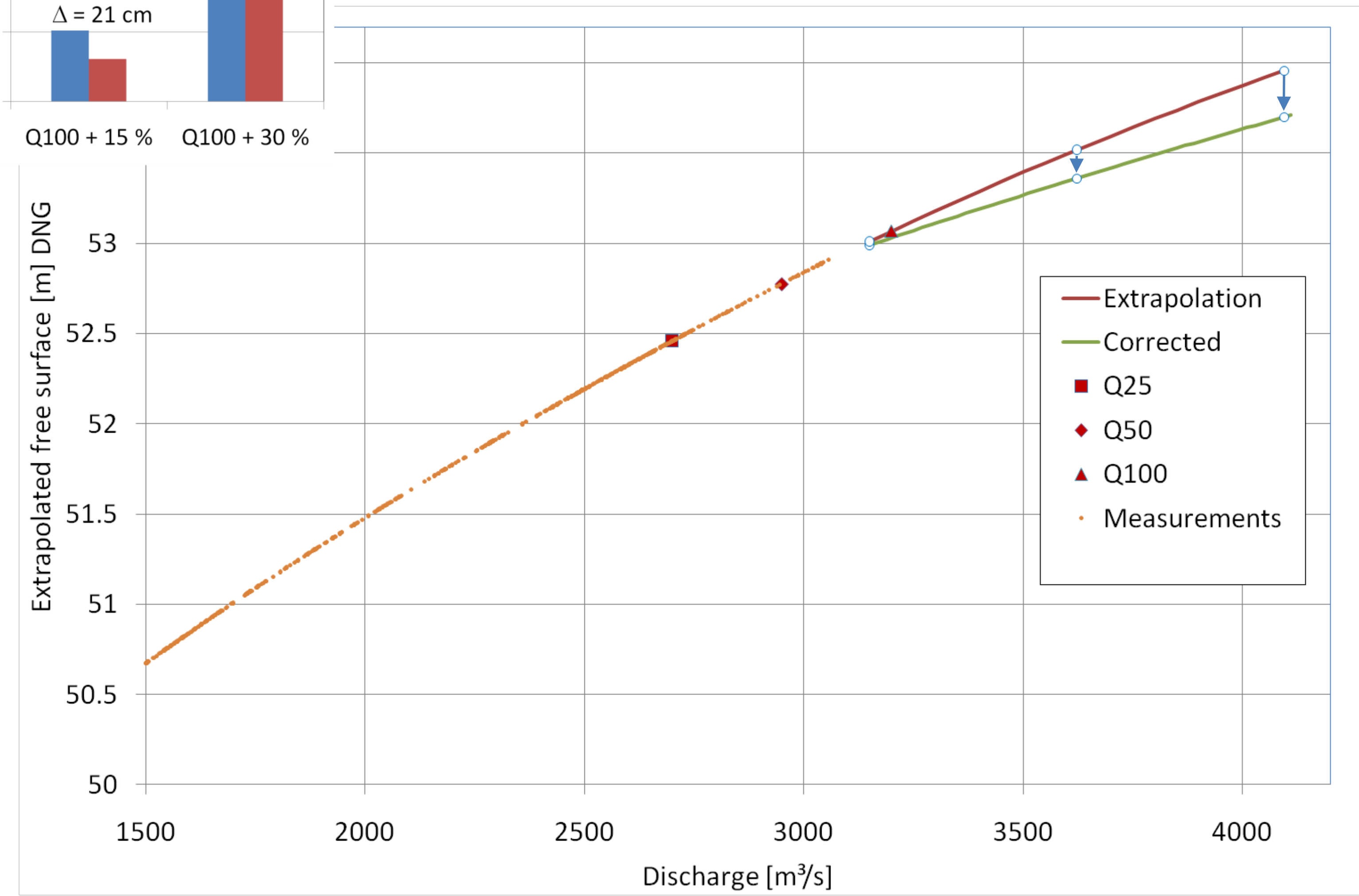
Comparison at borders (NL/W) after 1st run



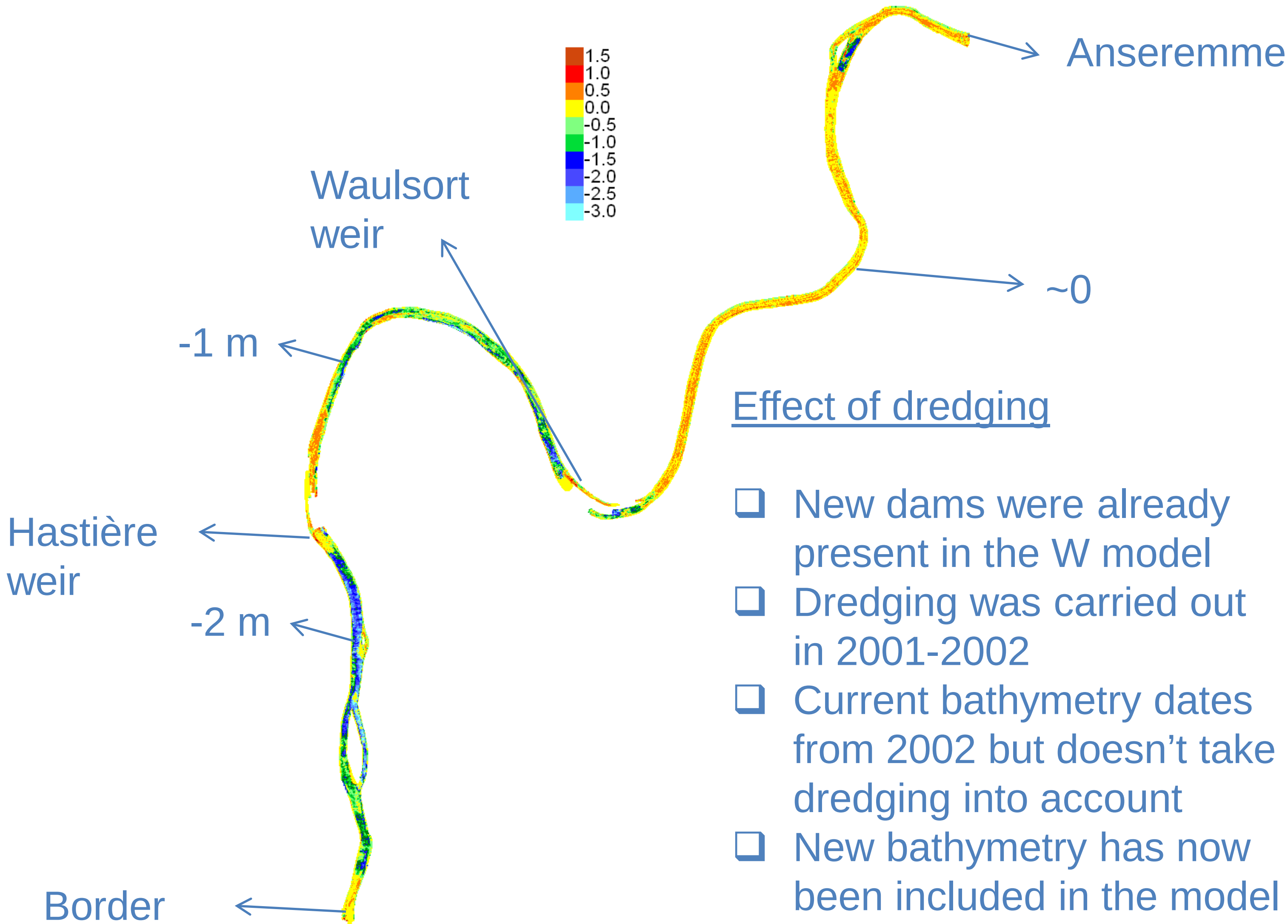
Free surface for Q100 (max historical discharge) are consistent (52.94 vs 52.99 m DNG)

Extrapolation of the H-Q relation to be corrected in W

Second run needed



Comparison at borders (F/W)



Effect of dredging on bathymetry between 2002 and 2007 [m]

Effect of dredging

- New dams were already present in the W model
- Dredging was carried out in 2001-2002
- Current bathymetry dates from 2002 but doesn't take dredging into account
- New bathymetry has now been included in the model

II - Preliminary results

- Hydrographs
- Maximum water levels
- Flooded areas
  [available so far for W, FL & NL]
- Volume stored in the floodplains
  [available so far for W, FL & NL]
- Detailed analysis of hotspots
  [to be presented in
  forthcoming AC6 report]

