
# Rhône Sediment Management Master Plan between Geneva and Mediterranean Sea

## An integrated and synergistic management of sediments as a response to ecological, safety-security and socio-economic issues

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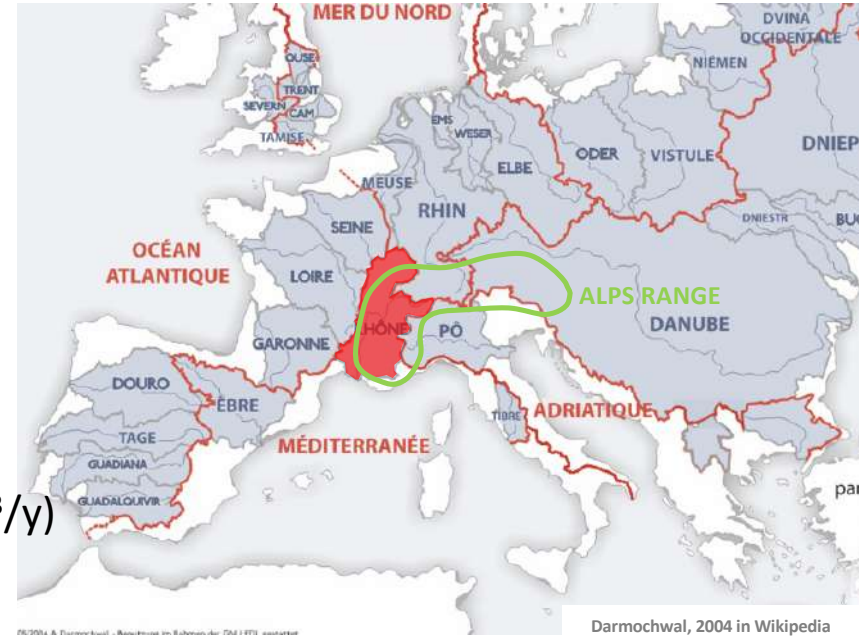
# Context

- **Presentation of the Rhône river (France)**
  - 810 km long (540 km downstream of Geneva Lake)
  - 98 000 km² watershed (western Alps)
  - in EU : 14th in length, 7th in watershed, 3rd in mean flow
  - major fluvial axis : transportation routes, economical basin and ecological corridor
  - sediments = the heart of the issues (dredging = 850,000 m³/y)



Darmochwal, 2004 in Wikipedia

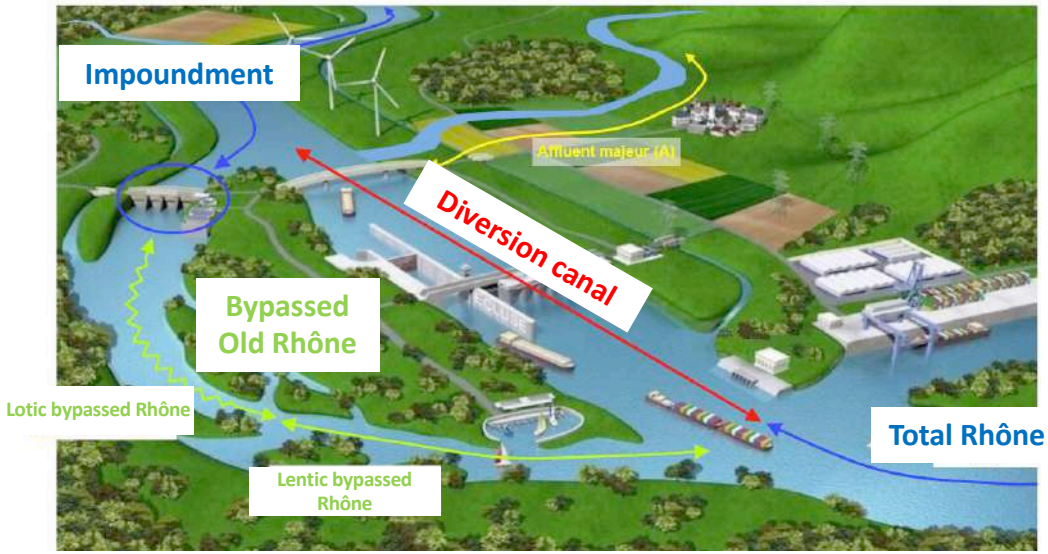
- **Context of the study (2018-2022)**
  - Led by French Administration and main stakeholders : DREAL, CNR, EDF, Water Agency
  - Answer to WFD : “implement a sediment management policy” to tend towards good status/potential
  - Means and objectives of the study :
    - apply an integrated approach of the river (past / present / future, all spatial scales, all sediments : fine, sand, gravel, pebble)
    - synthetize and complete numerous existing scientific works and studies (OSR, RhônEco, tributaries)
    - share diagnosis on morphological processes, issues in ecology, safety-security and socio-economic uses
    - propose new directions for sediment management and ecological restoration in the short (2027) and long term (2050)
  - Coarse sediments = supports for aquatic life + cause of challenging issues (flood risks, dyke safety, etc.)

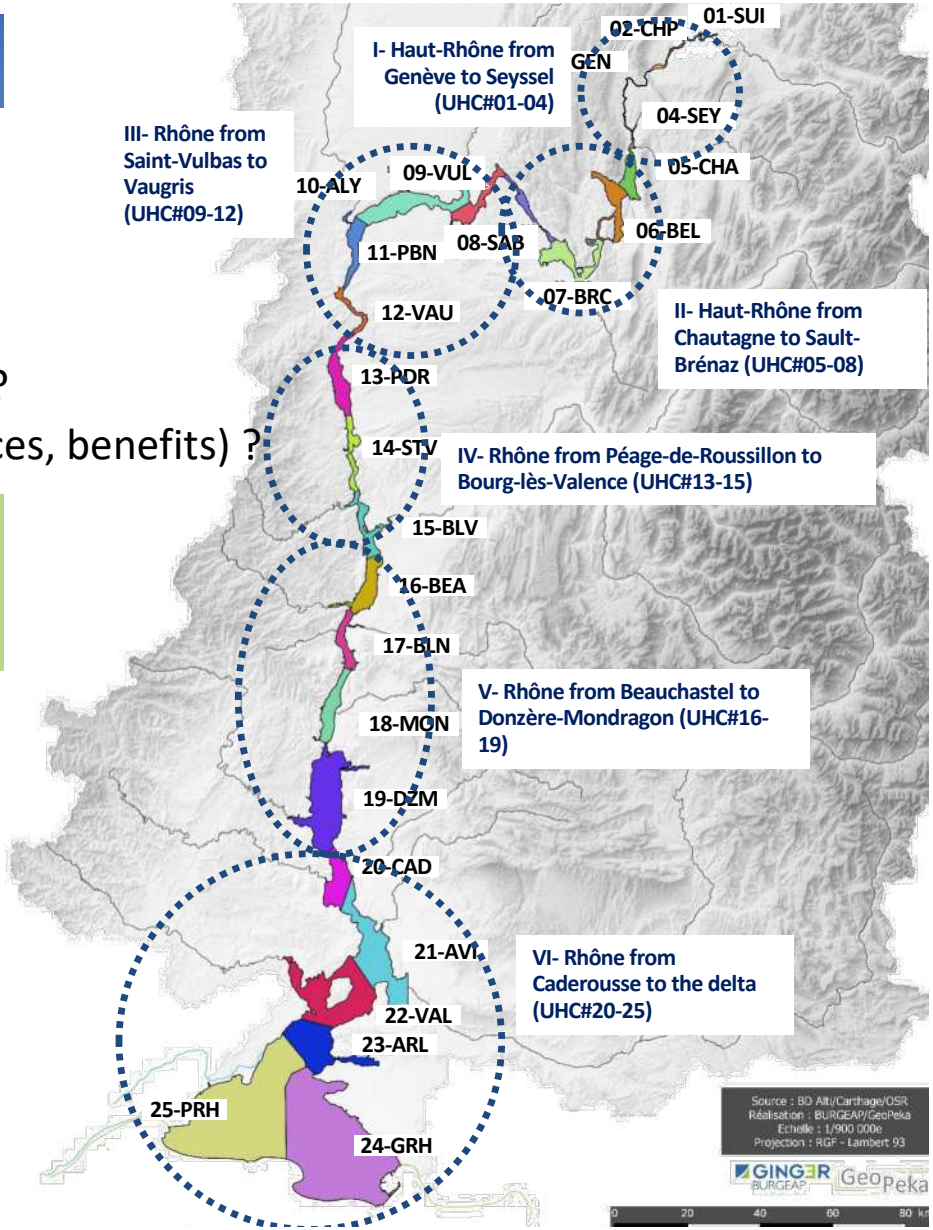
# Outlines :

1. Hydromorphological trajectory
2. What issues for fine sediments ?
3. What issues for coarse sediments (input, transport, fluxes) ?
4. What new management and restoration directions (guidances, benefits) ?

