International experiences on sediment transport measurements and management

Challenges of sediment management in the Rhône Mediterranean and Corsican river basins

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Back in time…

In 2011, a workshop on sediment management was organized in Vienna…

“Sediment management in the Rhône Mediterranean and Corsican river basins”

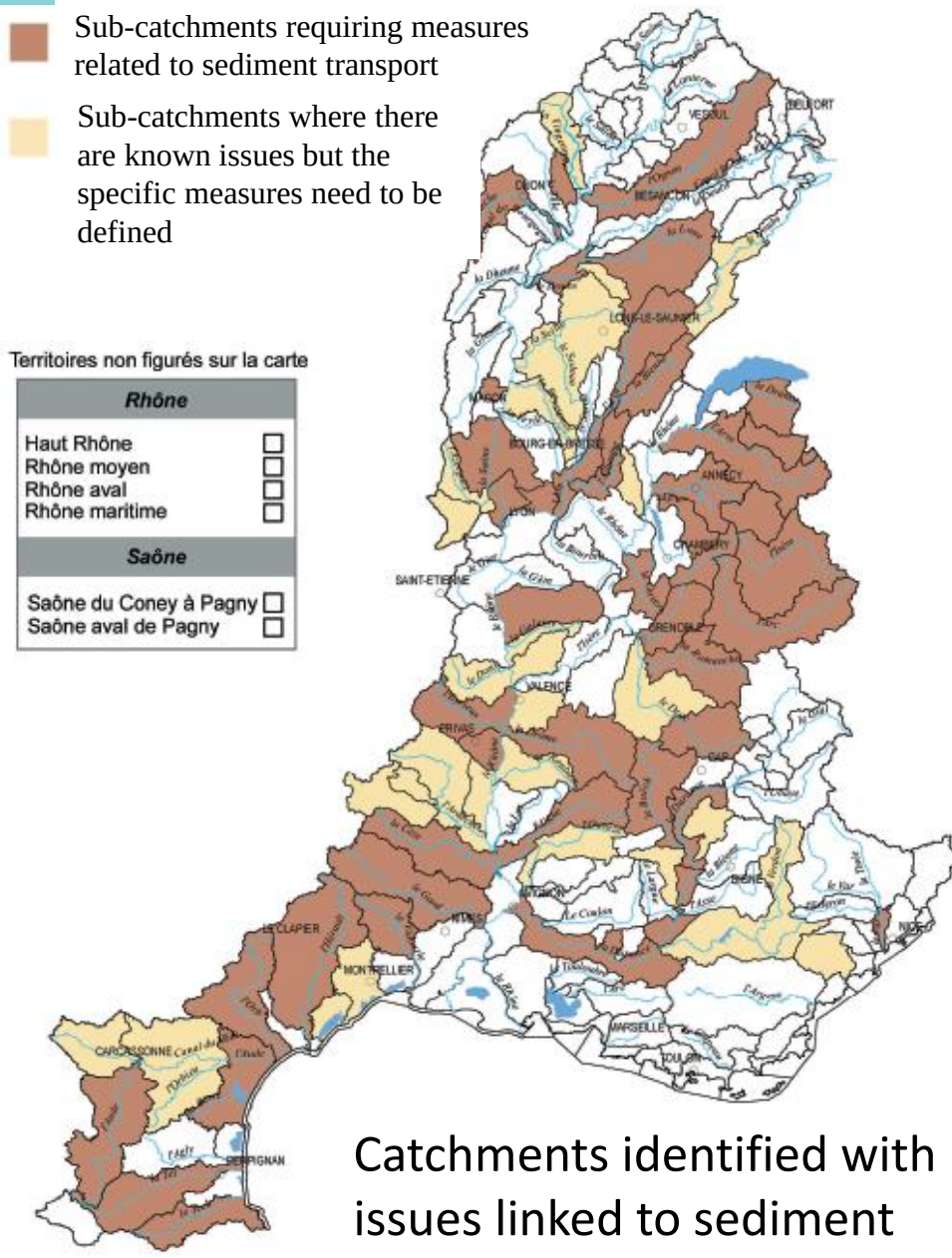
Now **in 2018** : a copy-paste presentation?

What has not changed…

On the Rhone and Mediterranean river basin:

Hydromorphological pressures and alterations remain very significant and widespread

- ❑ 35% of rivers have an **altered flow regime**
- ❑ 45% among them have their biological and sediment transport **continuity** disrupted by weirs or dams
- ❑ 49% have an altered **morphology** (channelization etc…)



Catchments identified with issues linked to sediment

On the Rhone and Mediterranean river basin:

Equally, the efforts to restore rivers remain significant

- ❑ Ecological river restoration is **a top priority for our agency**
- ❑ **About 415M€ spent on river restoration** between 2013 and 2018 (roughly the same budget is planned for the next 6 years)
- ❑ **Some sediment management plans** in priority catchments with sediment budgets and geomorphological trajectories of river systems
- ❑ **Ecological continuity restored on 150 to 200 weirs / dams per year** – (has increased) with the proportion of weir removal on the increase
- ❑ **Morphological river restoration** carried out on **100km-120km per year** (has increased)

Main types of restoration projects related to sediment:

- **Dam/weir removal/lowering or use of sediment valve to restore sediment continuity** (many examples, e.g. Var, Bozanson etc.)
- **Restoring channel morphology and functioning** (many examples, Yzeron, Drac, Ouvèze, etc.)
- **Restoring lateral erosion processes, e.g. setting back flood defences** (many examples, Durance, Rhône, Ain, Chéran, Guiers, Têt, Tanyari etc.) / **reconnecting oxbows** (Rhône, Ain, Saône, etc.)
- **Re-introduce sediment** / e.g. taking sediment u/s of a dam and re-injecting it further d/s – (few examples, e.g. Fontaulière, Têt etc.)
- **Artificial** (**mobilising) floods** (few examples : Isère, Durance…)

Cozanne, 5 weirs (<2m) in 5km (2013)