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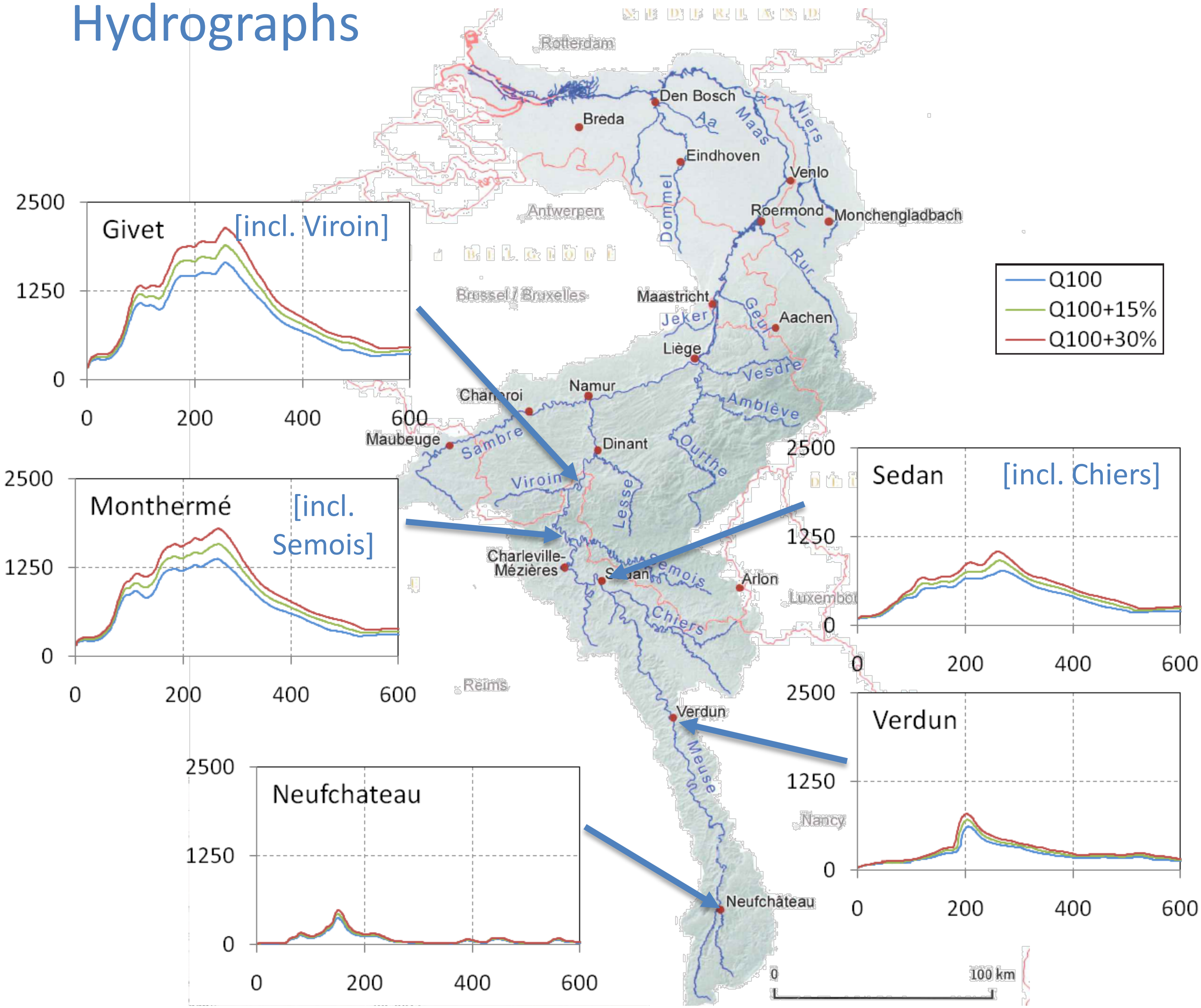
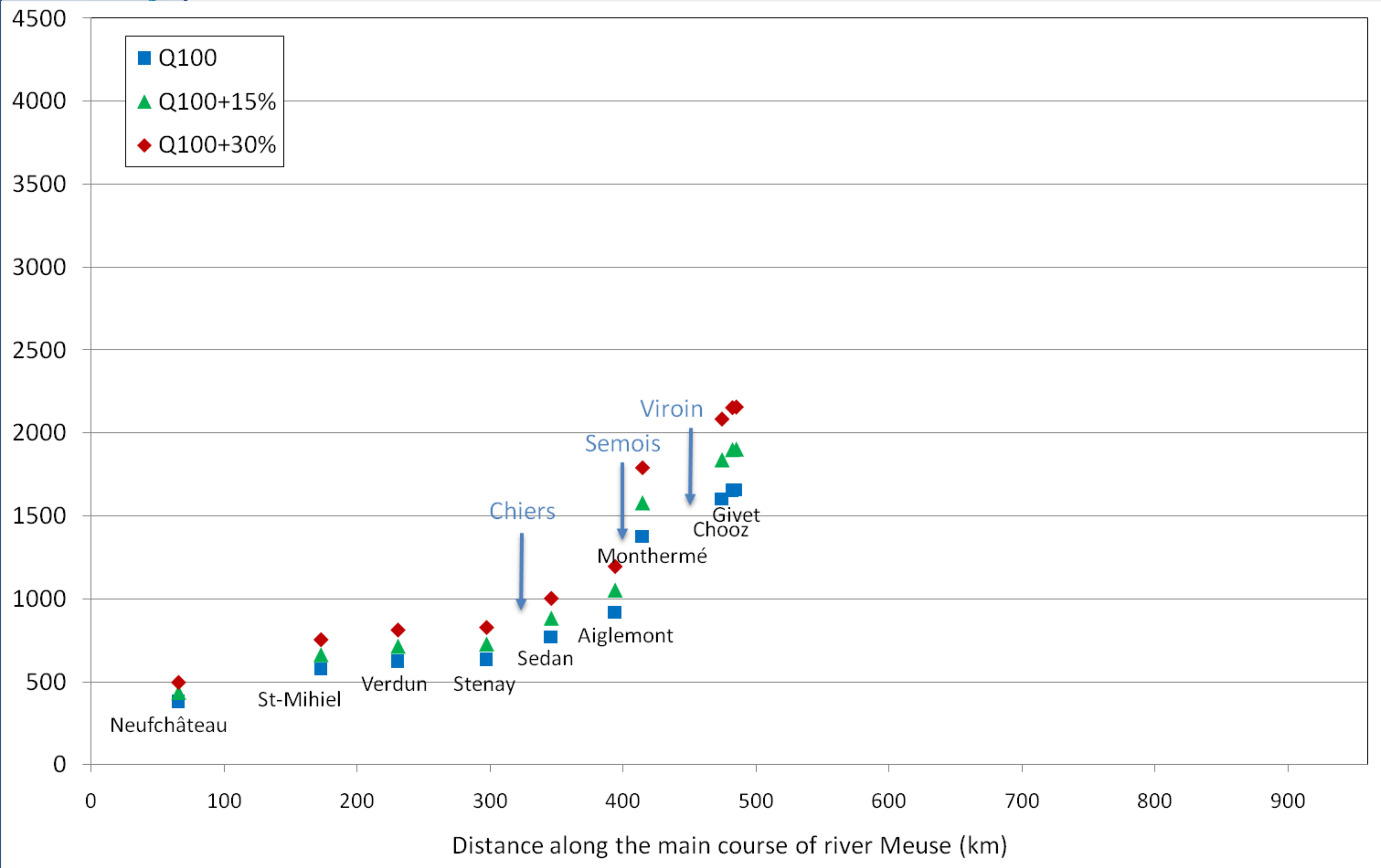
Hydrographs

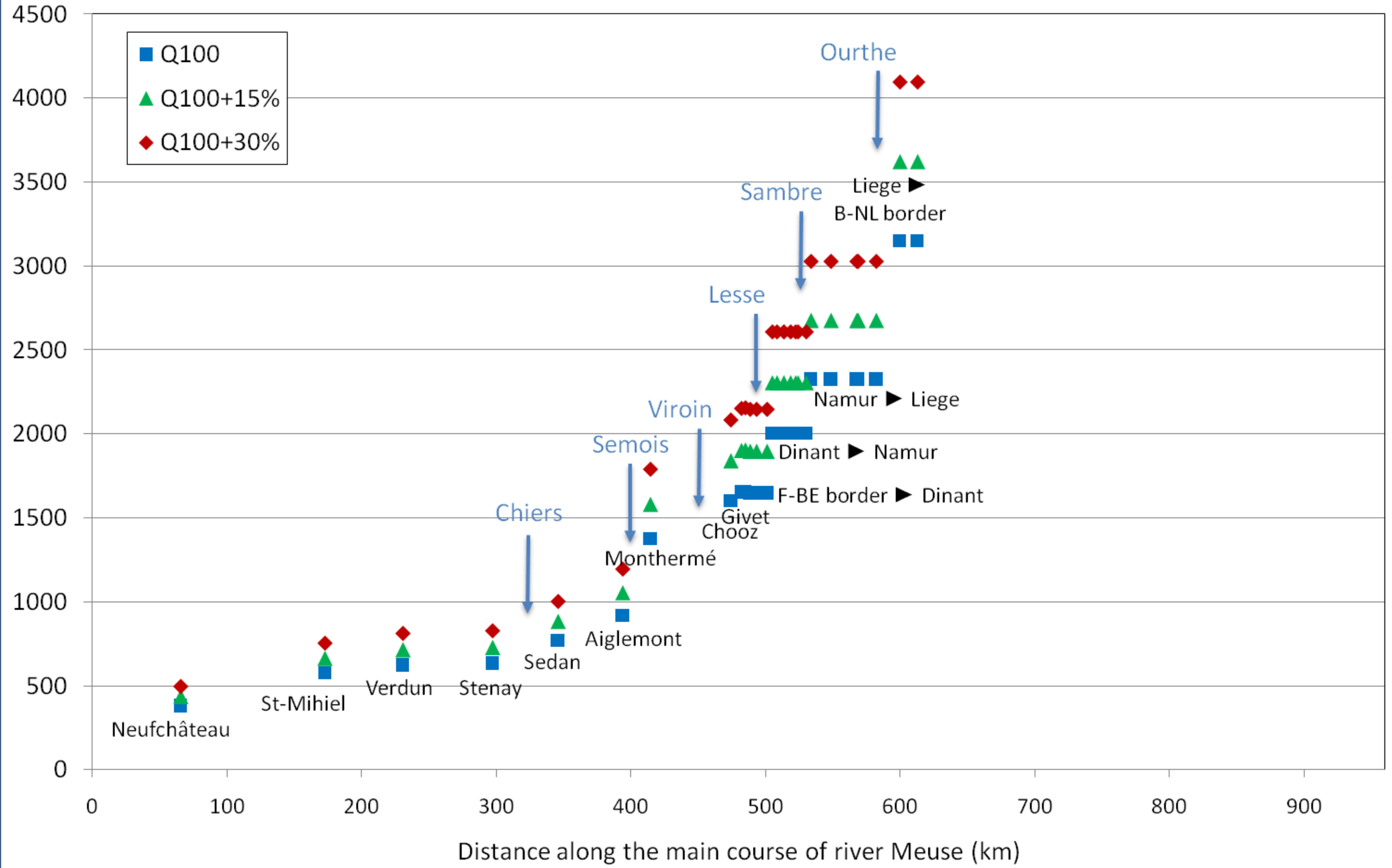


(M. de Wit 2008)

Peak discharges (m^3/s)



Peak discharges (m^3/s)



