A MULTI-CRITERIA APPROACH SUPPORTING THE INVESTIGATION OF A FLOODPLAIN POTENTIALLY CONTAMINATED BY PESTICIDES

L ZILIANI, B GROPPELLI, S CECCON, F COLOMBO (RAMBOLL ENVIRON)
D BOCCHIOLA, M C RULLI, G RAVAZZANI, R ROSSO (POLITECNICO DI MILANO)
M MARANGON, C PRESUTTI, L CONTI, A BASCIU (SYNDIAL SPA)

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A MULTI-CRITERIA APPROACH FOR THE HISTORICAL RECONSTRUCTION OF SEDIMENT DYNAMIC IN FLOODPLAIN

Dispersal, storage and remobilisation of sediment-associated contaminants in a fluvial system can be directly related to sediment transport processes, river channel adjustments and the flooding regime.

This study presents a multi-criteria approach combining historical, geomorphological, hydraulic and hydro-sedimentological methods that, in addition to previous investigation (sediments, biota etc), helped to increase the understanding of the river-lake system's evolution over the last few decades.

Technical team

- Ramboll Environ Italy
- Politecnico di Milano

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CASE STUDY: TOCE RIVER

Site

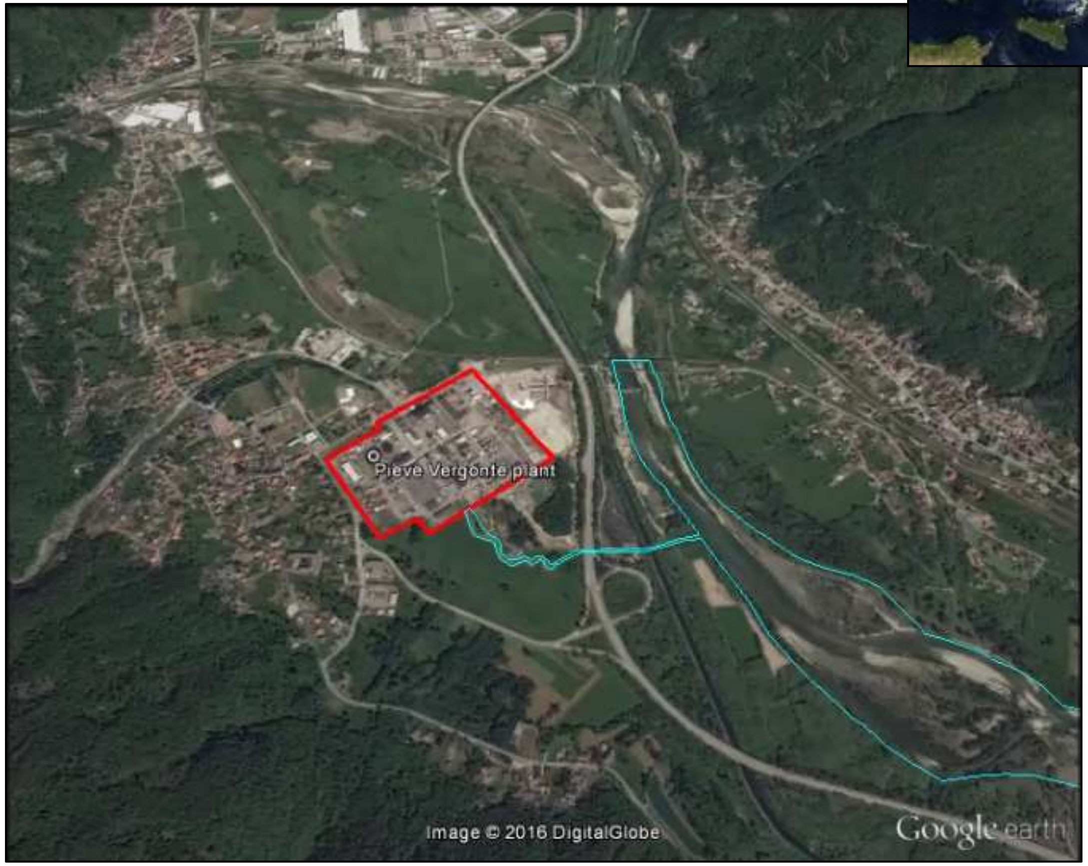
Pieve Vergonte, Remediation National Site (SIN), Piemonte, Italy