Le Bosançon, 2 dams of 5m (2012)

French Policy framework concerning sediment management

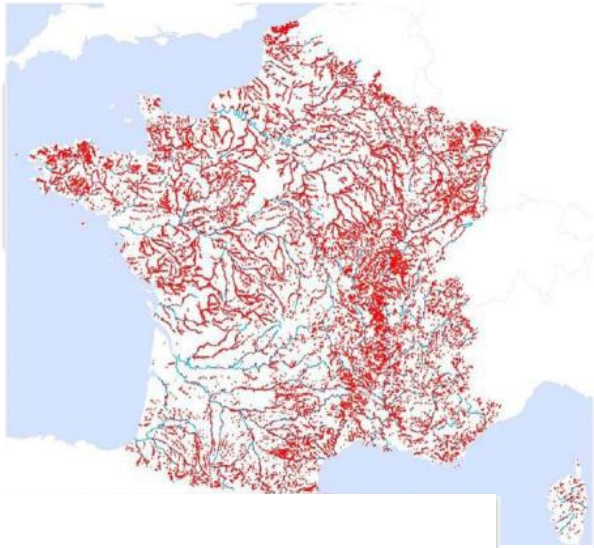
There was a legal requirement to publish a list of rivers for which it is necessary **to re-establish *sufficient* sediment transport and fish migration**

Two lists of rivers reaches had to be identified:

⇒ **List I**: rivers in very good ecological conditions (conservation)

⇒ **List II**: rivers for which restoring ecological continuity is required

It was **a legal requirement** to restore continuity before 2018 on identified dams and weirs which are located on rivers in list II.

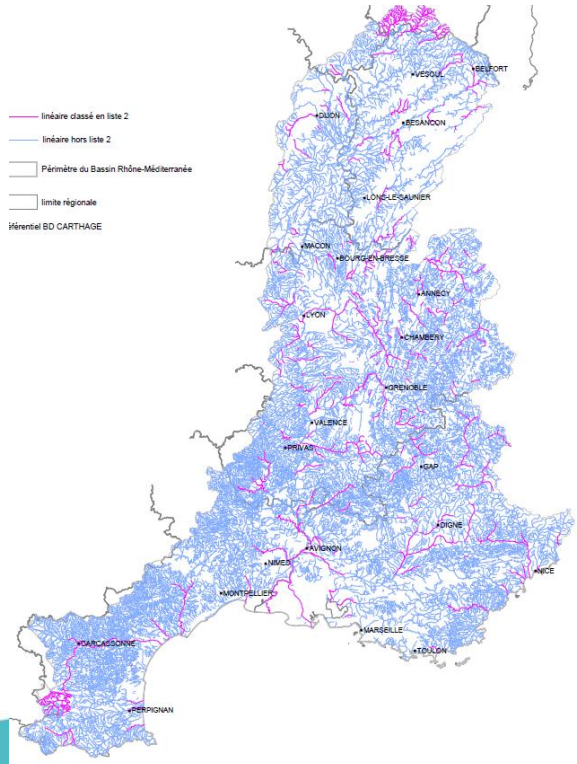


National database on barriers (weirs, dams etc.) – over 85000 barriers identified

Since then…

- **About 1400 weirs and dams** identified on list II on which continuity had to be restored **(or work started) before 2018**
- **Sediment continuity criteria accounts for less than 20 % of cases.**
- A **management tool** has been designed to help to monitor progress *(e.g. contact made with weir/dam owner? Studies carried out? Restoration work started? completed? Etc)*
- Restoration **completed on about 400 weirs/dams** and studies/work have **started on about 300 weirs** - possibility to extend the deadline by 5 more years

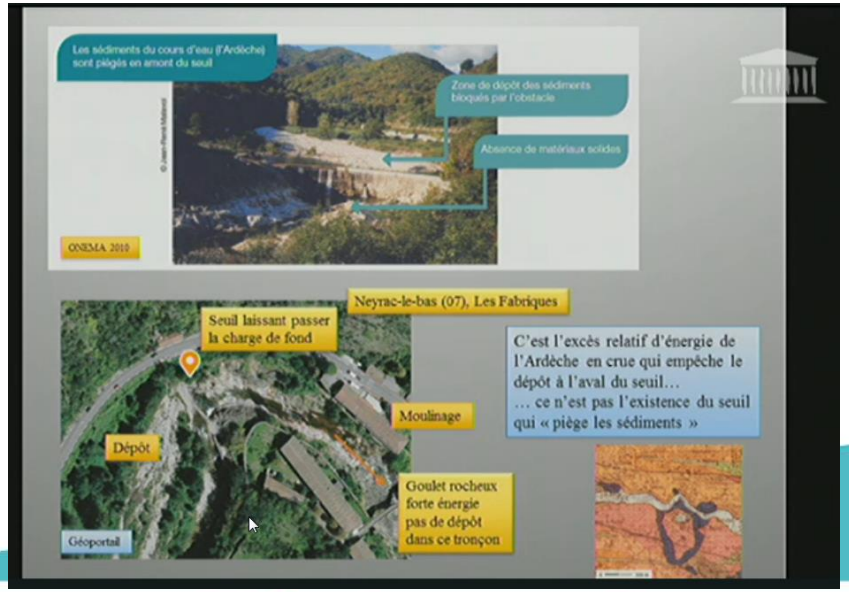
=> *Different approach from being solely opportunistic*



Official map of list II reaches

Since then…

- **A bit of national controversy…**
- **Not enough priorization in some river basins (over 6000 weirs on some list II), a lack of communication, sometimes a lack of concertation etc. have locally caused some strong opposition.**
- **Political lobbying** against the list I and II law
- A debate at the National Assembly



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A policy challenging to implement but it is happening.