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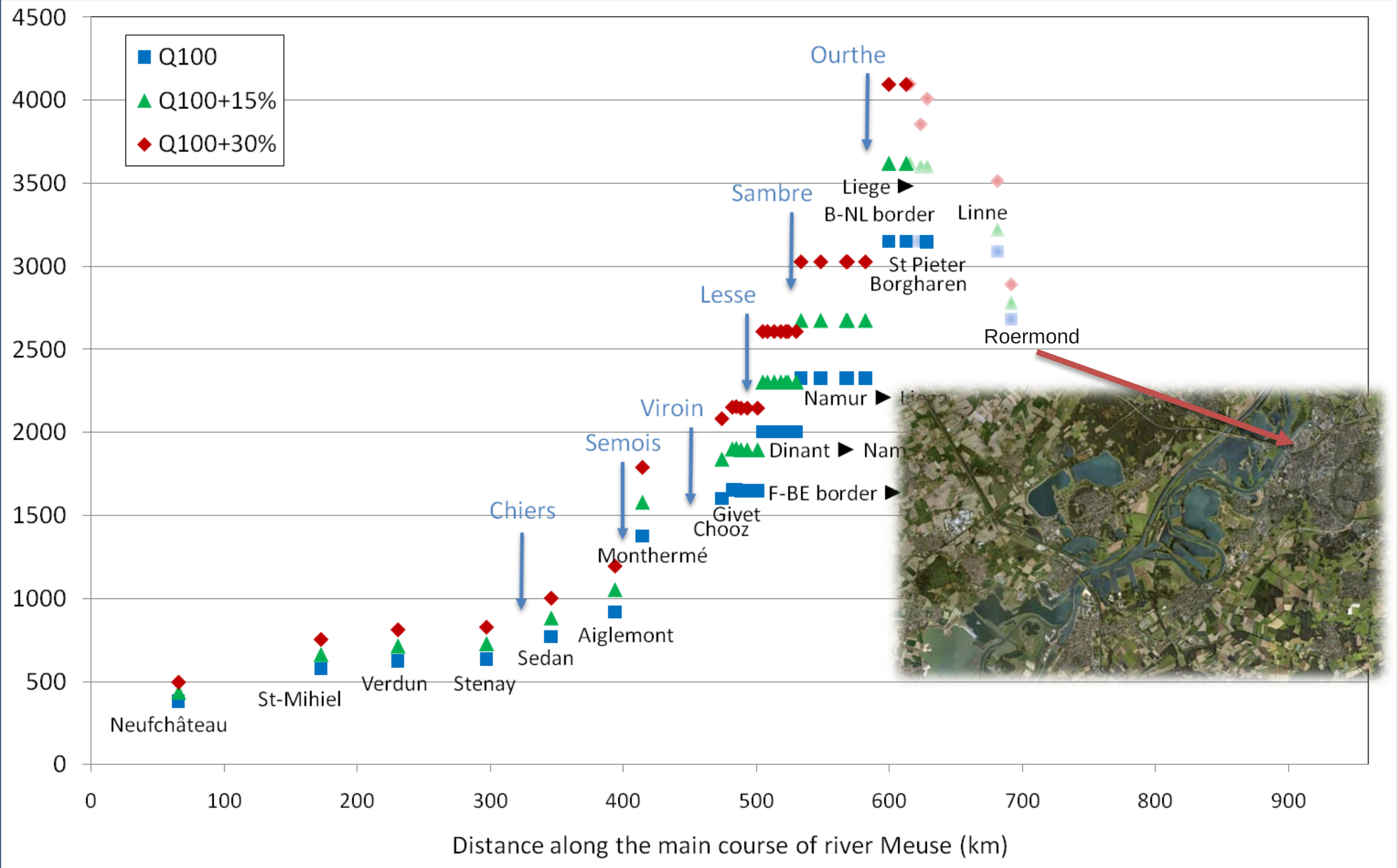
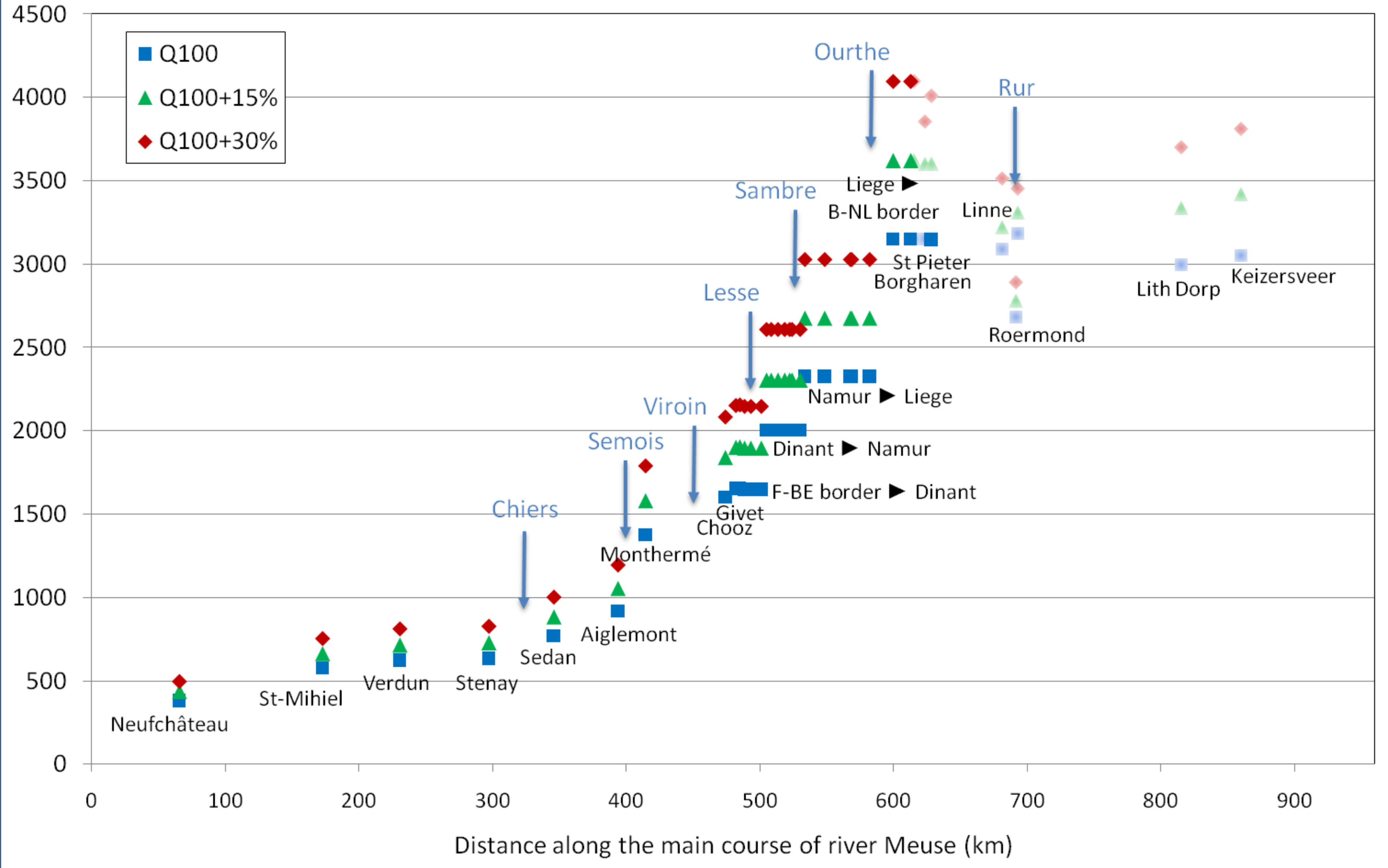
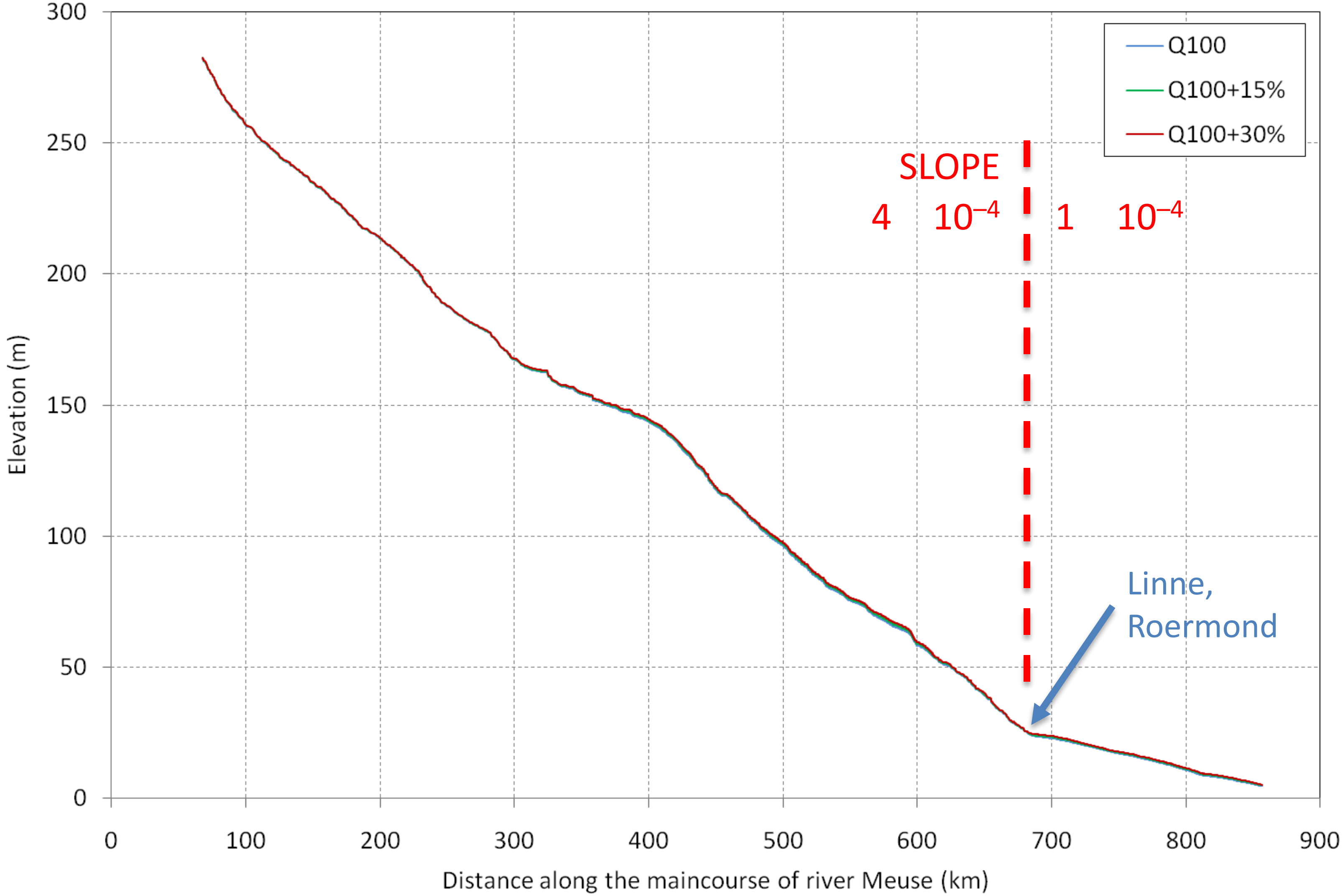