Main issue

Historical Dichlorodiphenyltrichloroethane (DDT) production and waste water discharges in the Toce river from 1948 (main production during 1970s)

Subjects of the study

- Toce river reach (≈22km) from the Pieve Vergonte plant to river mouth in Pallanza Bay (Lake Maggiore)
- Toce river floodplain downstream Pieve Vergonte (≈38km^2)



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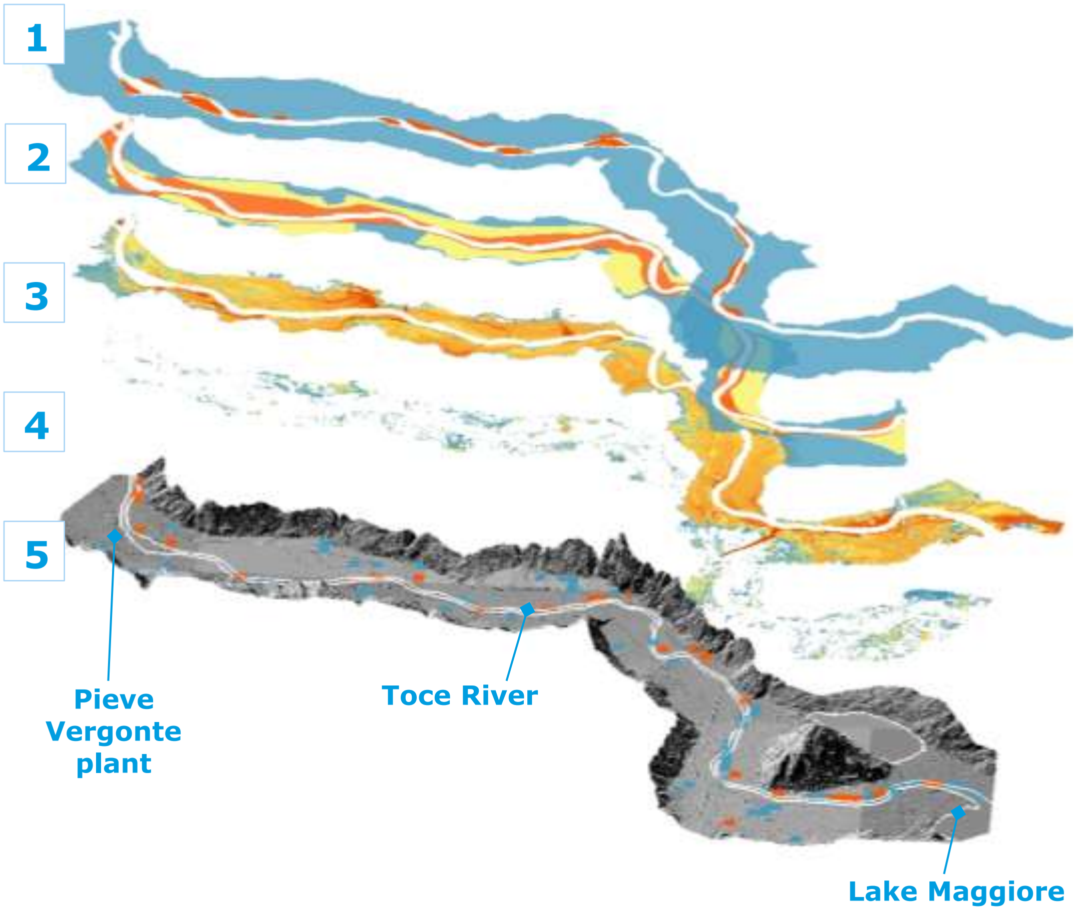
MULTI-CRITERIA APPROACH