## Sectorization into homogeneous reaches

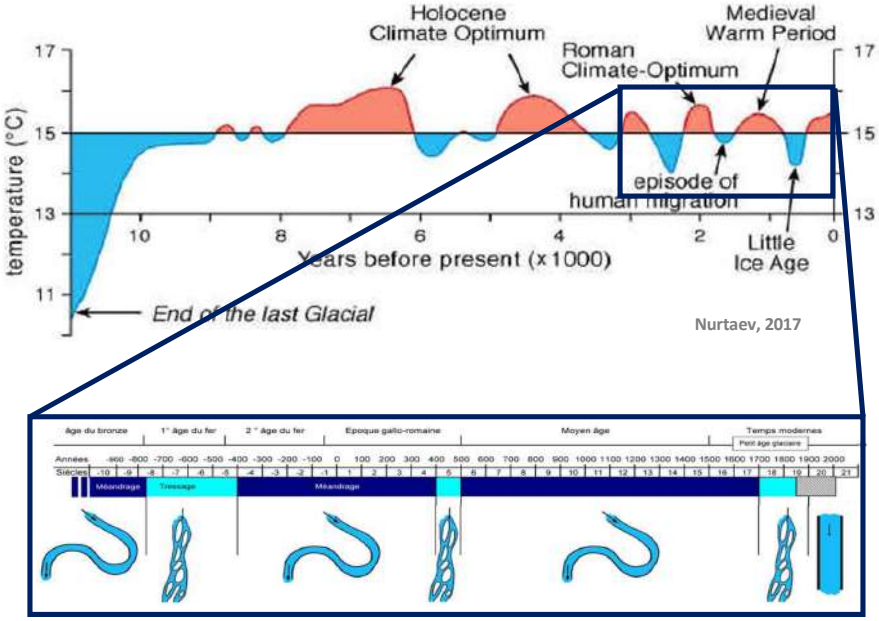
- Series of run-of-river dams with diversion and bypassed reaches
- 25 coherent hydrographic units (UHC) + 6 major sectors for management



# 1/ Complex hydromorphological trajectory

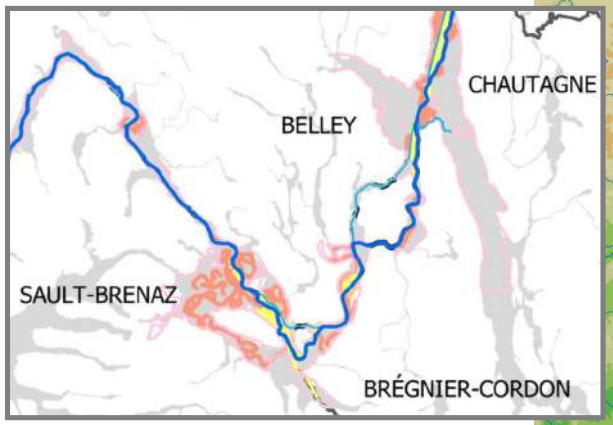
- **in the past, sediment continuity from springs to sea has never been totally reached, except for fine sediments**
  - Role of deglaciation lakes (refilling) + sea level (delta)
  - Role of climatic variations (Little Ice Age)
  - Roles of grain sizes: fine, sands, coarse (gravel, pebble)

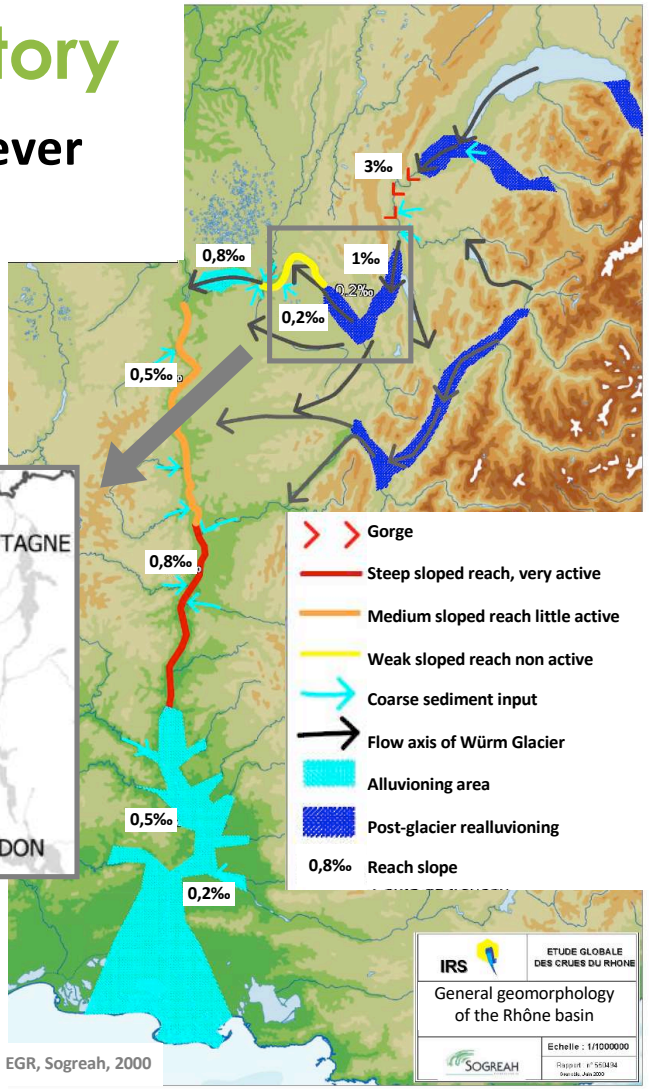



Nurtaev, 2017



Bravard et al., 2010

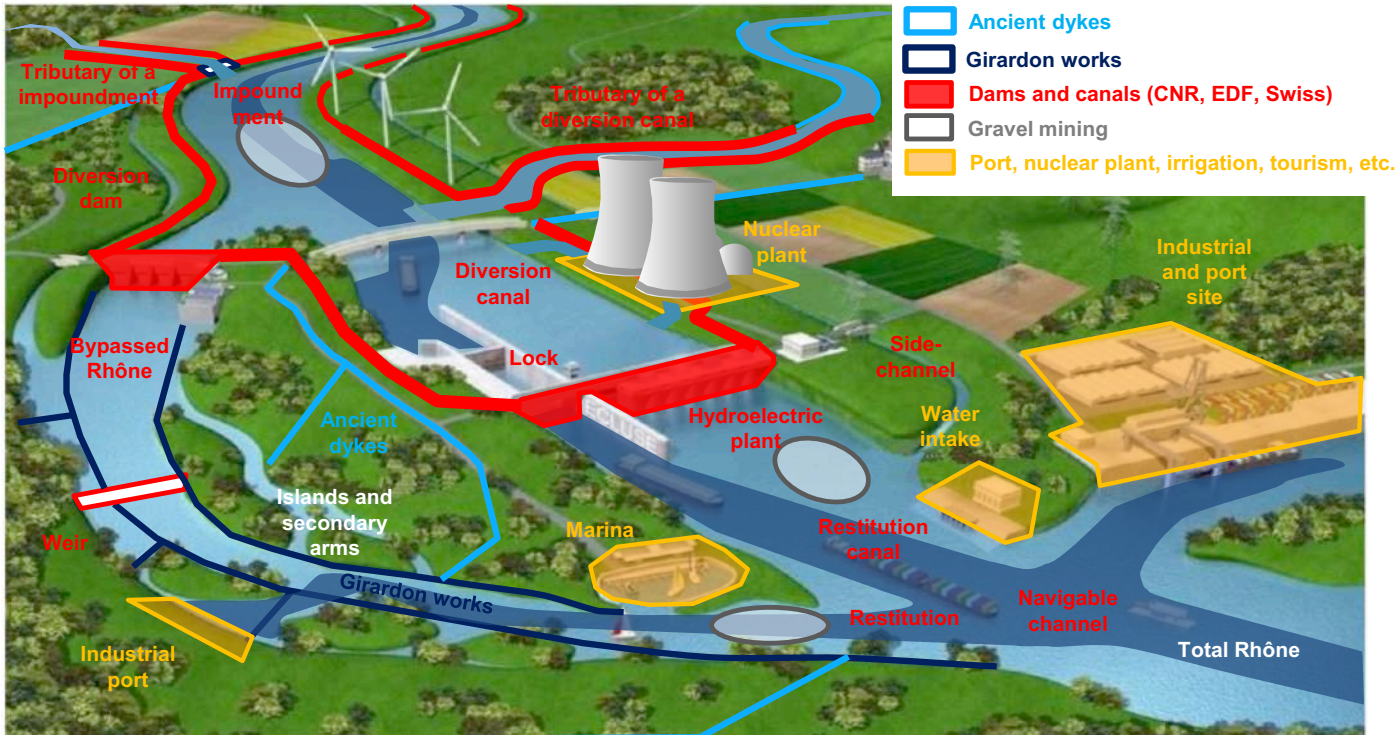



EGR, Sogreah, 2000

# 1/ Complex hydromorphological trajectory

- **Several stages of human development imposed forcing on the hydrosystem**
  - before 1860 : first dykes ; 1840-1940 : first waterways (Girardon works), first hydroelectric plants
  - 1950-1990 : hydroelectricity (22 hydroplants), navigation, irrigation developments + sediment mining
  - 1960-2020 : others uses (nuclear plants, drinking water, tourism). Similar developments on tributaries



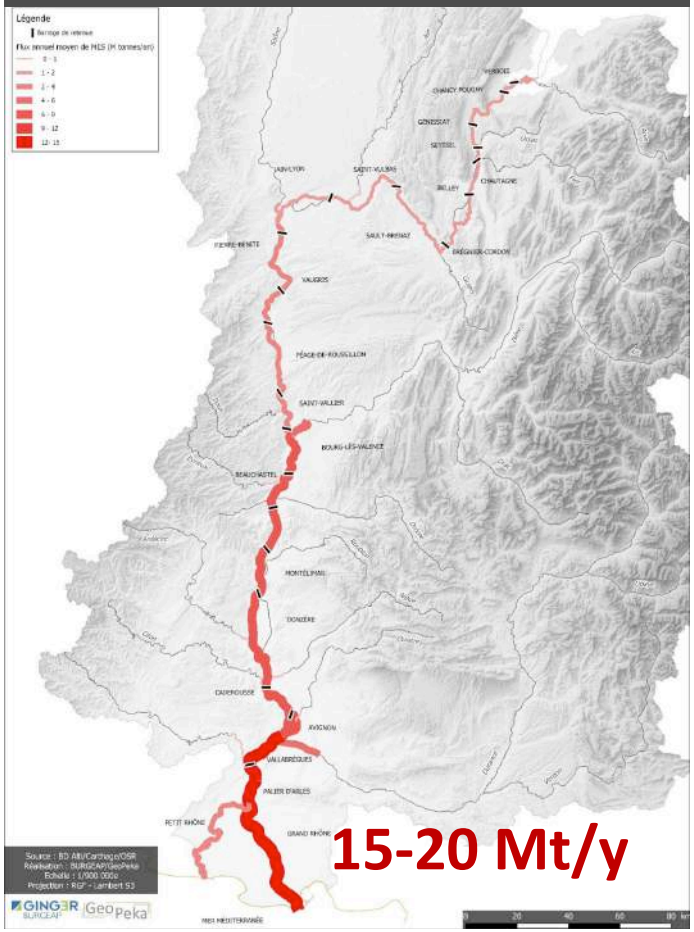

## Consequences on morphology and processes

- Bed incision : -2m on average
- Channel bed armouring
- Reduction in the active channel width
- Reduction in sediment supply from the Rhône (sediment mining) and tributaries
- Reduction in bedload transport capacities due to dams (slope) and bypassed channel (hydrology)