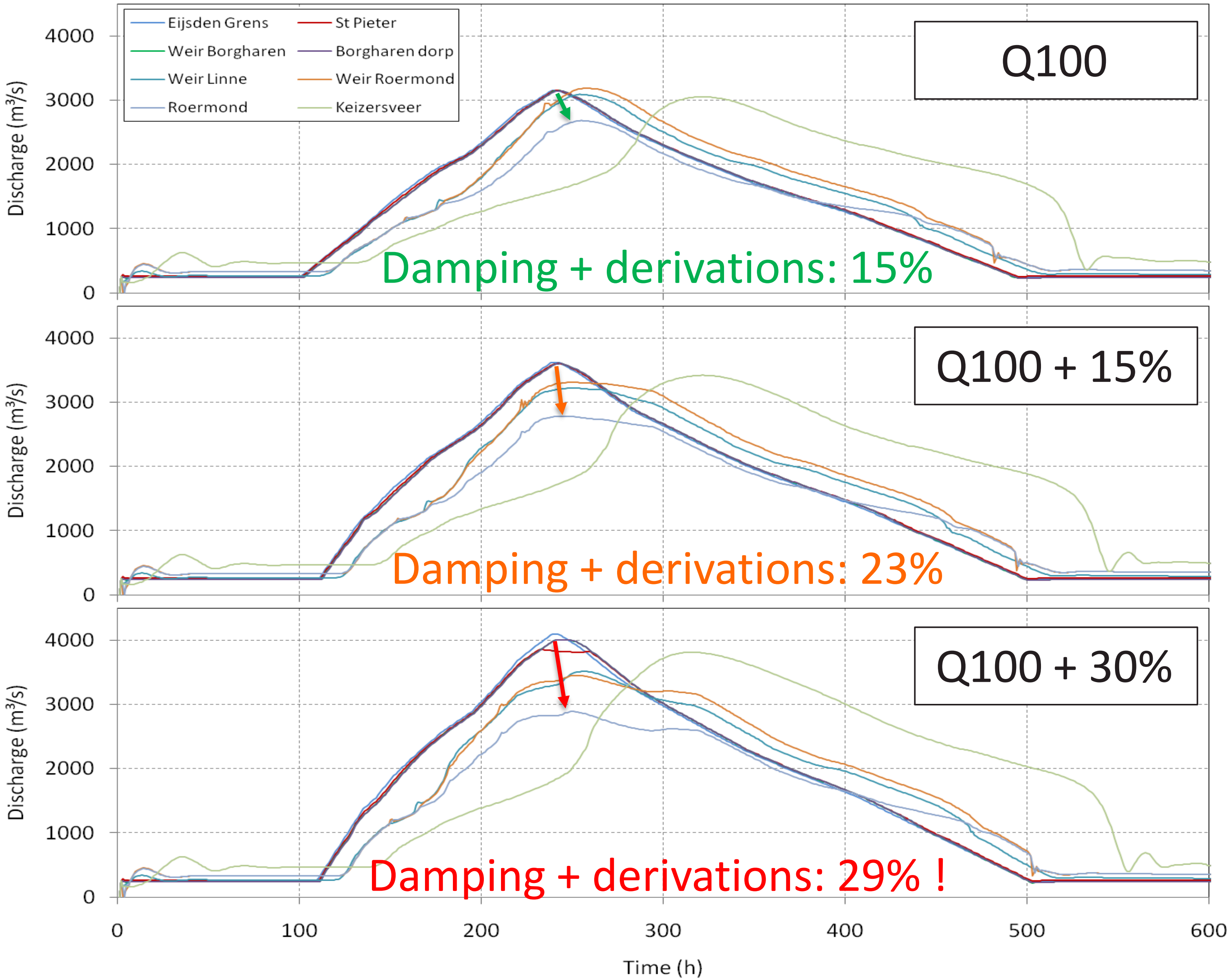
Peak discharges (m^3/s)



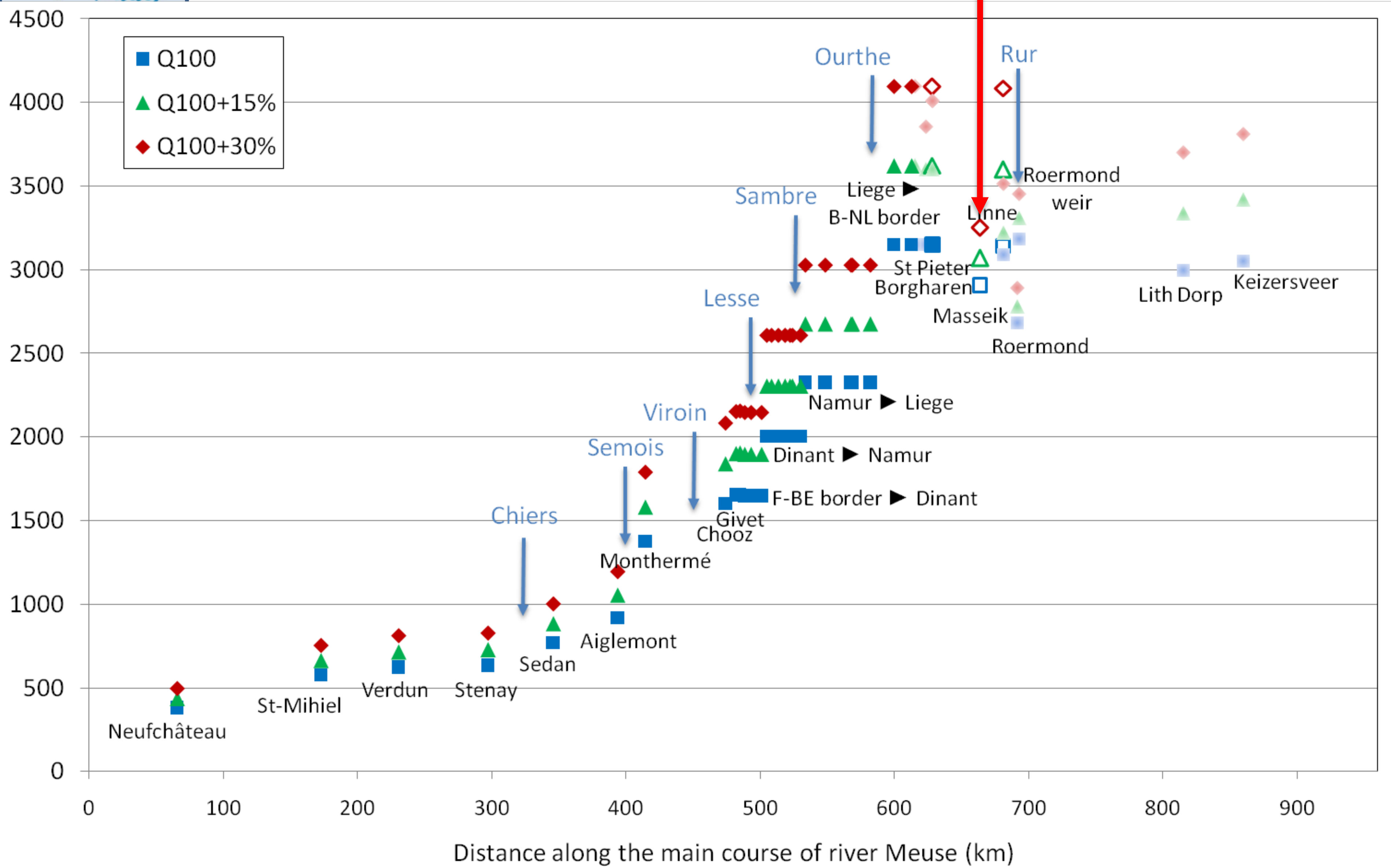
Maximum water elevation (m)