Significant improvements in terms of monitoring (1/2)

- **Improvement on passive acoustic measurement - hydrophones**

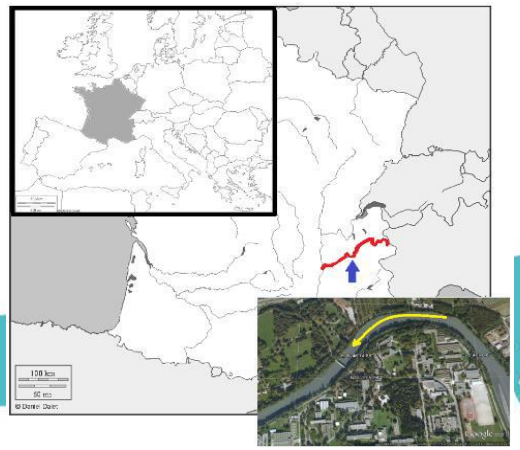
Tested in the Alps on several **gravel-bed rivers** (Arc, Arve, Grand Büech, Isère, Romanche and Severaisse)

"has the potential to be used as a standalone method that could ensure high spatial and temporal resolution measurements for sediment transport in rivers" *Petrut et al. 2018*

Attempts to estimate grain size distribution from self-generated noise.

About 5000€ when installed in a hydrometric station

Test on the Isère river with comparison with Helley Smith, Camenen



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e.g. Estimating grain size distribution from self-generated noise.

About 5000€ when installed in a hydrometric station

Still a challenge to make it fully operational but we're definitely making progress

Significant improvements in terms of monitoring (2/2)

- **Development on active transponders (ultra high frequency 433MHz) for tracking pebbles**

Benefits (vs PITs):

- High detection range (in atmosphere up to 80m, buried in sediment up to 4m when depth>2,6m, submerged : up to 2m)
- Excellent recovery rate and lower prospection time
- Accurate positioning, anti-collision

Drawbacks:

- Minimum size (25 to 30mm)
- Production cost

Cassel et al 2018

Useful to assess sediment transport continuity, propagation from upstream or from a restored site etc.

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Study sites	Dist. max (m)	Dist. mean (m)	Recov. rates	Prospec. time (man/day)	Accuracy (m)	Observations
Le Rhône Jons Dam	1066	323	70%	8	≈ 2	Water depth up to 3 m Rapid turbulent flow
Le Buëch St-Sauveur Dam	3240	982	72%	5	≈ 10	Quickest prospection

Compared to PIT tags studies

Cassel et al 2018

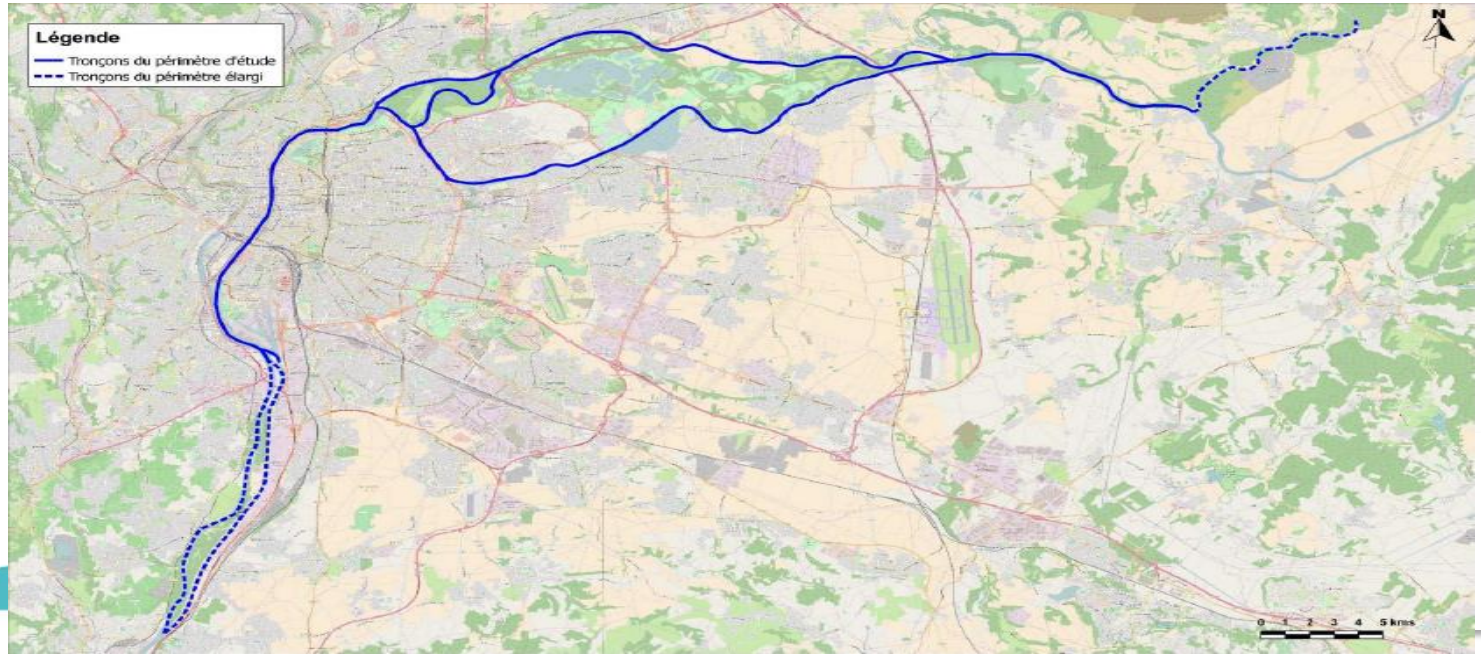
Le Rhin Arnaud et al. (2017)	658	171	43%	11	≈ 1 .5	Environment similar to Rhône
La Durance Chapuis et al. (2014)	668	83	40%	16	≈ 1 .5	Environment similar to Buëch

More ambitious modelling carried out

Sediment transport numerical modelling and physical models are becoming more ambitious (space and time scale), modelling more complex processes (fine / coarse sediment, vegetation)

e.g. Rhône, Isère, Durance etc.