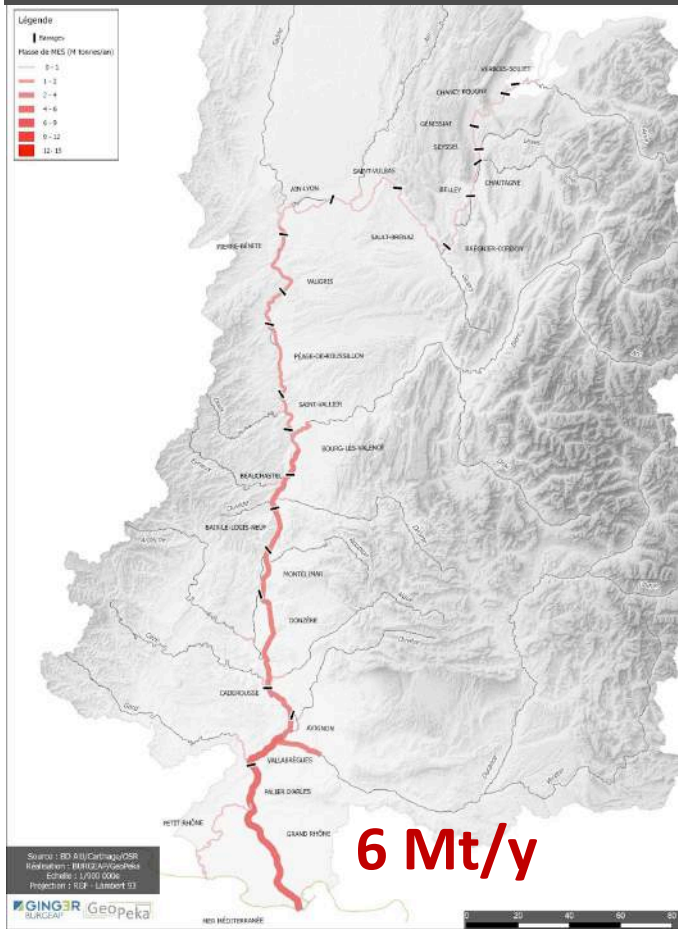
# 2/ What issues for fine sediments ?

- **Relatively good continuity**
  - even with 22 impoundments
  - thanks to flushing / sluicing
  - though tricky for coarse sand
- **Loss of 50-60% of fluxes compared to 19th century (delta : 6 Mt << 15-20 Mt/y)**
  - long term issue for coastal sediment balance
  - any volume of sand has to be led down to the sea
- **Pollutions in the ancient depositions**
  - Issue when restoring the river space

**19th century fine fluxes**




**Current fine fluxes**



# 2/ What issues for fine sediments ?

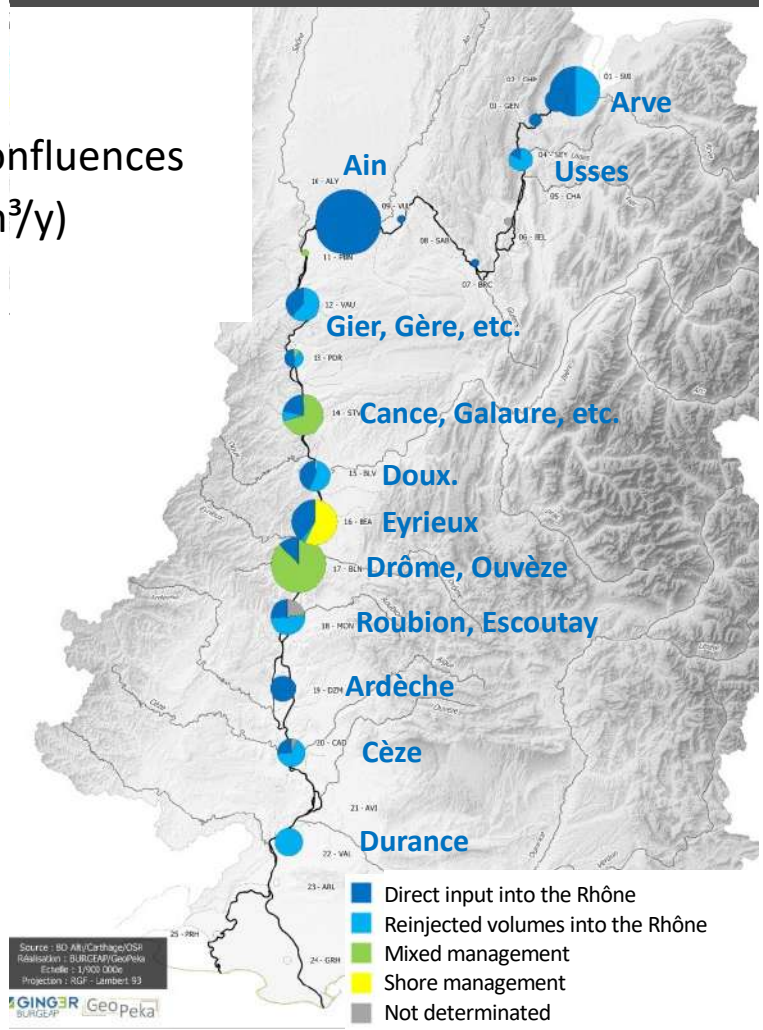
- **Long term safety and security stakes for usptream impoundments**
  - Verbois (22% filling)
  - Genissiat (51% filling)

- **Isère confluence**
  - confluence into a diversion canal
  - annual mean fine flux of 1,8 Mt/y
  - Improvement thanks to a coordination between dams managers (EDF, CNR)

# 3/ What issues for coarse sediments ?

- **Average bedload inputs from tributaries (1995-2018)**
  - Method : bedload transport (> 2mm) + dredged volumes at confluences
  - 36 tributaries over 241 with significant input (500 to 30,000 m³/y)
  - Total mean annual input : 151,000 m³/y
    - 151,000 = 72,000 m³/y (direct input) + 79,000 m³/an stored then dredged
    - 79,000 = 42,000 m³/y (reinjected) + 37,000 m³/y (shore management)
  - 2015-2019 : increasing reinjected volumes (80,000 m³/y)

**Input of coarse sediment from tributaries by UHC**



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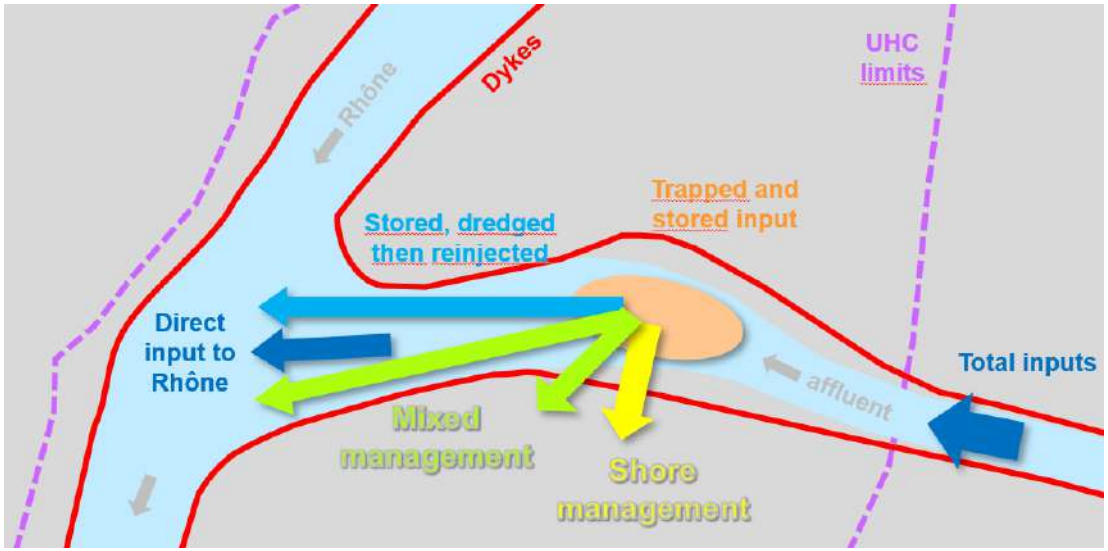