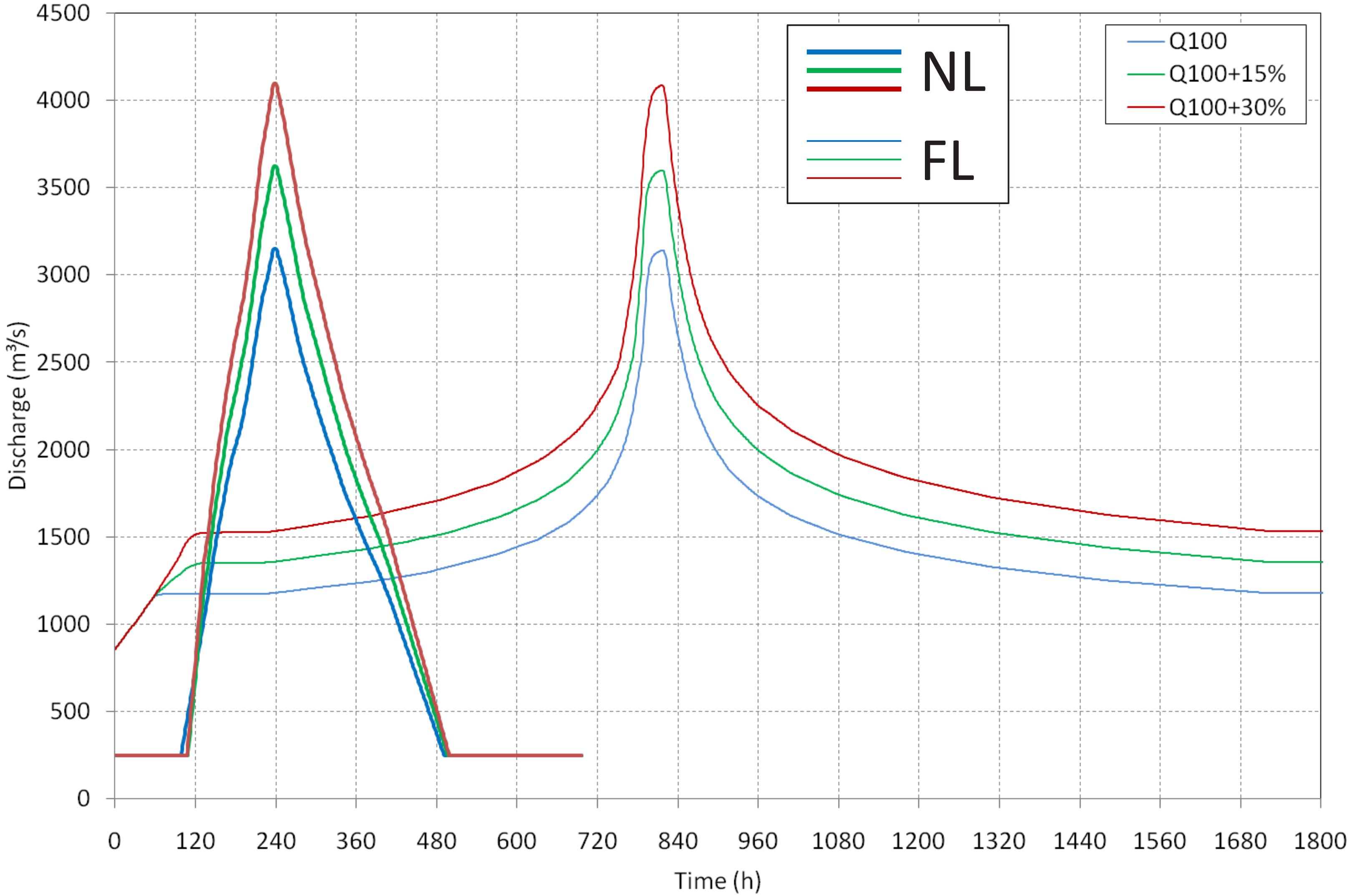
Hydrographs in the NL



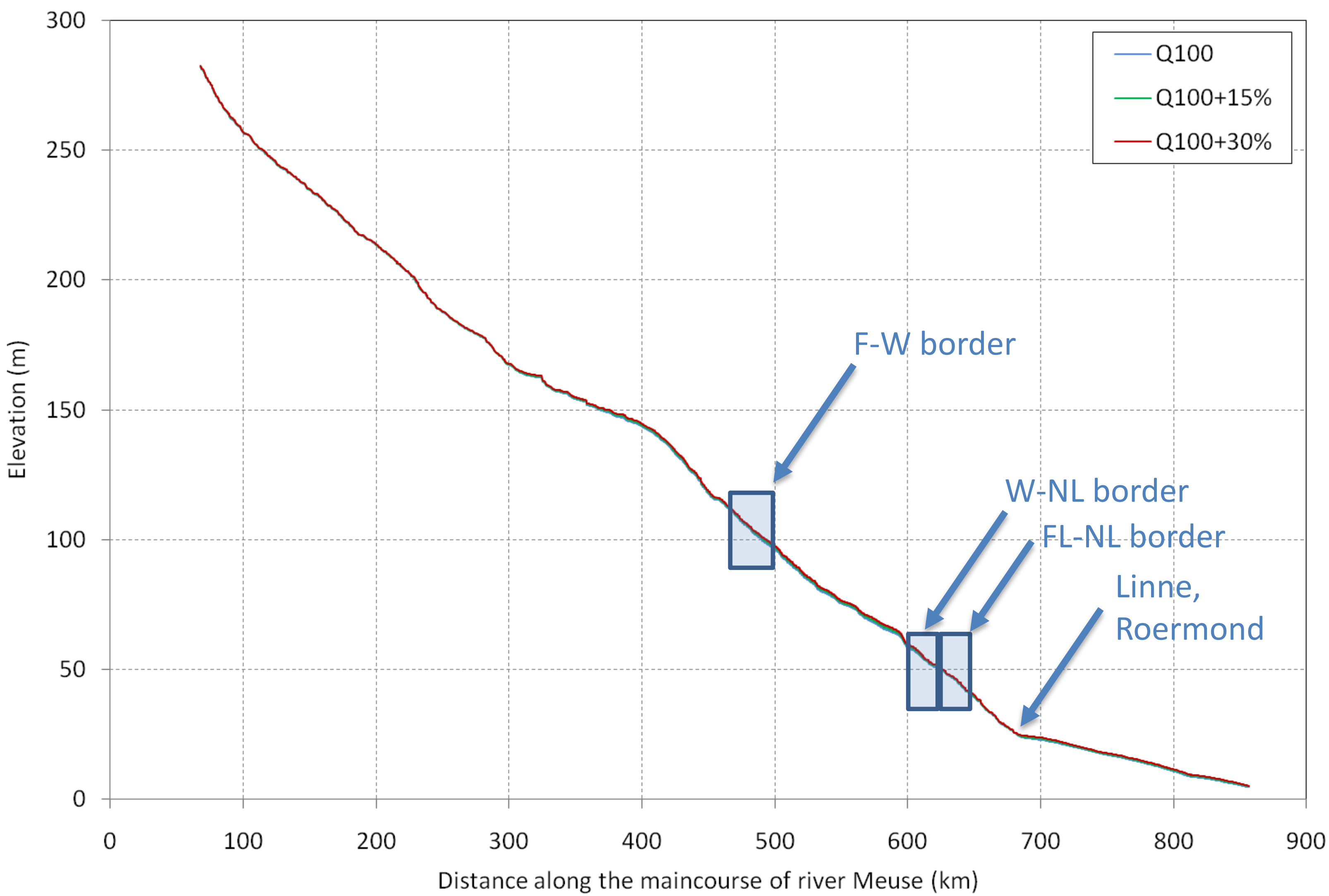
Peak discharges (m³/s)



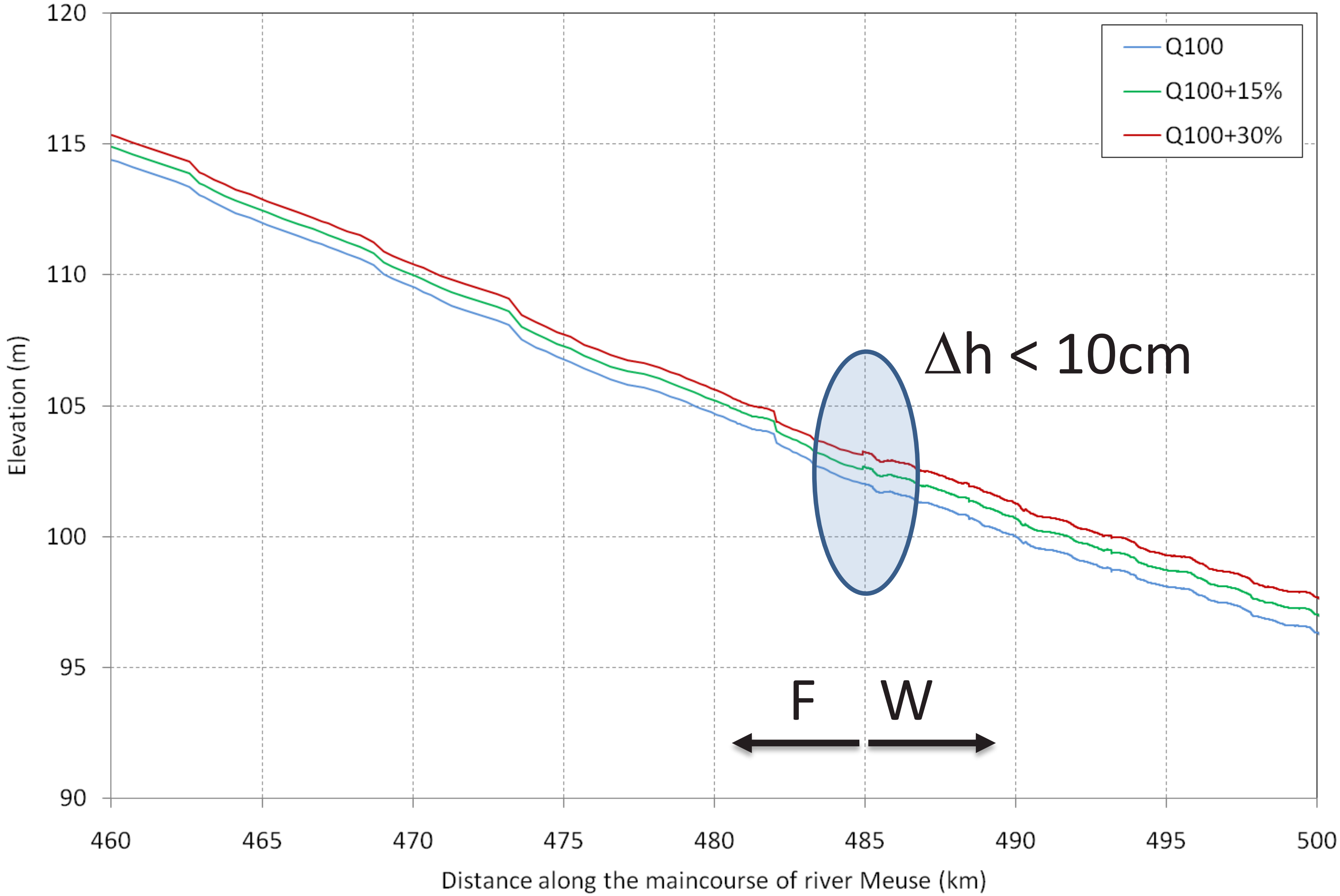
Hydrographs used in NL vs. FL



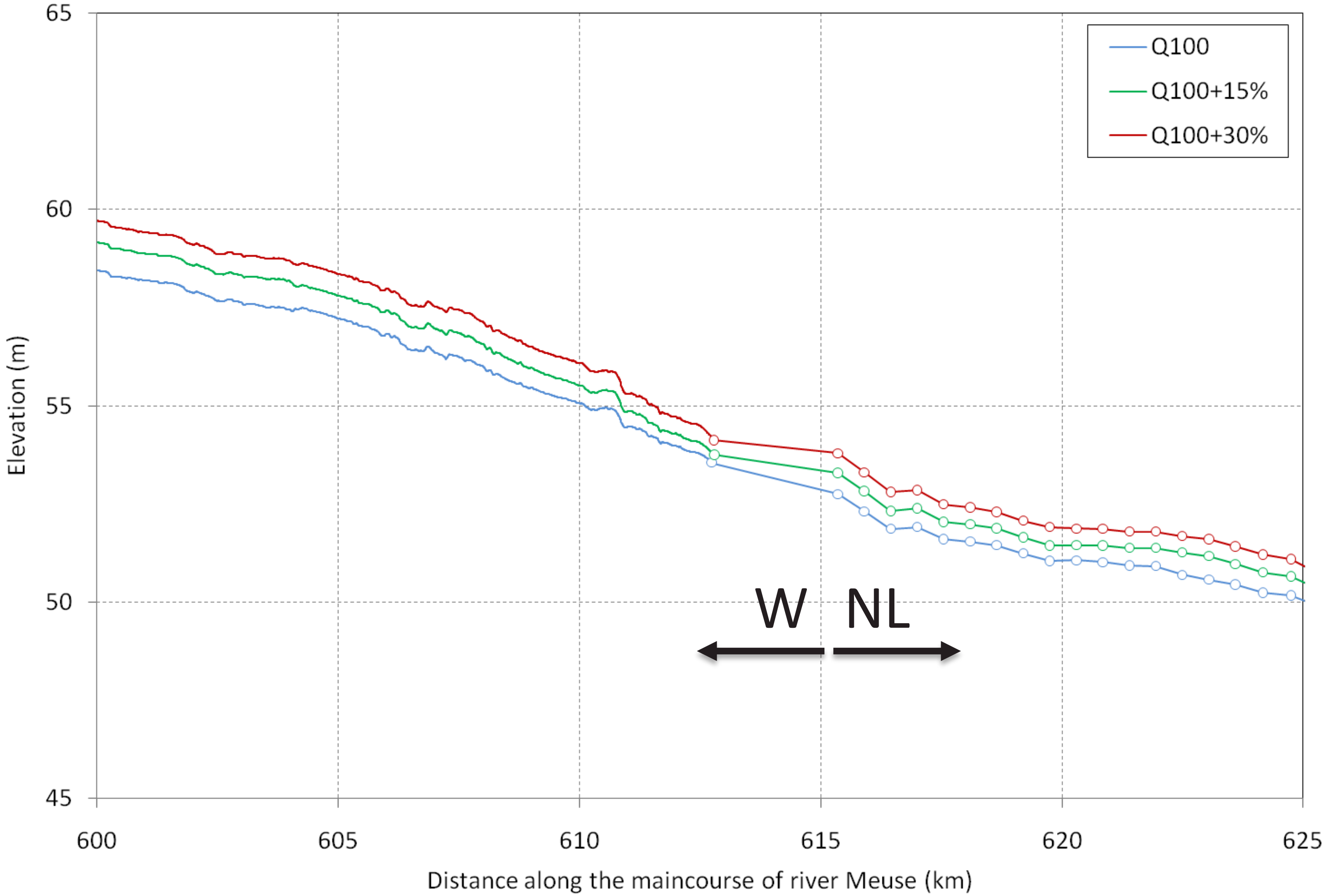
Maximum water elevation (m)