- Example of a Telemac 2D and SISYPHE model of the Rhône between the Ain confluence (u/s of Lyon) and Pierre-Bénite dam (d/s of Lyon) - 43km
- Calibration over a 5 year period (2011- 2016)
- Used as a tool to design river restoration project



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It remains challenging to reduce models set up and running time and models uncertainty

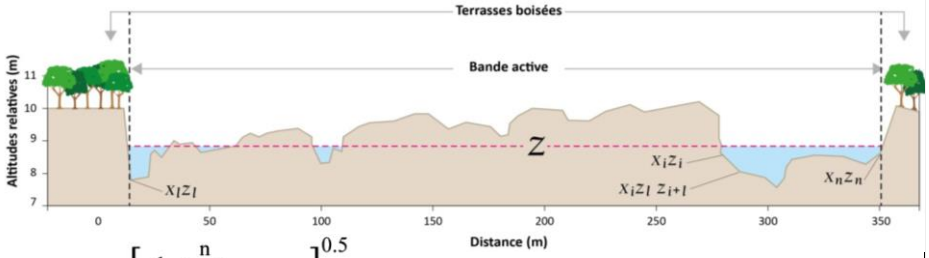
Improved knowledge on braided rivers

A **4 year multidisciplinary research project on braided rivers**:

- Development of new (regional) indicators **on 50 reaches** to assess the **geomorphological trajectory** and the **braided pattern activity** (Belletti et al 2013)

=> Helps to design river restoration strategy (e.g. Drac)

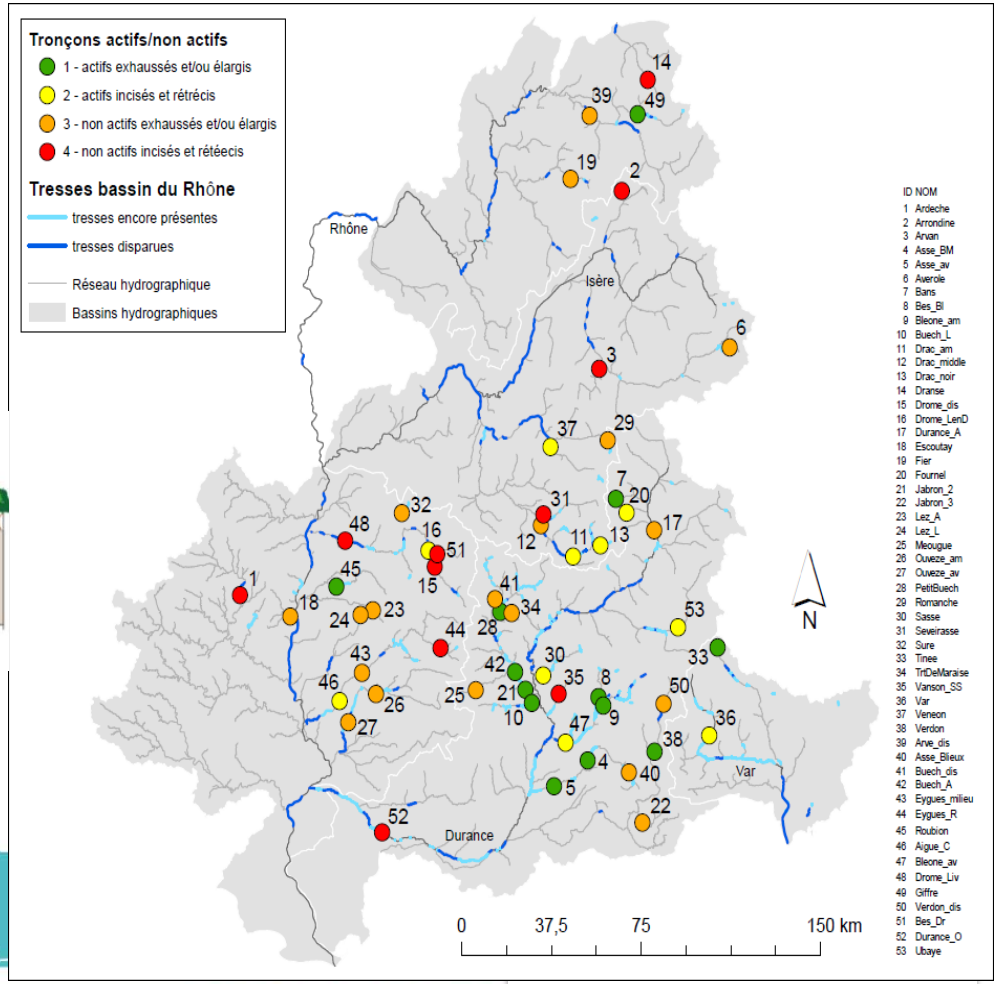
- A **technical guide** to be released early 2019 (Piegay, Terrier, et al.)