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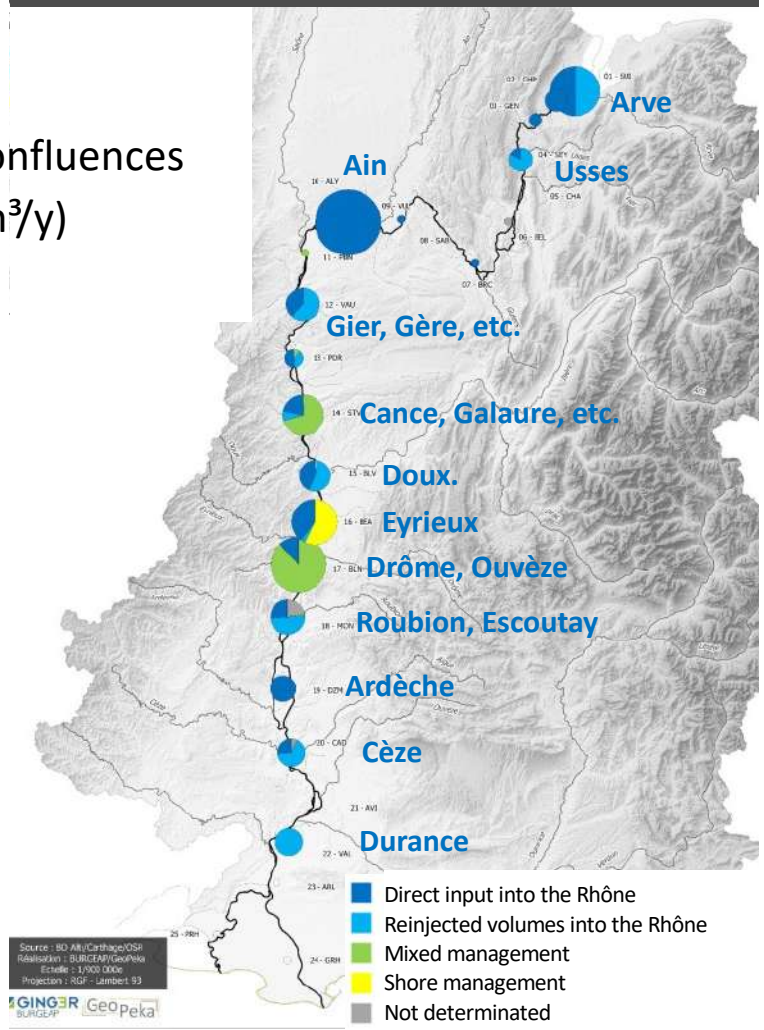
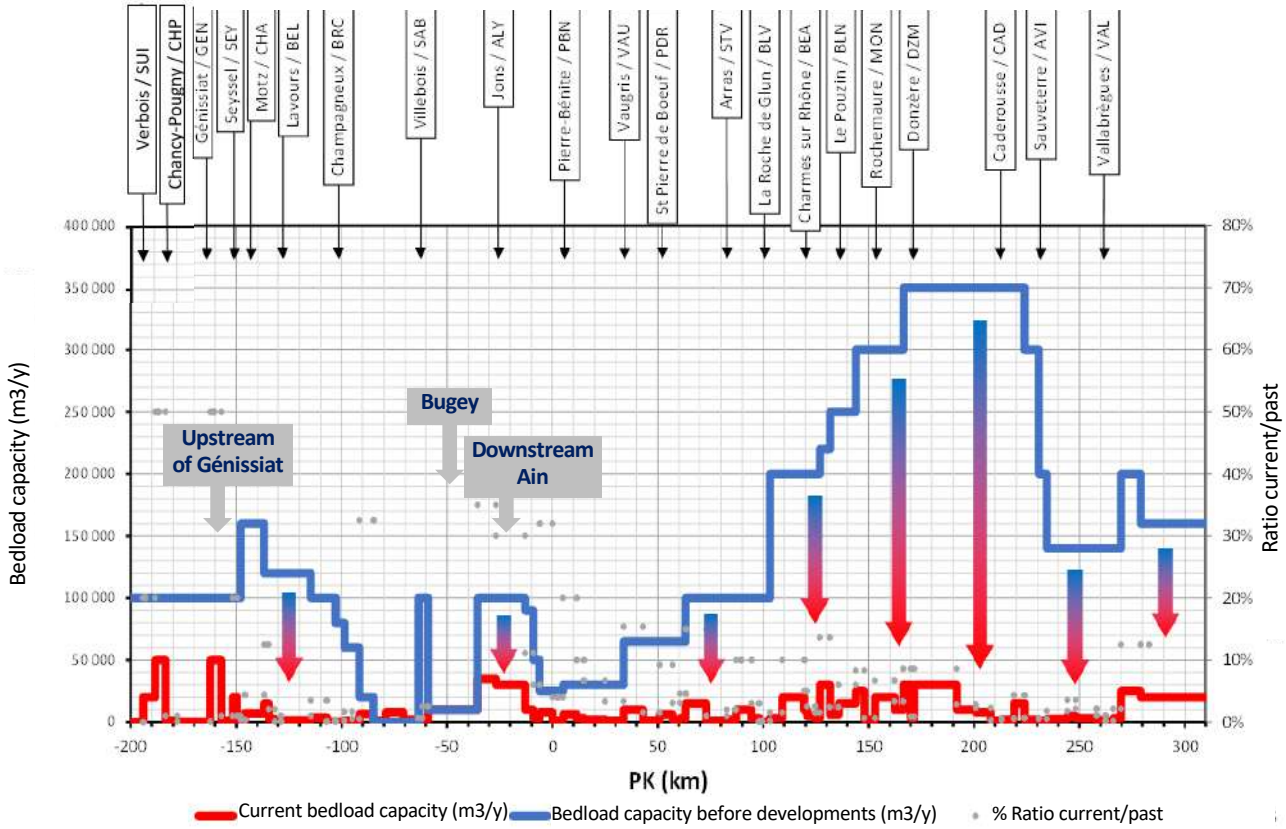


# 3/ What issues for coarse sediments ?

- **Decrease in mean annual bedload capacities along the Rhône axis**
  - 1-10% of the original capacities, except local exceptions (up. of Genissiat, Bugey, dw. Ain)
  - Residual capacities : 0 up to 50,000 m³/an

**Long profile of mean annual bedload capacity in the current state and before development**

From Vázquez-Tarrío (2018, 2020) and EGR (2000) data



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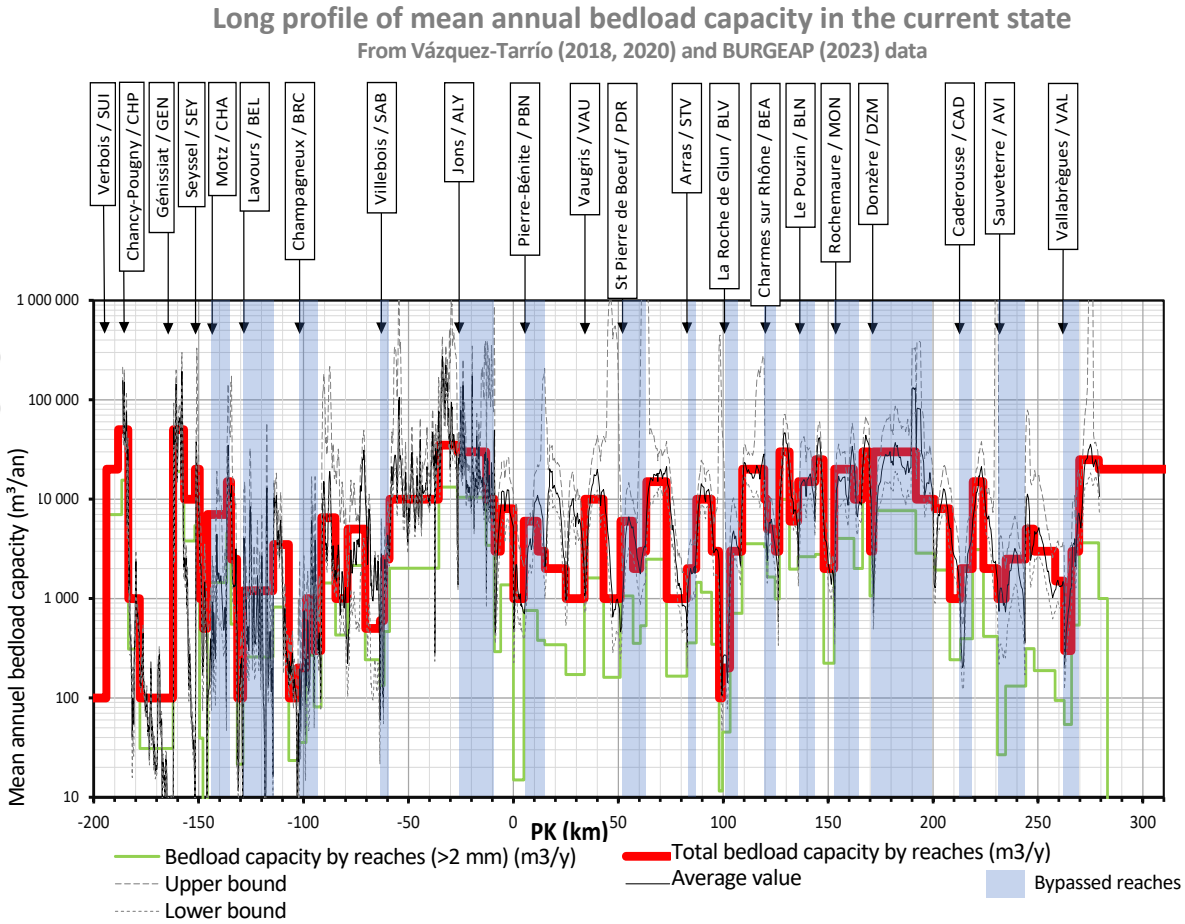
  - Residual capacities : 0 up to 50,000 m³/an
  - Causes :
    - Energy slope in impoundments (÷30 to 100)
    - Modified hydrology in bypassed reach (÷25)
  - Knowledge about bedload capacities is still improving (studies in progress)
- **Strong weakening and large discontinuity of the residual bedload capacity (= no downstream outlet)**