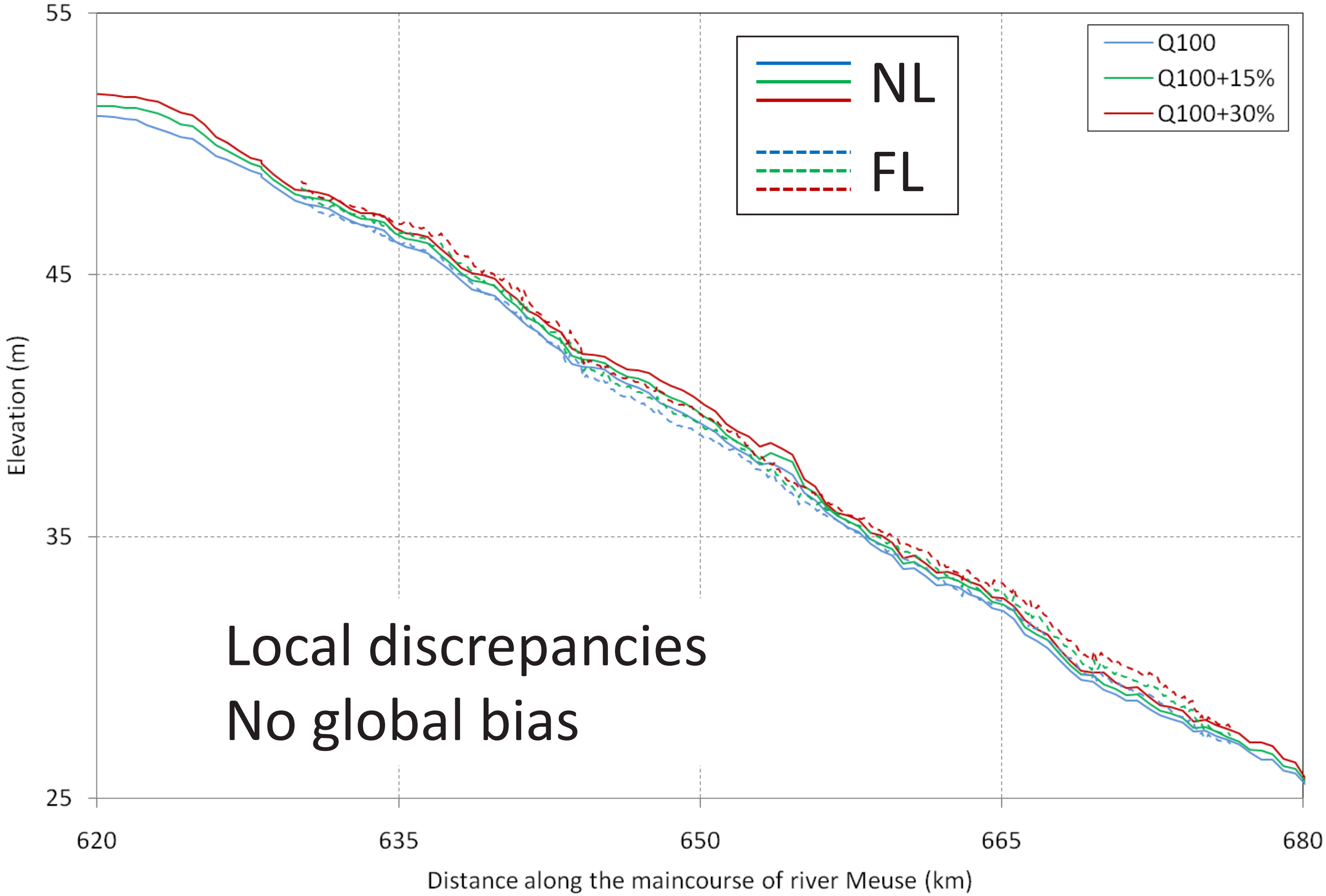
Maximum water elevation (m)
at the F-W border



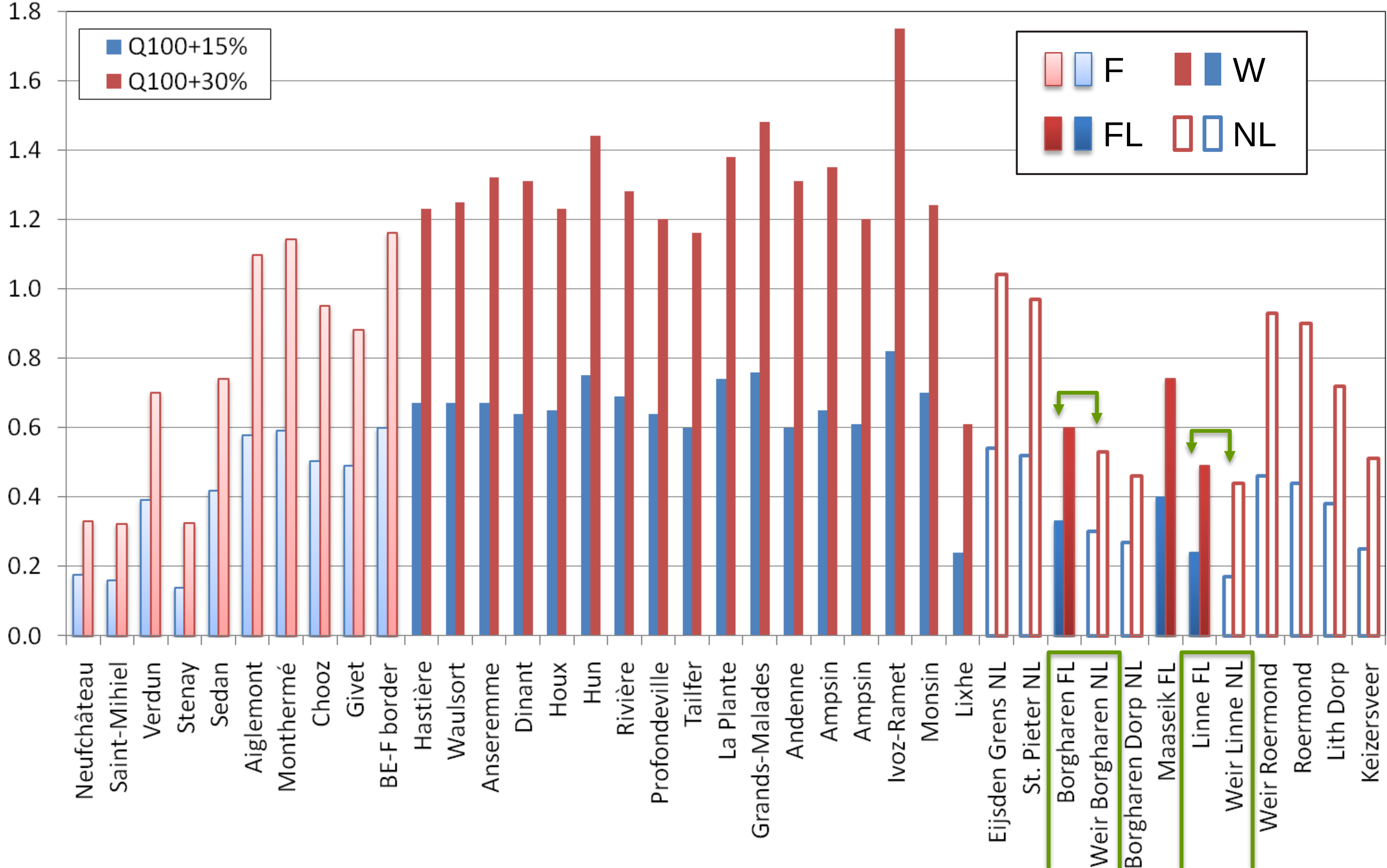
Maximum water elevation (m)
at the W-NL border