$$BRI = \left[\frac{1}{n-1}\sum_{i=1}^{n}(z_i - Z)^2\right]^{0.5}$$

$$BRI^* = \frac{BRI}{x_n - x_1}$$

Bed relief index, gives an indication of the intensity of sediment supply



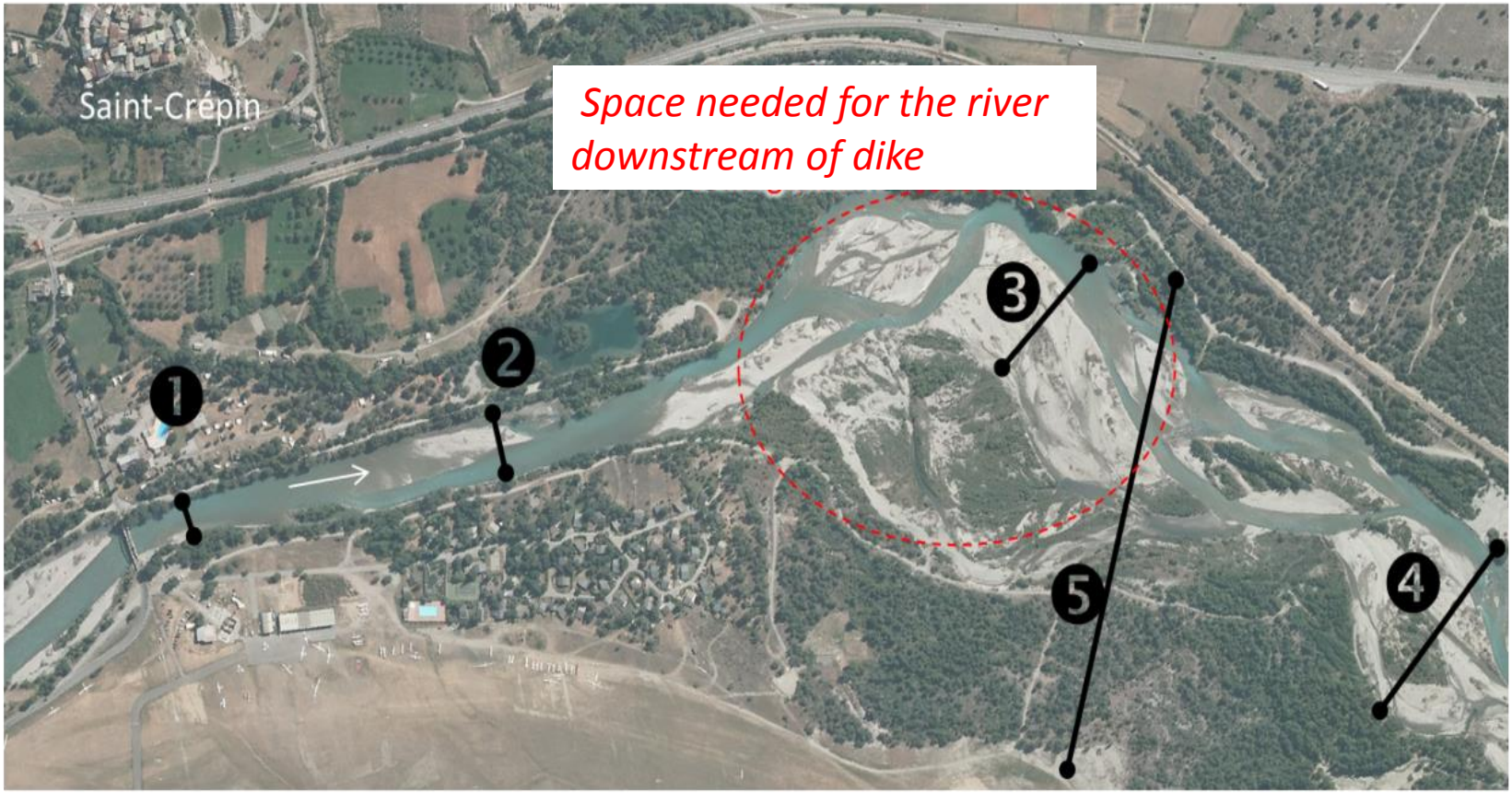
Progress on space for rivers (1/4)

A technical guide on space for rivers

(Terrier et al. 2016)

- Methods proposed by **fluvial style to define morphological and hydraulic spaces**
- Takes into account **hydrogeology, biogeochemistry** and **biology**
- Also provides methods for **project management and concertation (multidisciplinary project)**

From the concept of “erodible corridor” (1996) to the more integrated concept of “space of good functioning” (2/4)

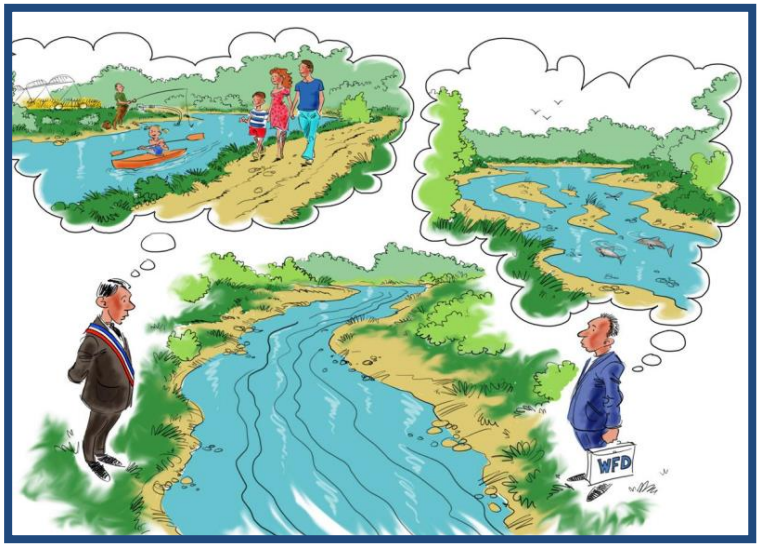


River Durance at Saint Crepin

Alternate bars / braided fluvial style

The space of good functioning contributes: (3/4)

- To reach and preserve good ecological status ;
- To preserve the resilience of aquatic ecosystems;
- **To deliver functions and sustainable services**.