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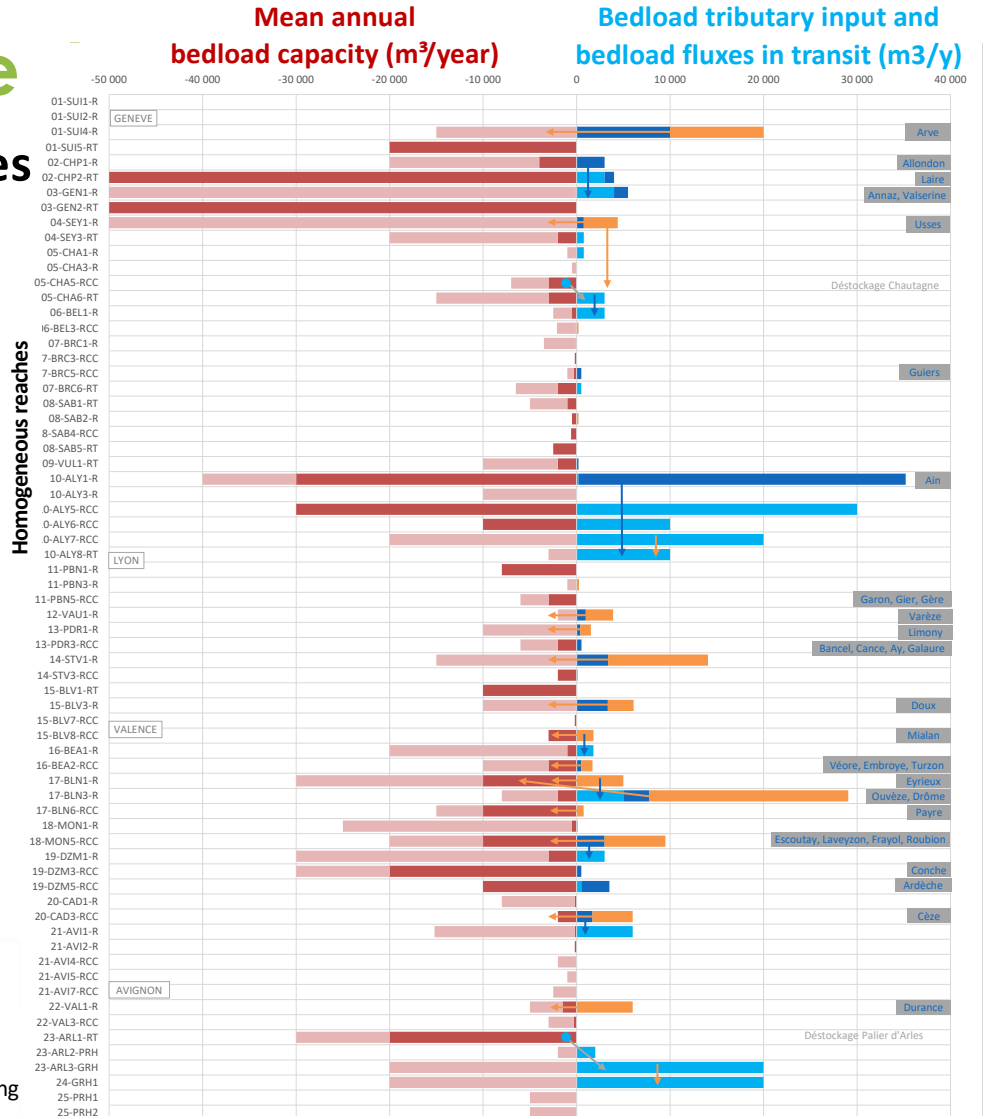
- **Balance between bedload inputs and capacities**
  - Some fluxes validated with local sediment balances
  - If inputs > capacities
    - many tributaries fluxes trapped into reservoirs
    - no remobilization, no ecological interest, sediment excess
  - If capacities > inputs
    - Vieux Rhône bypassed reaches are degraded. Sometimes, bedload generated by destocking (Chautagne, Palier d'Arles)
    - habitats and biodiversity are depleted



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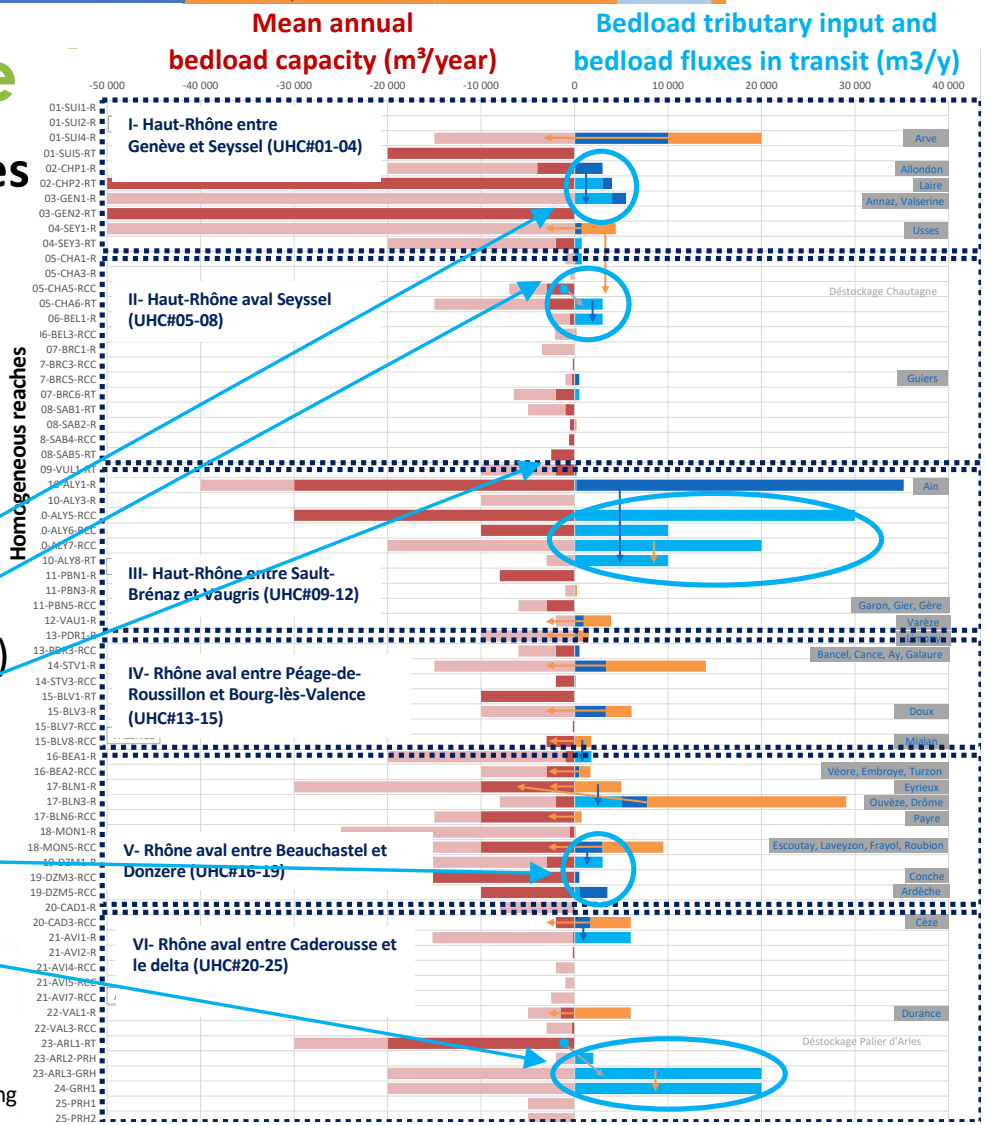
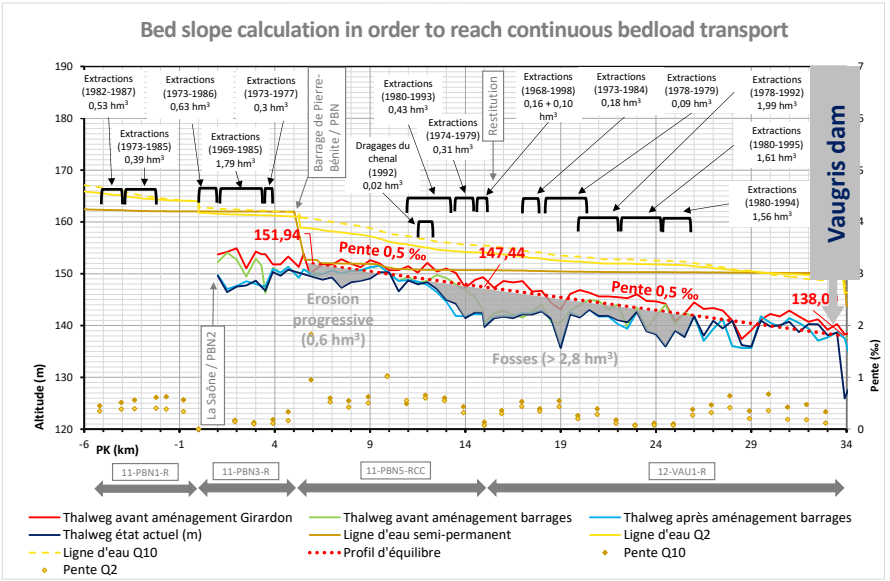
  - If capacities > inputs
    - Vieux Rhône bypassed reaches are degraded. Sometimes, bedload generated by destocking (Chautagne, Palier d'Arles)
    - habitats and biodiversity are depleted
  - Only a few reaches with bedload continuity (≈70 km)
    - upstream of Genissiat : 6 km
    - Chautagne bypassed : 12 km
    - downstream Ain : 18 km
    - Donzère bypassed : 25 km
    - downstream Arles : 10 km