Maximum water elevation (m)
along the FL-NL border



Change in water depth
at gauging stations or mobile weirs



Change in water depth
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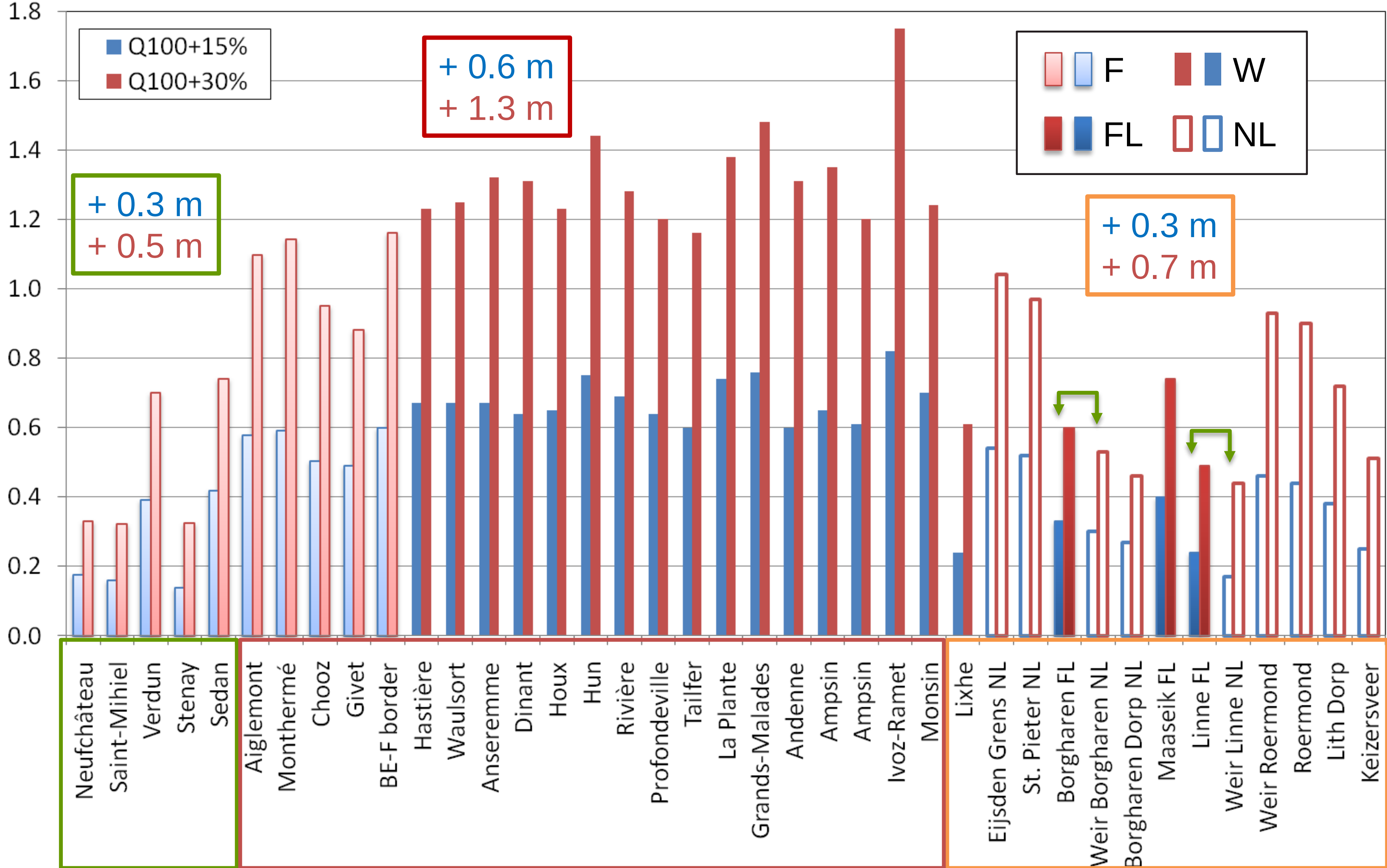
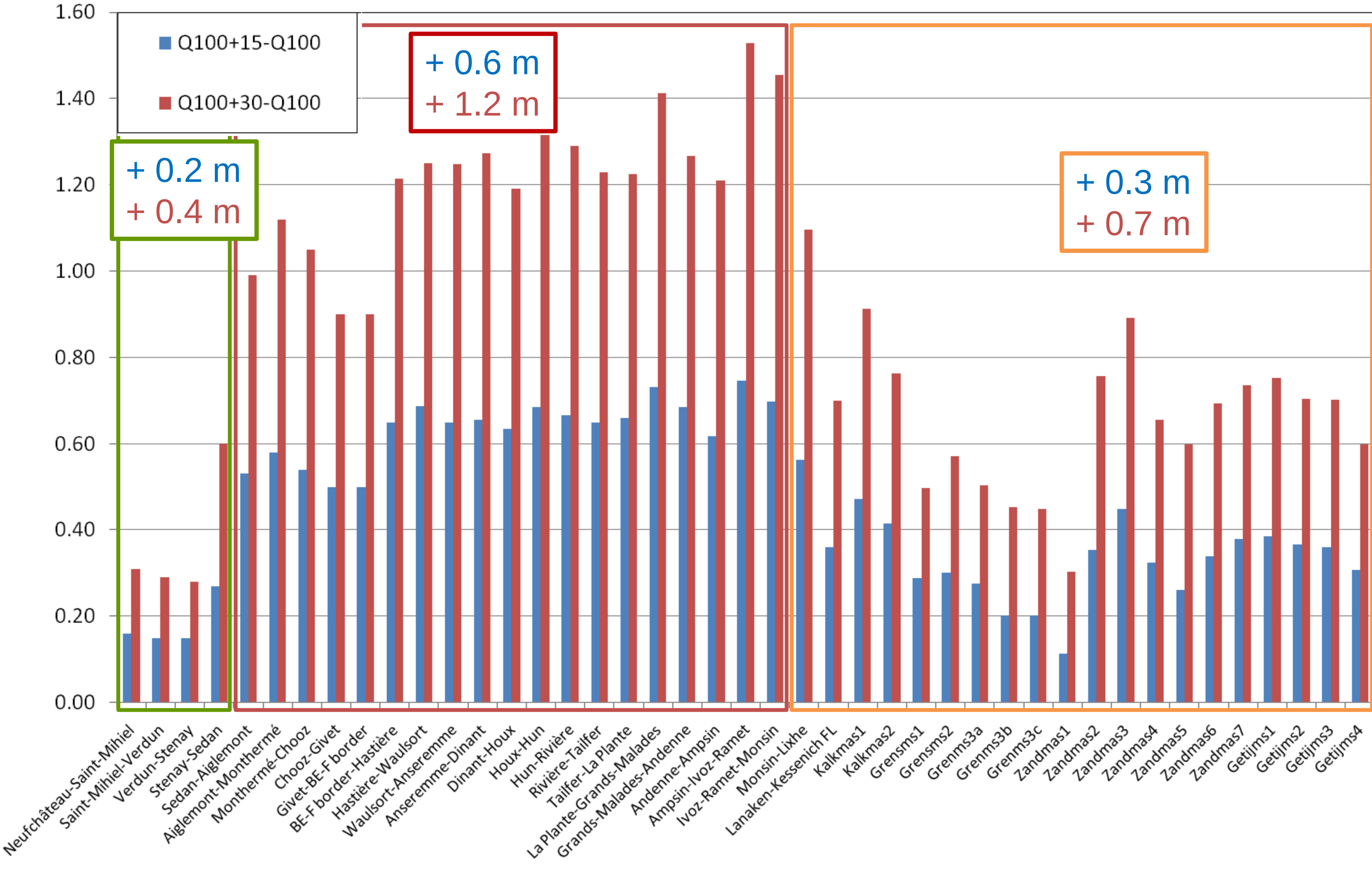


Change in water depth

averaged per reach

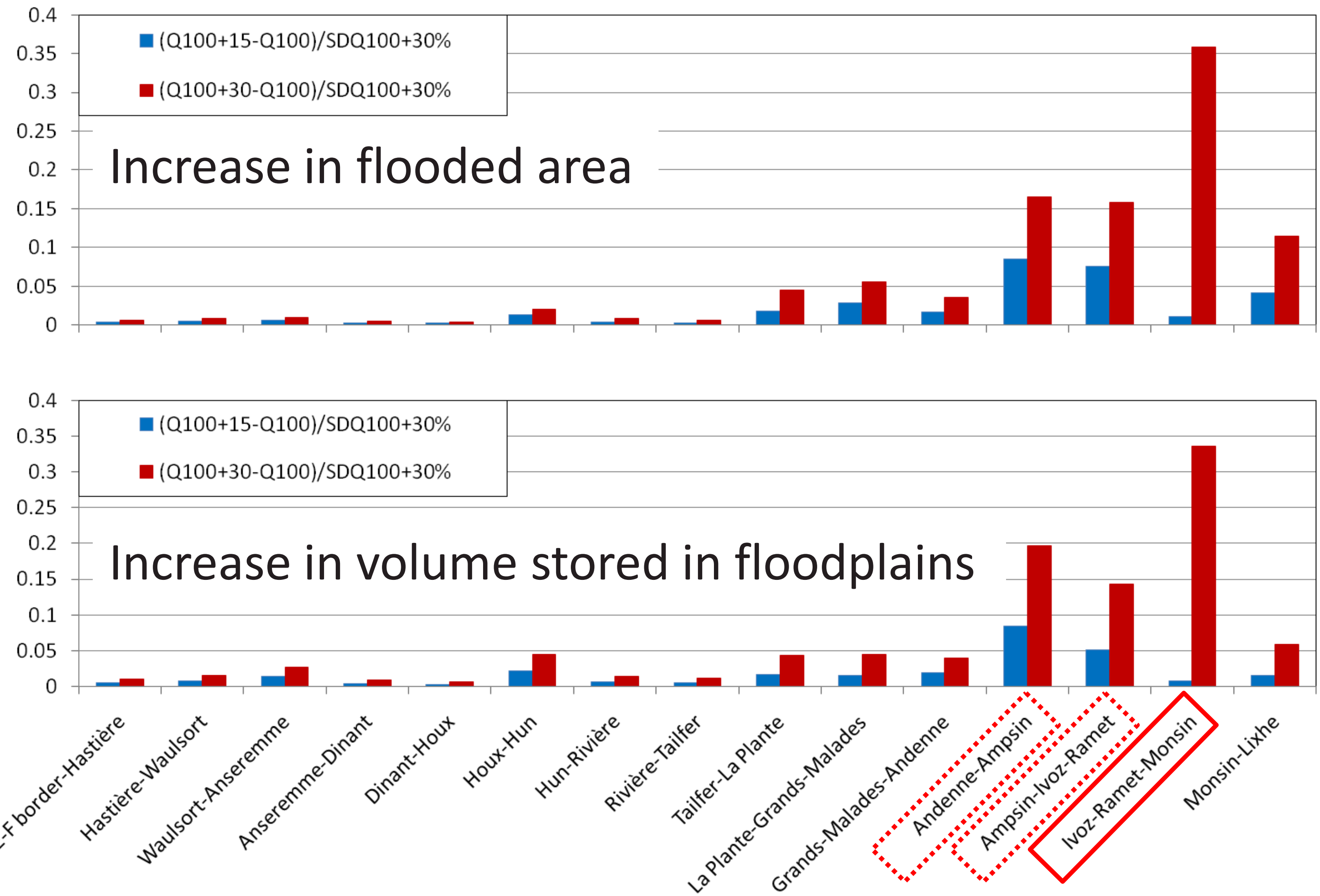


Mean changes in water depth

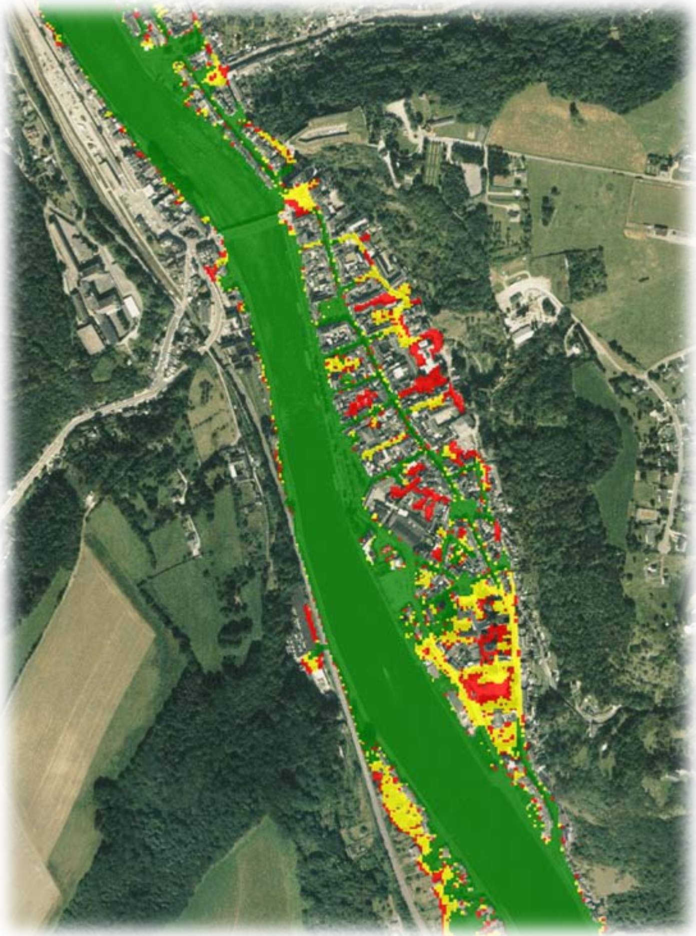
	2021-2050 Q100 + 15%	2071-2100 Q100 + 30%
Upper part *Upstream of Sedan*	+ 0.3 m	+ 0.5 m
Central part *Sedan → Monsin*	+ 0.6 m	+ 1.3 m
Lower part *Downstream of Monsin*	+ 0.3 m	+ 0.7 m

Change in flooded area / stored volume (W)