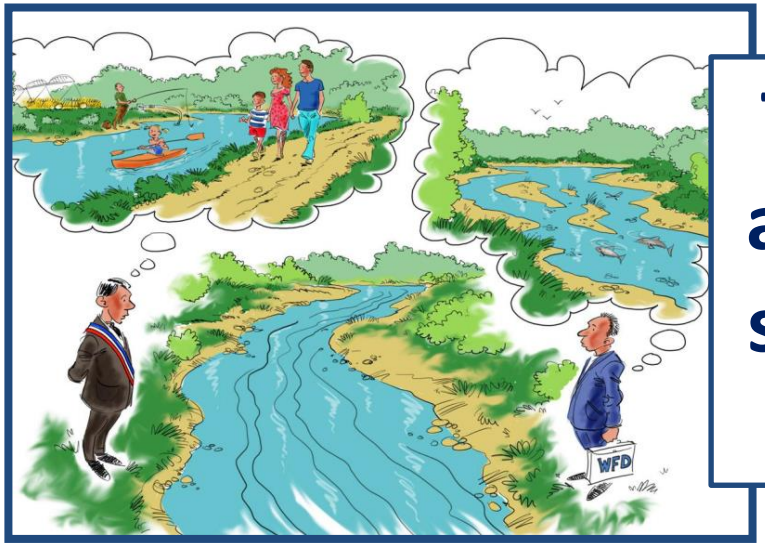
Functions : sediment transport, flow dynamics, exchange with groundwater, self-purification, support of biodiversity

Services : flood risk, water quality, green tourism, amenity, ecological patrimony

The space of good functioning (4/4)

- The river basin management plan makes it compulsory to **take this space into account in urban planning** when it has been defined

- Gravel mining cannot take place in space for rivers



The challenge is to have more and more decision makers and stakeholders who use this tool for planning

More attention paid to social and human sciences (1/2)

- Rivers where coarse sediment is abundant can be **less appreciated**, may seem **more chaotic** and in **needs of maintenance** (*study on the river Roubion, Le Lay et al. 2013*)

- **More integrated projects are set up** with engineering consultancies associated with consultancies specialized in **human and social sciences**

- **Many projects now have a planned "listening phase"** where consultancies will listen to people (typically through interviews) to design more integrated projects

More attention paid to communication (2/2)

At the start of a project, it helps to :

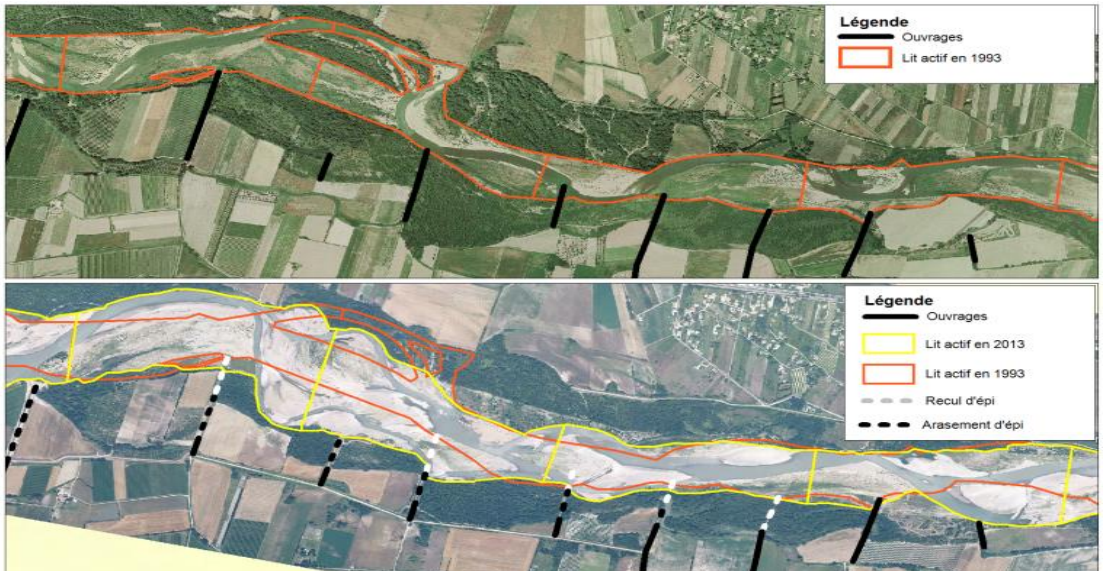
- **explain to stakeholders and decision makers** in a very simple and illustrated way **how a river works** (basic principles of hydromorphology, fluvial dynamics)
- **tell the history** of the river

Example of documents used in a workshop on the Lez river (Southern France)

Data on the financial benefits of setting back flood defenses

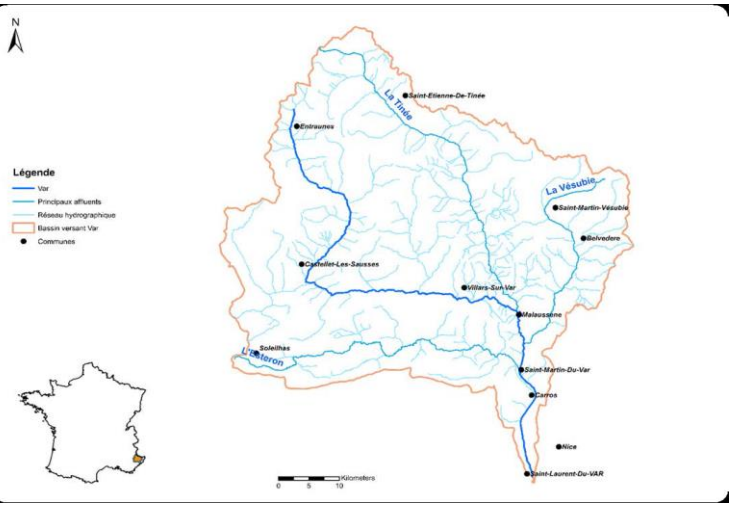
- River Durance (Southern Alps) :
  - In 1997, after the 1994 flood event, **4km of dikes were setback from between 100m and 200m**. On average, the river Durance has now widened from 240m to 350m.