# 4/ What new management directions ?

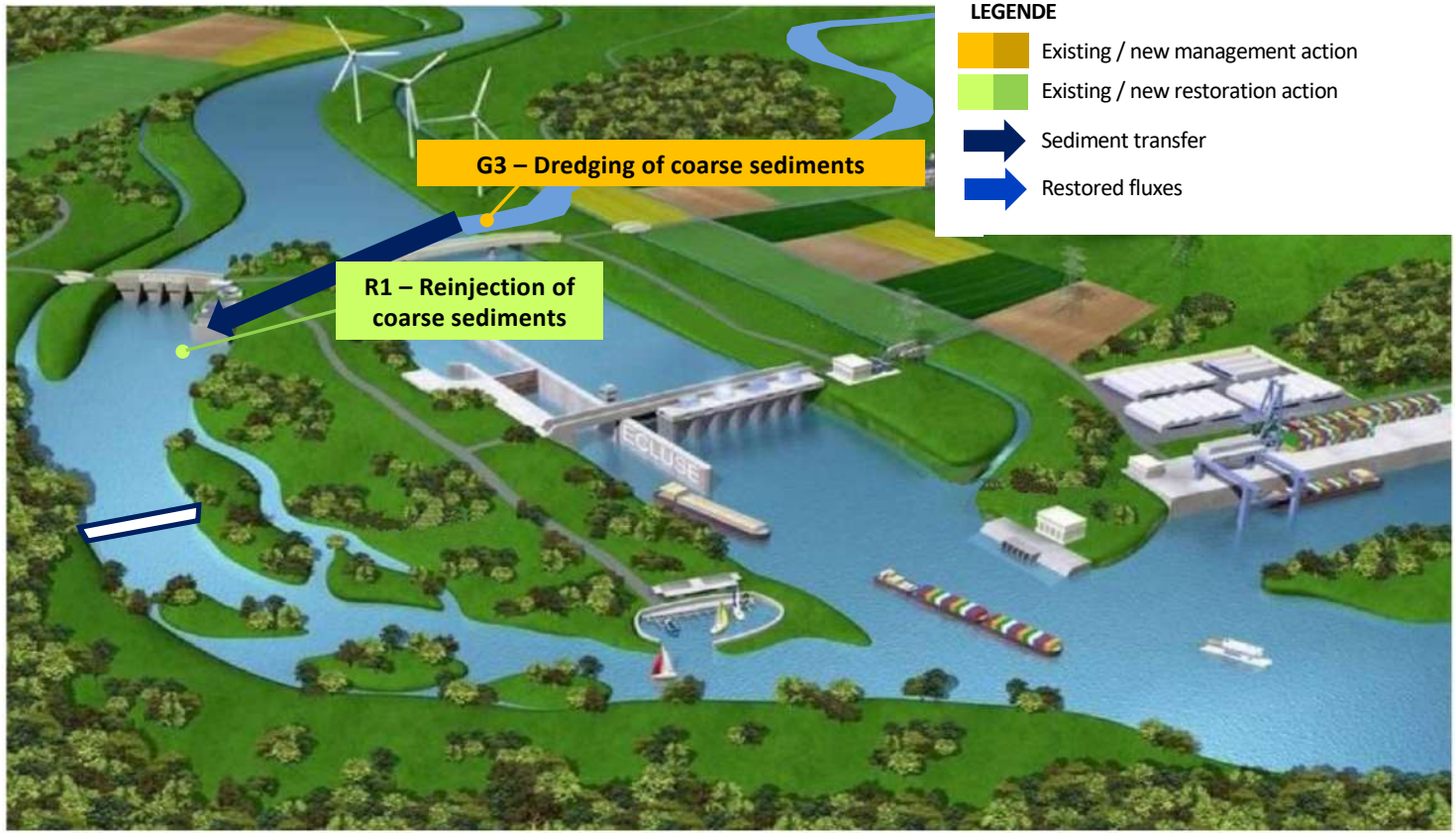

- **Where bedload continuity can be improved ?**
- **How to maintain a good balance between issues ?**
  - Good ecological potential for 26 water bodies (WFD)
  - Safety-security (dams, nuclear plants, drinking water)
  - Socio-economic issues (hydroelectricity, navigation)
- **Which new parameters for the future ?**
  - Climate change: what evolution of hydrology ?
  - Sediment yield and input: decreasing, increasing ?
  - How much sand needed for Mediterranean coast ?
- **In summary, which trajectory for the future ?**
- **Testing different combined scenarios**
  - 1/ Making dams transparent to bedload transport
    - ➔ Technical and economic impacts (navigation, hydroelectricity, safety), only possible for a few dams
  - 2/ Dredging / reinjection of coarse sediment into bypassed reaches
  - 3/ Reactivation of ecological functionalities for bypassed reaches




Possible synergies

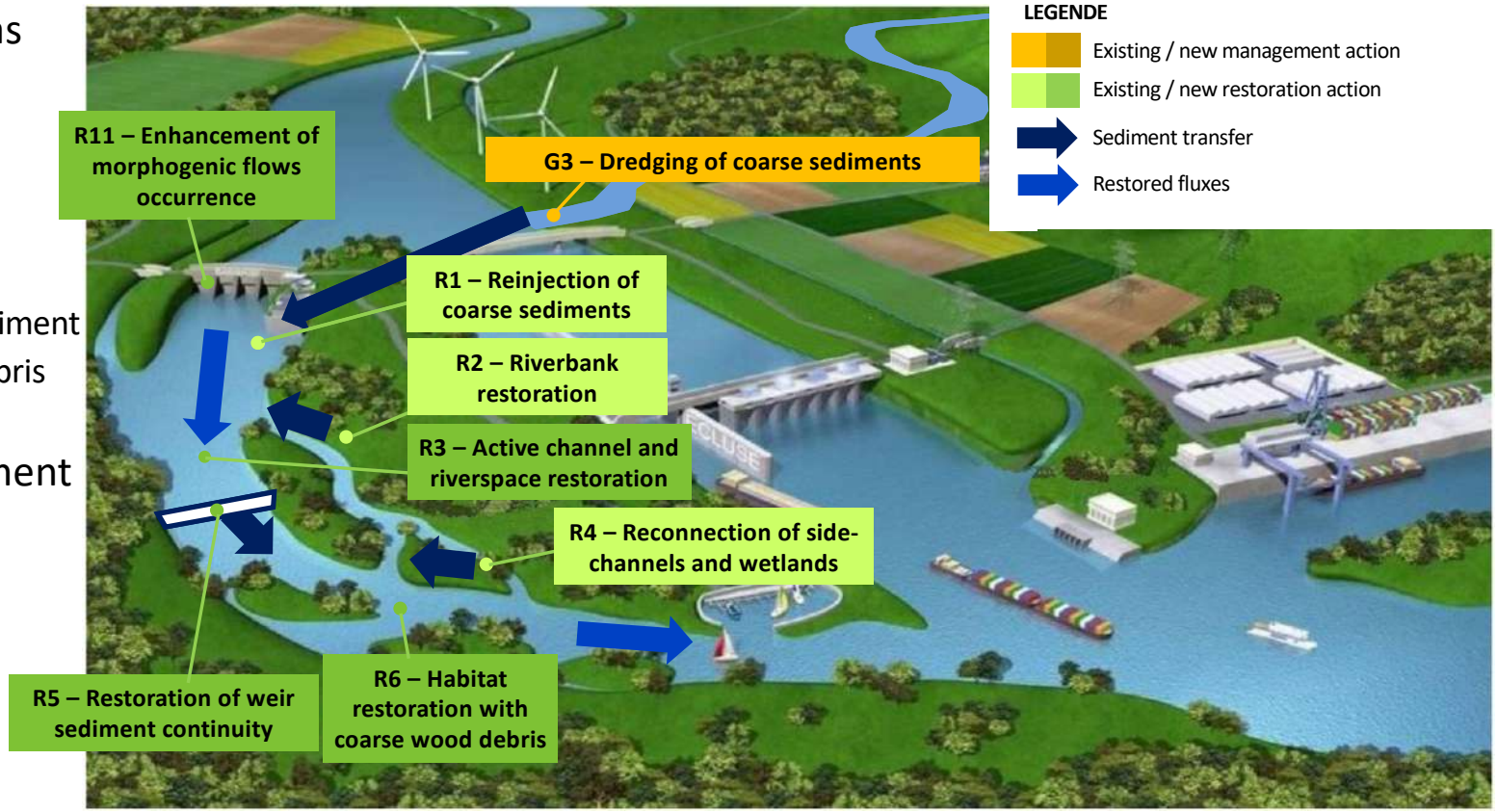
# 4/ What restoration directions ?

- **Guidance#1 : reinject dredged coarse sediments into bypassed channels to restore bedload continuity**
  - Possible synergies on:
    - dredging needs, especially for confluences and tails of impoundments
    - ecological reactivation of the bypassed Rhône
    - financial savings



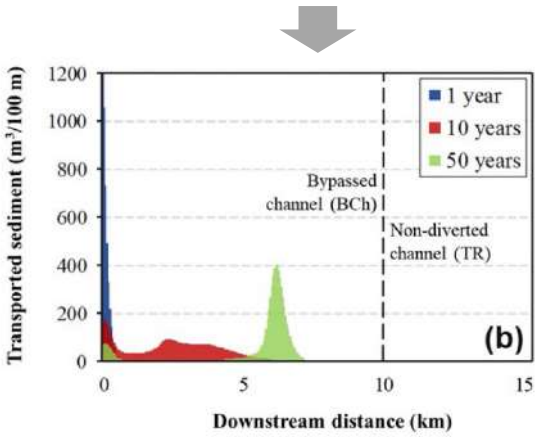
# 4/ What restoration directions ?