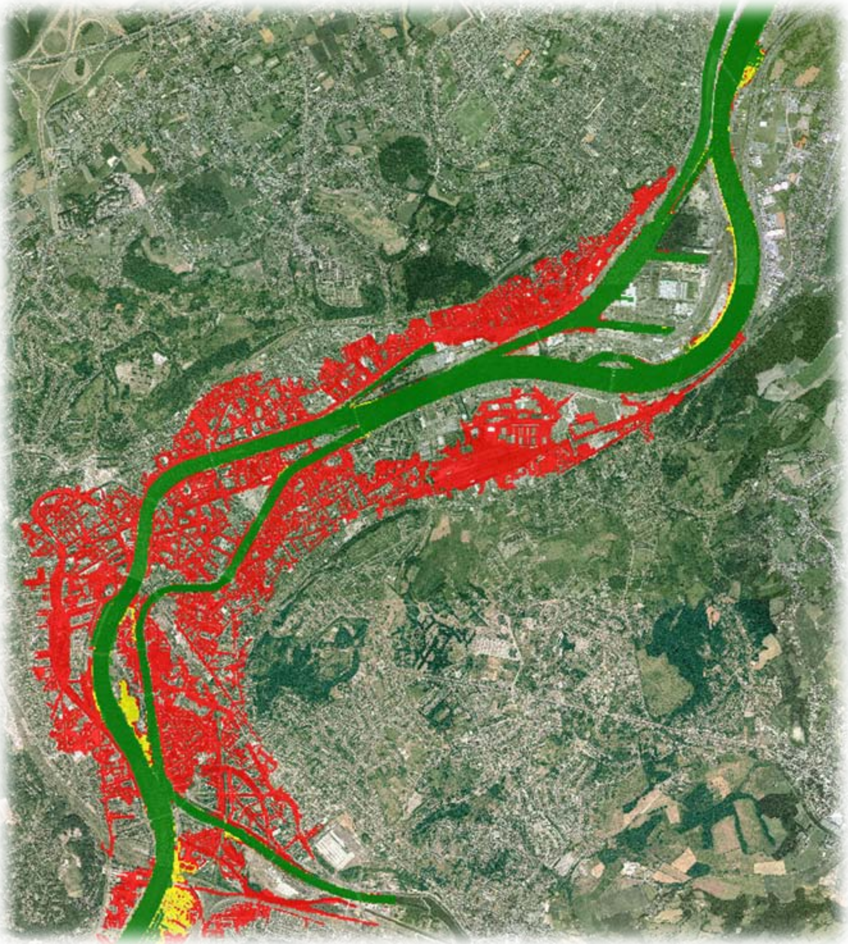
expressed as relative contribution of each reach to the total increase for Q100 + 30%



Inundation extents in Dinant vs. Liege



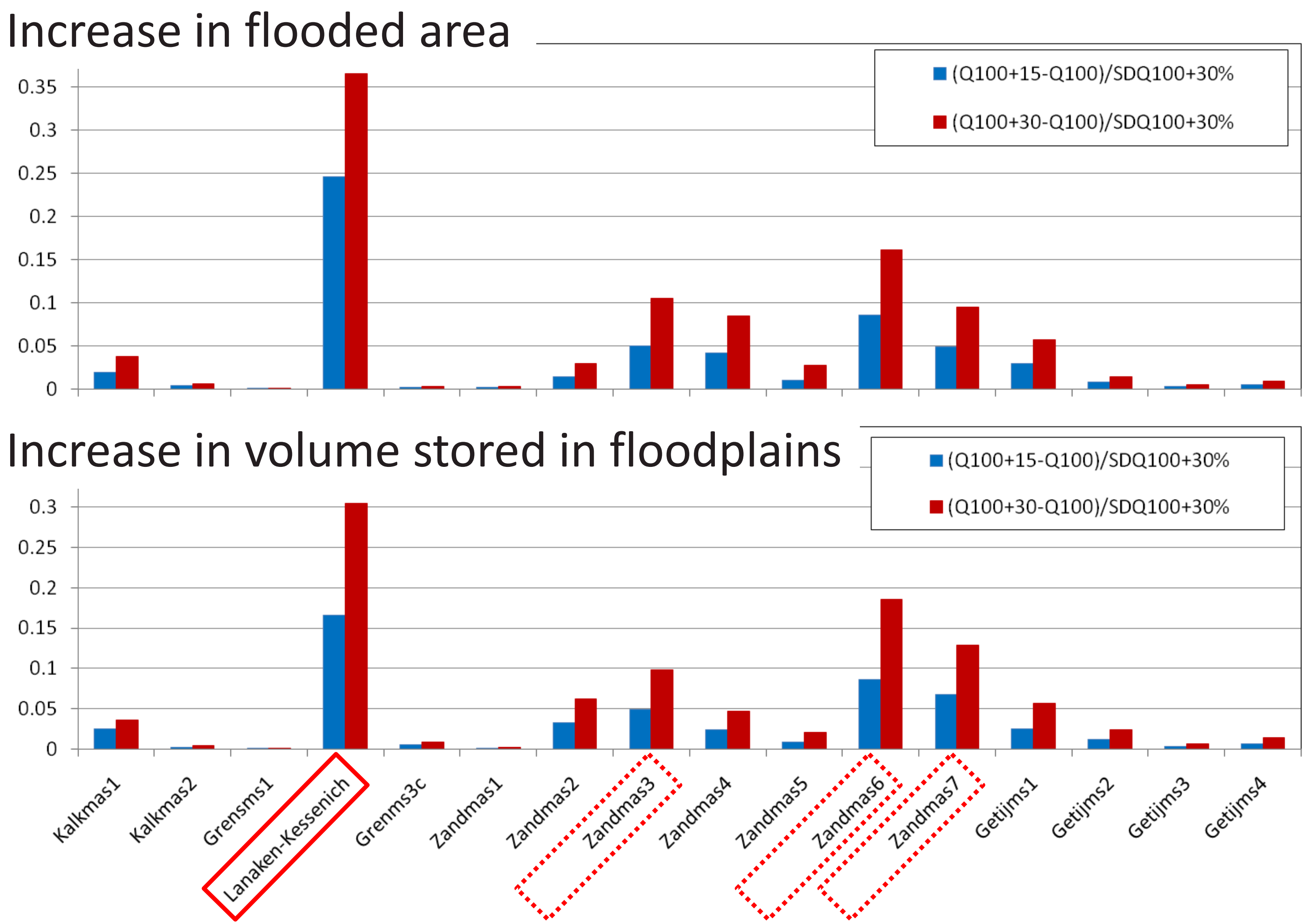
Dinant



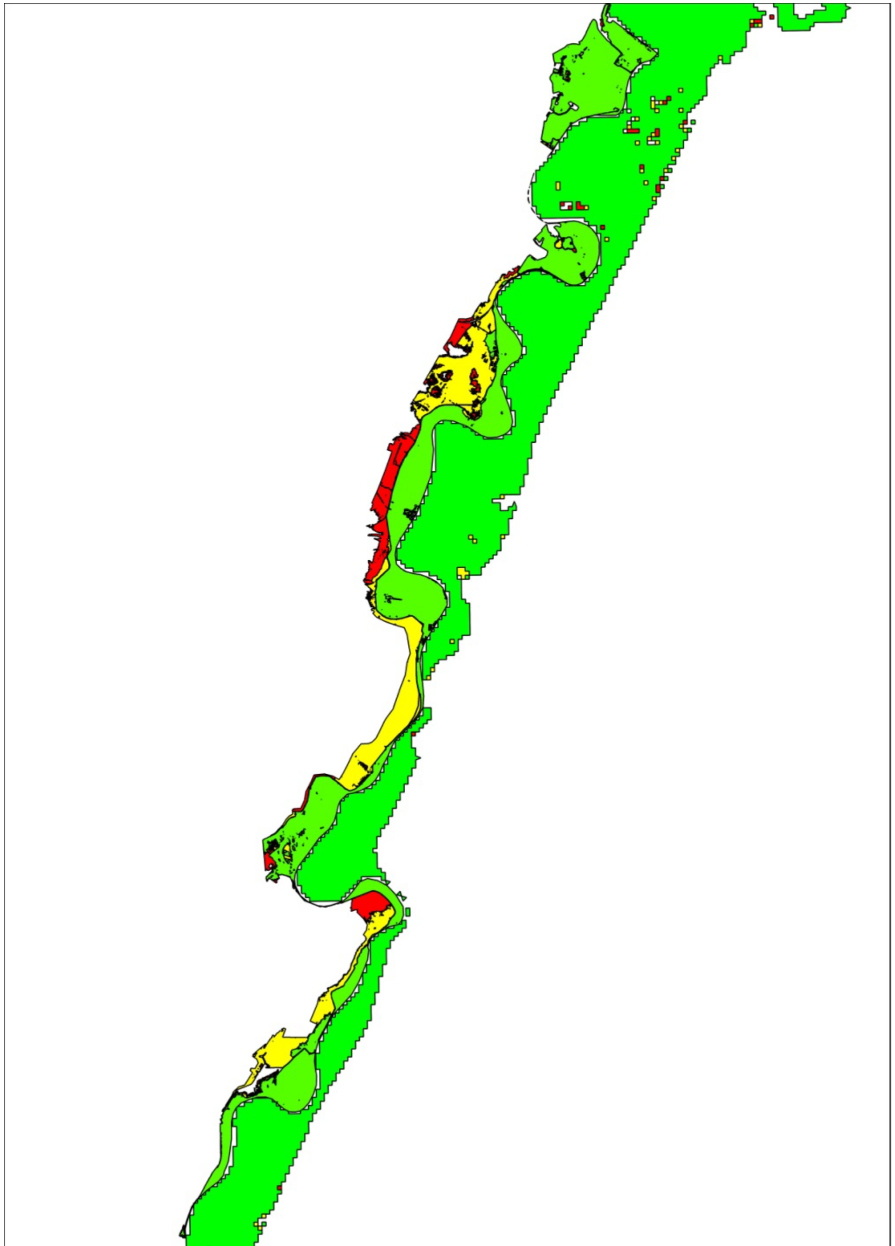
Liege

Change in flooded area / stored volume (FL/NL)

expressed as relative contribution of each reach to the total increase for Q100 + 30%



Inundation extents along Lanaken - Kessenich



Significant increase on the left bank (FL)

No change on the right bank (NL)

Effect of dikes

Q100

Q100+15%

Q100+30%

Conclusions (1/2)

- Set up of a transnational modelling methodology having required max. 2 runs of each model to achieve consistency of results across the borders

- Hydraulic simulations run for two time horizons, corresponding to the wet scenario identified in Ac3

- Sensitivity of water elevations with respect to perturbations in discharge :
  - higher in the central part of the basin
  - lower in the upper and lower parts of the basin

- Mean changes in water depth in the ranges
  - 0.3 – 0.6 for 2021-2050
  - 0.5 – 1.3 m for 2071-2100

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Conclusions (2/2)

- Effect of damping and derivations on hydrographs between Borgharen and Roermond twice stronger for Q_{100} + 30% than for Q_{100}

- Reaches mostly contributing to the increase in flooded area as a result of climate change:
  - between Andenne and Monsin (W), especially Ivoz-Ramet - Monsin
  - Lanaken - Kessenich (FL/NL)

Next steps:

- Delivering hydraulic modelling results (incl. GE) for risk analysis (Ac7) as well as other parts of the project (Ac8 ...)

- Detailed analysis of hotspots, including spatialization