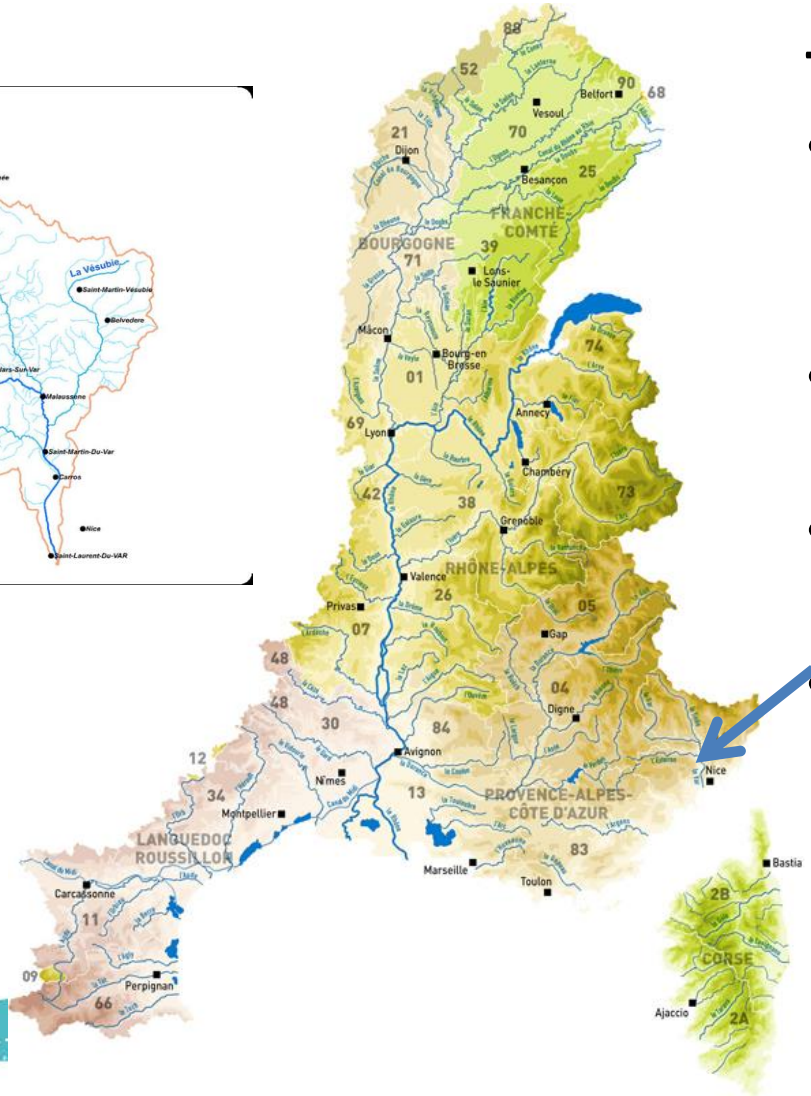
=> It avoided 10M€ if one had to rebuilt the dikes near the river



- Near the industrial area of Saint Maurice at Manosque, **the cost of setting back 400m of dikes was 500k€ compared to 900k€ to strengthen the existing dikes** close to the river (2016)

Lowering the weirs of the Var (1/6)
Example of a carefully planned restoration





The Var river:

- River source in Mercantour (1800m asl)
- River length of 110 km
- Catchment area of 2822 km²
- Still high coarse sediment inputs from upstream