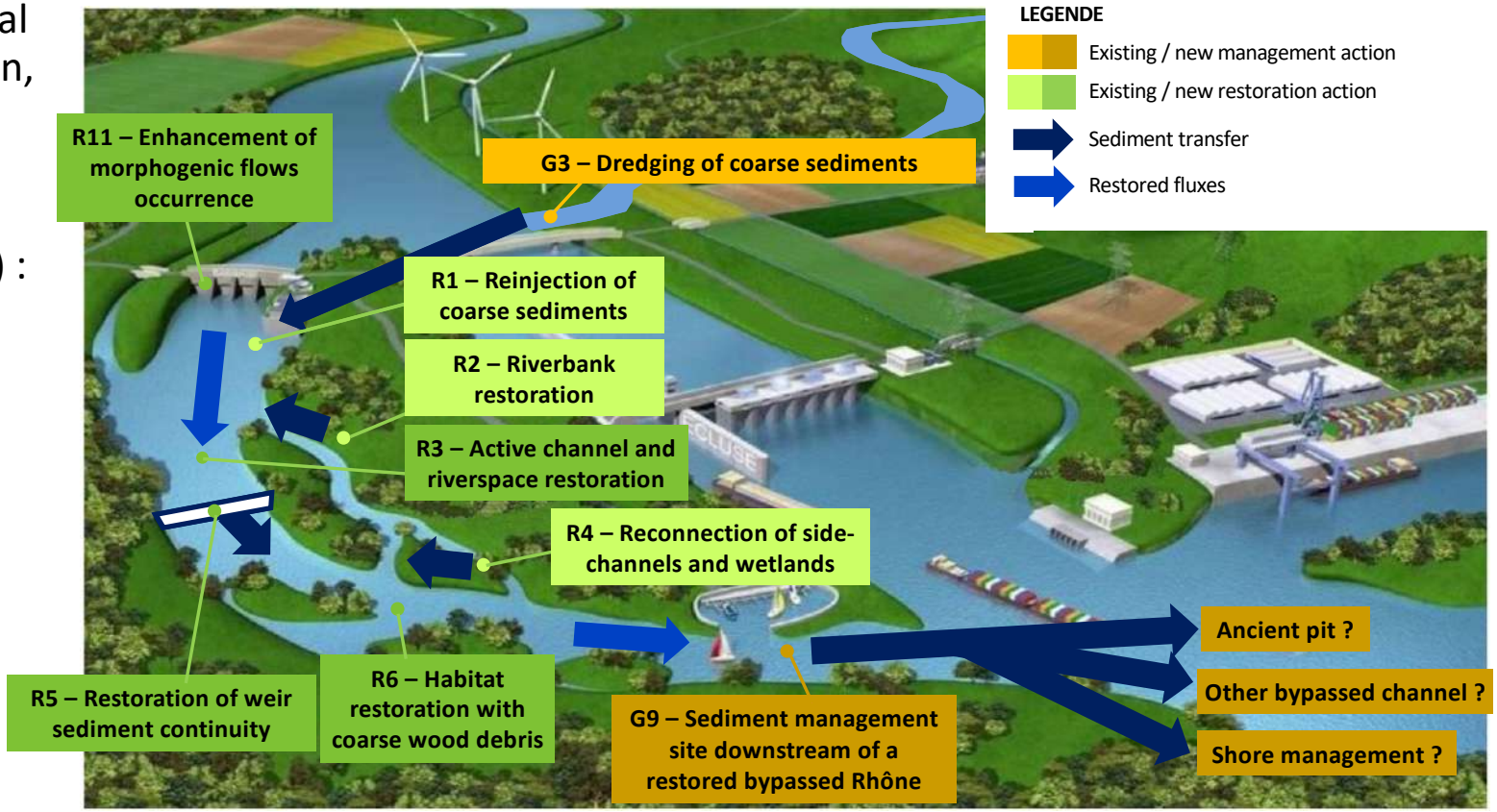
- **Guidance#2 : increase the ecological "value" and "lifespan" of coarse sediments**
  - Purpose : avoid reinjecting sediment into a pipelike river
  - River morphology has to be restored
    - Active channel
    - Riverspace
    - Riverbanks
    - Side channels
    - Weir continuity for sediment
    - Habitats with wood debris
  - All these actions will slow down the sediment transit and enhance the diversity of fluvial forms



# 4/ What restoration directions ?

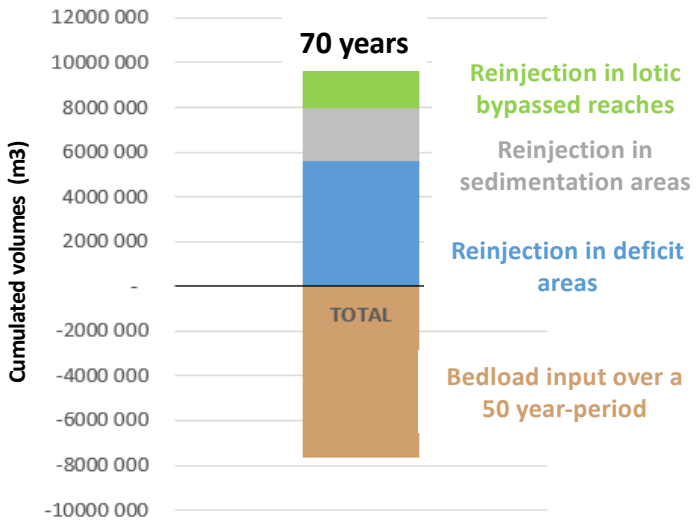
- **Guidance#3 : anticipate downstream impacts of restored bedload fluxes**
  - Dredging of new deposits before downstream potential impacts on navigation, inundations, dykes…
  - how many times before dredging ? First results (models) : several decades after reinjection

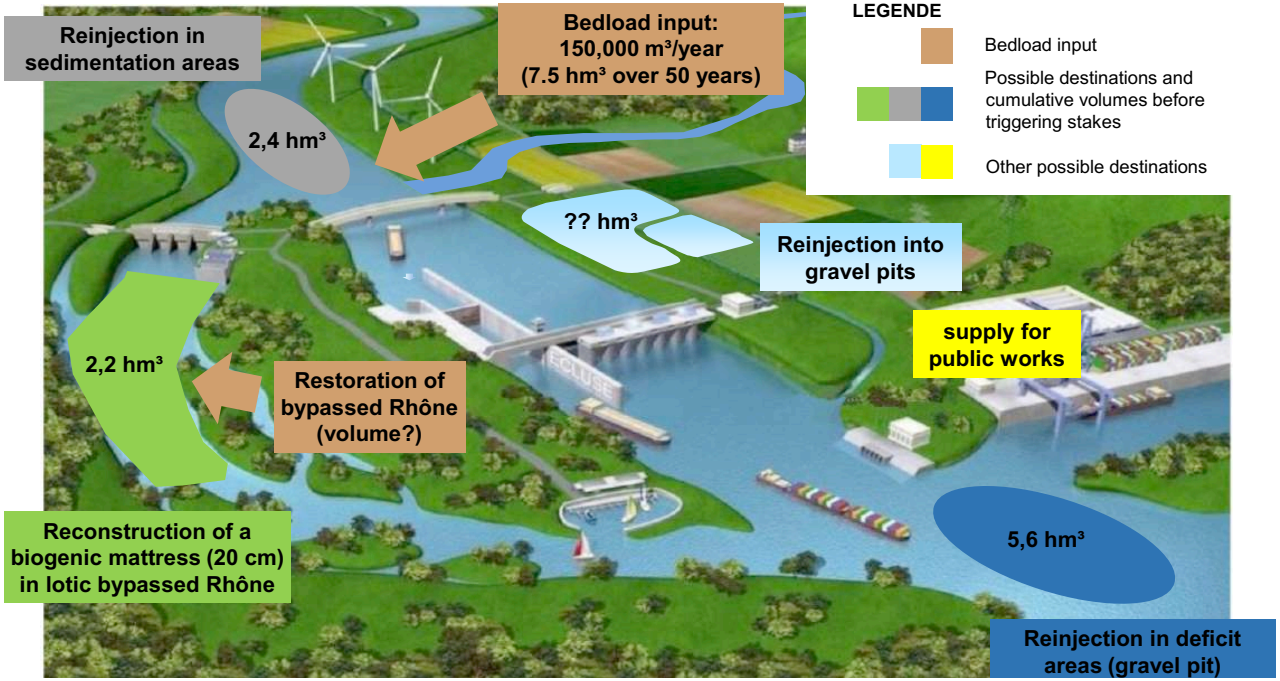


# 4/ What restoration directions ?

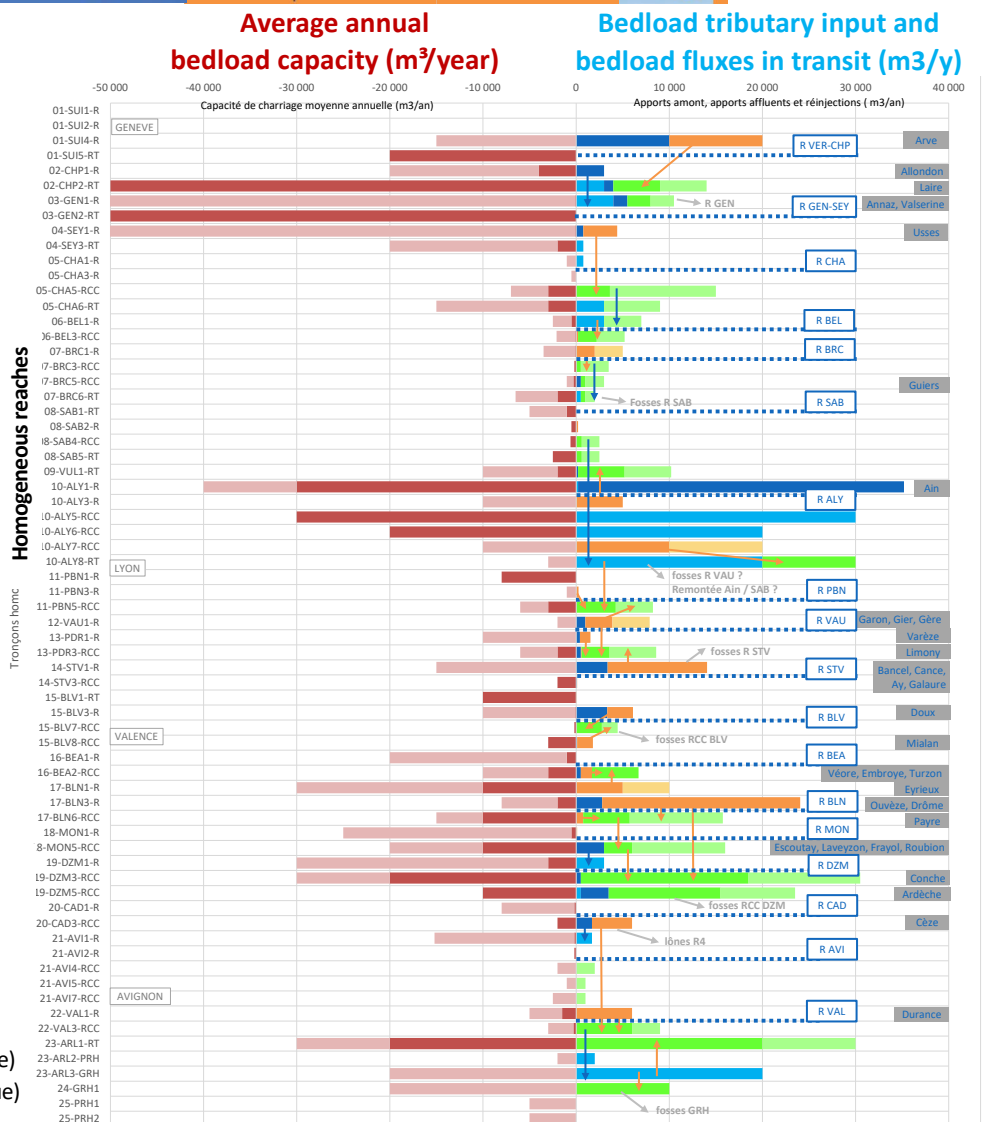
- **Guidance#4 : anticipate saturation and search for new destination for the sediments**
  - around 10 hm³ of "absorption capacity" for coarse sediments
  - bedload input (150,000 m³/year) = around 70 years of accumulation before triggering issues
  - figures to be confirmed after integrating restoration actions (that also produce coarse volumes)
  - look for new destinations: old gravel pits, tributary basins, supply for public works, etc.



# 4/ What main benefits ?

- **Benefit#1 : recovery of bedload continuity for some bypassed reaches**
  - For the most ambitious scenario (2050)
  - 9 over 16 bypassed reaches where this scheme would be possible:
    - Haut-Rhône: CHA, BEL, BRC, ALY
    - Rhône downstream: PBN, PDR, BLN, MON, DZM
    - cumulated length with continuity : 55 km ➔ ≈ 80-90 km
  - + 3 portions of total Rhône:
    - Chancy-Pougny, Bugey, Palier d'Arles
    - cumulated length with continuity : 16 km ➔ ≈ 40-50 km
  - Large benefits for aquatic habitats, improving ecological potential

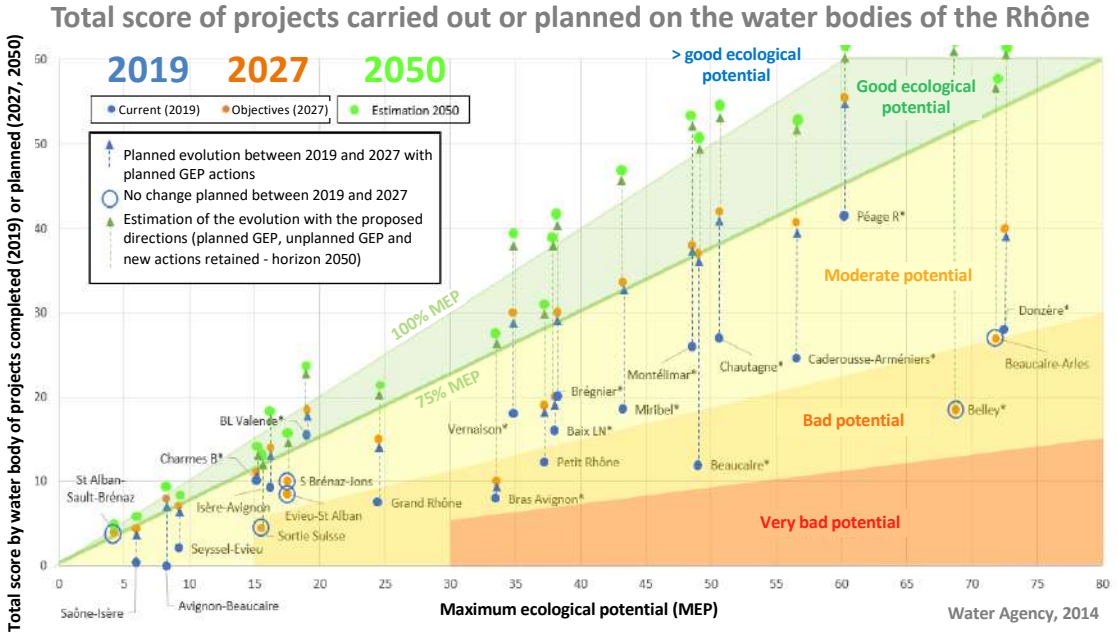


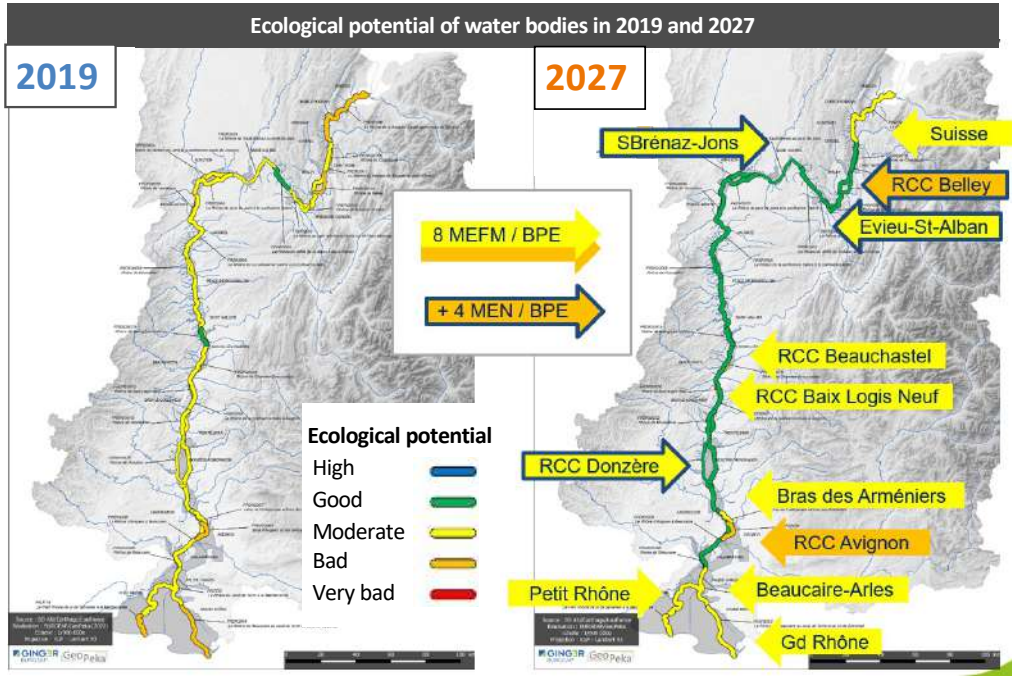

Proposed directions : bedload capacity (m³/y) (MIN value)
Proposed directions : bedload capacity (m³/y) (MAX value)
Proposed directions : bedload flux from upstream (m³/y))
Proposed directions : bedload direct input (m³/y)
Proposed directions : coarse dredging (m³/y) (MIN value)
Proposed directions : coarse dredging (m³/y) (MAX value)
Proposed directions : reinjected flux after dredging (m³/y) (MIN value)
Proposed directions : reinjected flux after dredging (m³/y) (MAX value)

Destination en fin de linéaire
Continuité de flux
Destination après dragage

# 4/ What main benefits ?

- **Benefit#2 : achievement of good ecological potential (GEP)**
  - Good potential defined in a 2014 study according to Prague mitigation measure approach
  - 2027 : GEP to be reached for 14 water bodies over 26 (GEP=75% Maximum Ecological Potential)
  - 2050 : GEP should be reached for all water bodies



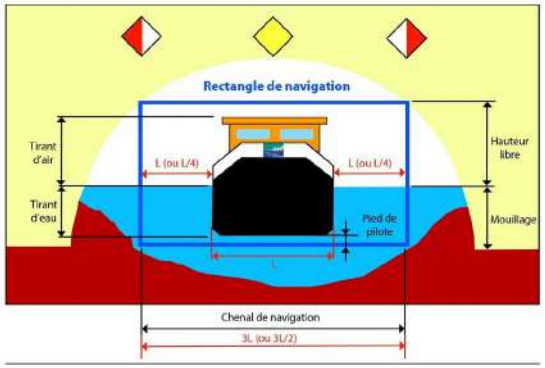



# 4/ What main benefits ?

- **Benefit#3 : preservation of humans stakes**
  - Dam and dyke safety

  - Security during floods

  - Navigation conditions




*Rectangle de navigation / VNF*

- Nuclear plants safety

- Drinking water safety

- Tourism facilites

# Conclusions

- **Sediment management definitely requires an integrated basin approach, especially to achieve good ecological potential and respect other issues**
- **It is welcome to combine management actions with restoration actions ; this gives synergy to projects and allows all stakeholders to be involved**
- **With a consultation approach, it is possible to achieve a good balance between ecological (good ecological potential), safety-security and socio-economic issues**

# Outlook

- **Directions are validated, stakeholders move on to an operational phase**
- **We have to specify technical feasability of each local project**
- **More and more, integrate the consideration for climate change :**
  - What evolution in bedload fluxes ?
  - Limit the GHG impacts of operations
  - Optimize resilience of hydrosystem

- Link to final reports : https://nextcloud.inrae.fr/s/pLmcxcpCb8ypYcb (only in French for the moment !...)
  - see Factsheets in Mission 8 : https://nextcloud.inrae.fr/s/pLmcxcpCb8ypYcb?path=%2FMission_8_M%C3%A9thodes

- We are looking for scientists and practitionners working on coarse sediment management including the sequence : dredging + reinjection in bypassed channel + restoration + monitoring
  - Please contact us at f.laval@groupeginger.com

13th International SedNet Conference
Faculty of Sciences of the University of Lisbon, Lisbon, Portugal
6 - 8 September 2023

# Thank you for your attention !

Technical secretariat and funders

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