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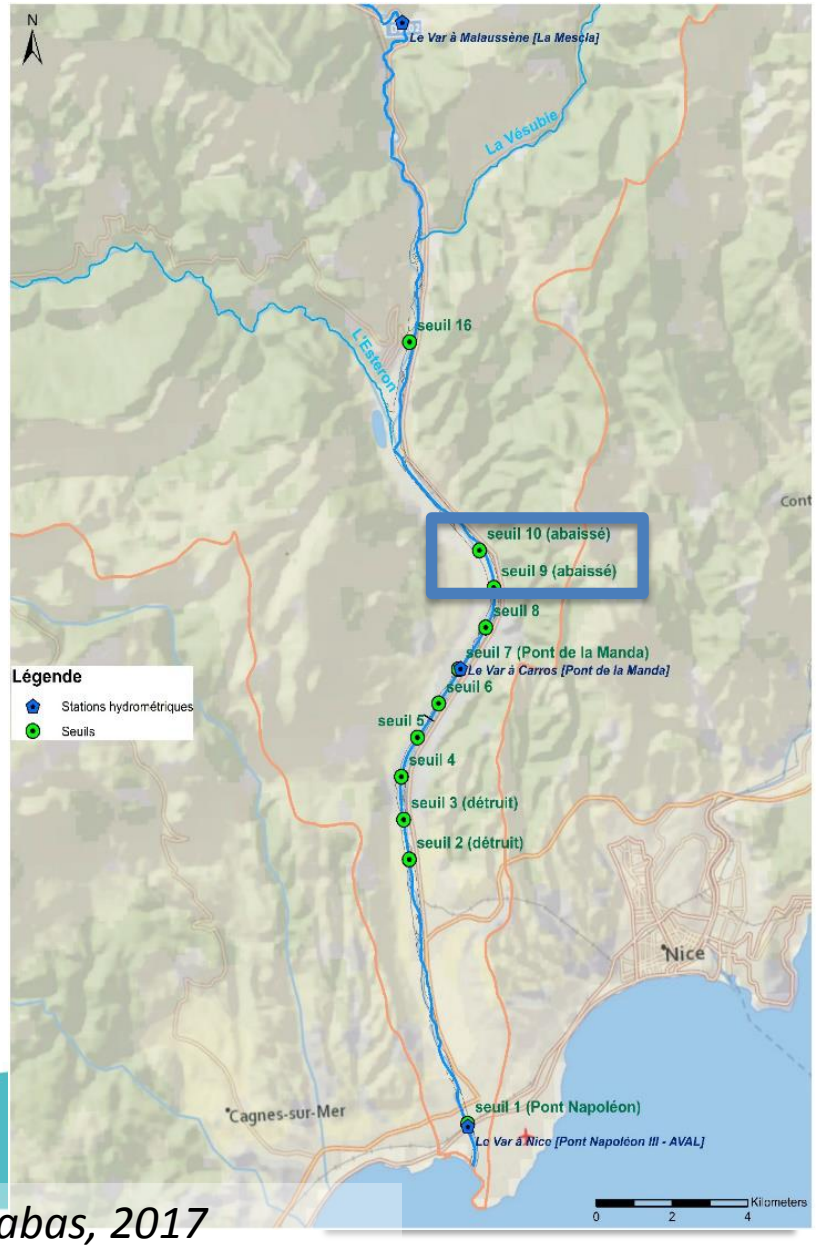
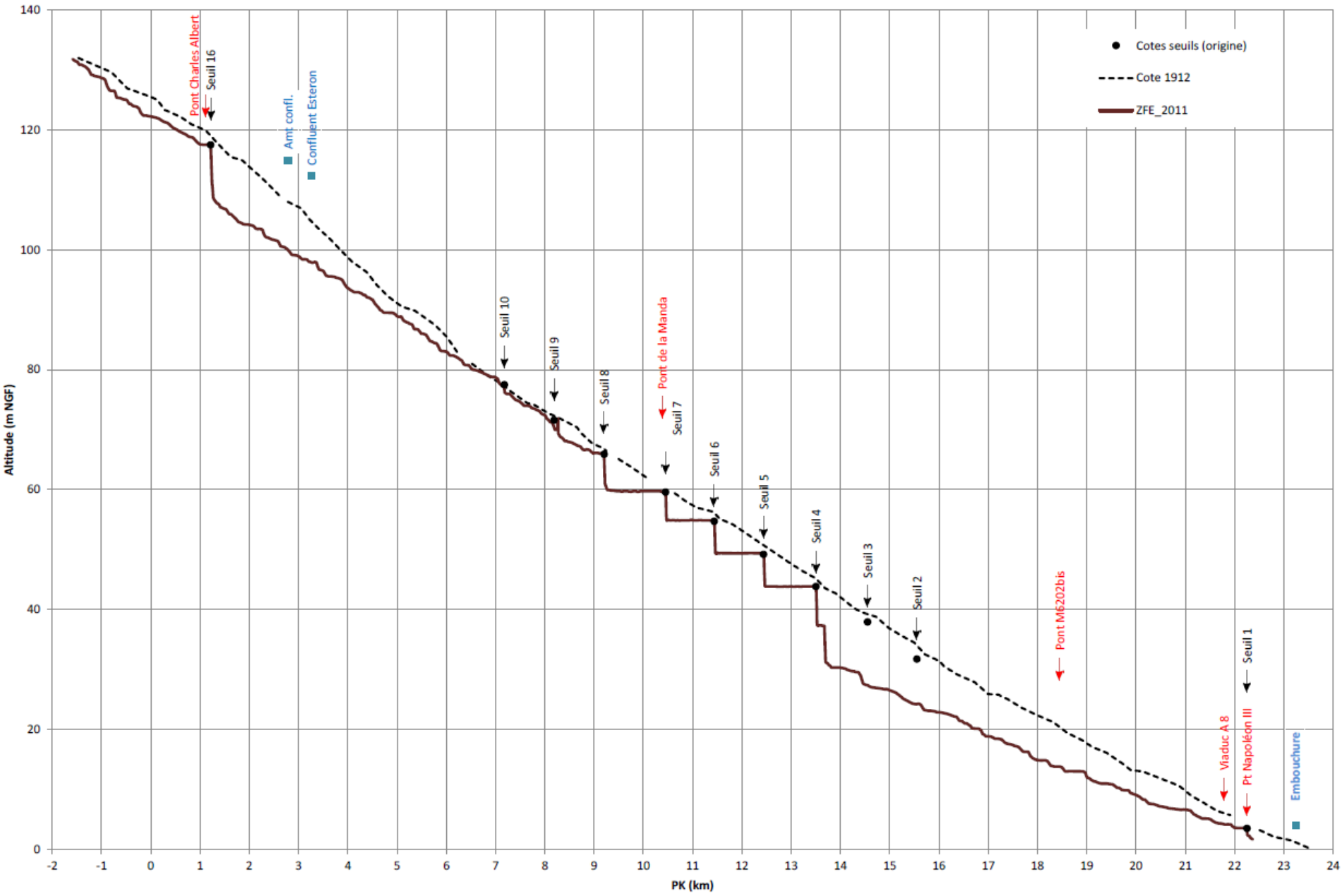
Lowering the weirs of the Var (2/6)

- In 40 years, the **dredging of 50 Mm³** of sediment caused severe incision and significant lowering of ground water table.
- **11 weirs of about 5m were built** to stop incision (btw 1971 and 1986)
- Some weirs began to fill up with sediment (1994 flood, 3000m3/s) and there was a **risk of flooding in some areas**
- **Downstream, incision was still severe**

=> The decision was made **to phase the lowering of the weirs** to reach a new equilibrium



Source: Ait Elabas, 2017



Lowering the weirs of the Var (4/6)

A **SAGE** (a tool at catchment scale with stakeholder committee and legal scope) was set up and approved in 2007

“Bringing back the Mediterranean style of the river”

2014

1943

Source: Ait Elabas, 2017

Lowering the weirs of the Var (5/6)

- First, in 2009 and 2012, 2 weirs were lowered by 2m (weir 9 and 10, in 2009 and 2012, for about 3,5M€)

Carros, 1999

Carros, 2014

Lowering the weirs of the Var (6/6)

- **Braided pattern** came back after restoration downstream of the lowered weirs

- Work was carried out on weir 8 last month (cost about 1M€).
- Several morphological data and indicators are used for monitoring (e.g. Lidar, bed relief index) and a thesis will start in 2019

Concluding remarks

- **Significant technical progress made** (hydrophones, active transponders, teledetection etc.), **helping us to better understand what moves, when and where it moves, etc.**

  => A need to increase efforts on monitoring (**network of pilot sites set up in 2011**)

- Still work to do to design better **sediment management plans on large catchments** and **on the long-term,** while adopting **adaptive management (more ambitious projects coming)**

- **More efforts needed on communication** and **the training of stakeholders** to bring a cultural change on sediment (especially in relation to flood risk)

"What if the river was becoming an asset for my region?"

Thank you for your attention !

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