Criteria	Layer
Geomorphological	1. Geomorphological map
Hydraulic	2. Flood hazard 3. Inundation frequency (1948-2010)
Hydro-sedimentological	4. Deposition frequency (1948-2010) 5. Short-term deposition tendency

Layers were linearly combined to identify the areas with the highest historical net deposition tendency



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GEOMORPHOLOGICAL CRITERIA
LAYER 1: GEOMORPHOLOGICAL MAP

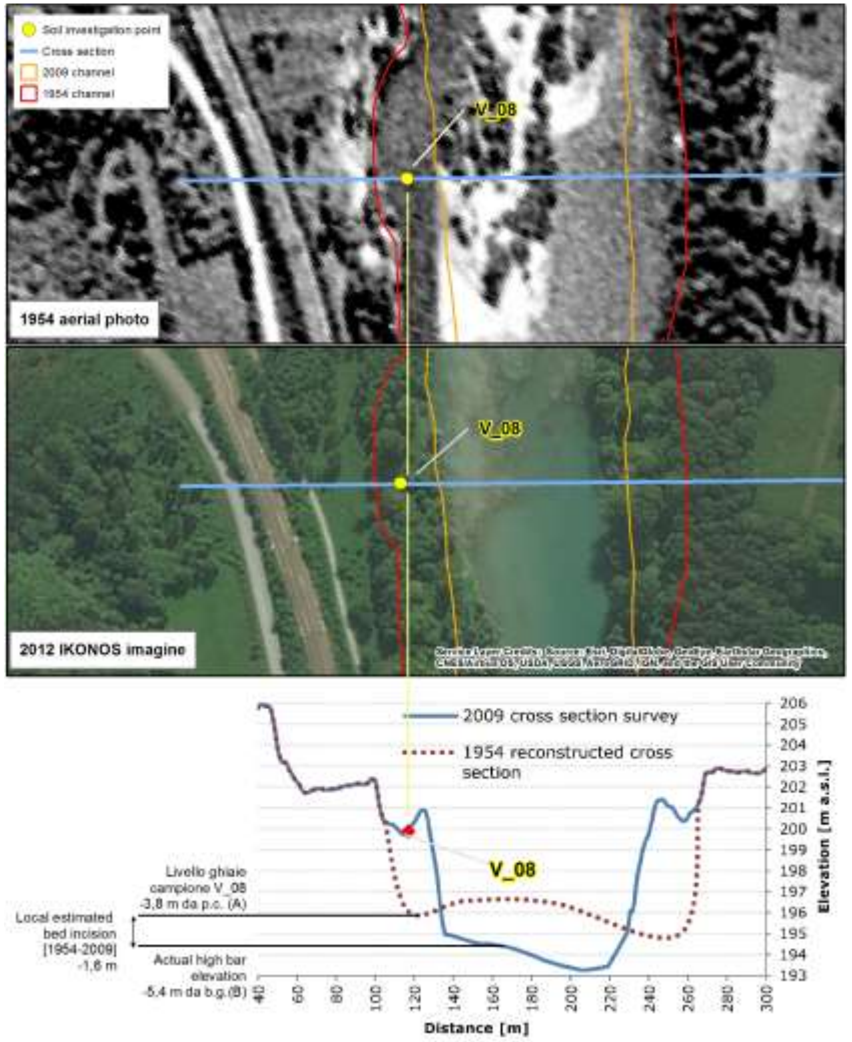
Activities

- Collection and analysis of historical aerial photos and maps, topographic surveys and gravel mining documentation
- Geomorphological field survey

Results

- Reconstruction of 1886-2012 channel adjustments (IDRAIM method[1]): negligible pattern alteration, moderate channel narrowing
- Estimation of the average bed incision: ~3m since 1960s (due to gravel and sand mining)
- Mapping of geomorphological units with highest tendency to store sediment (recent and incipient fluvial terraces)

[1] Rinaldi *et al*, 2015



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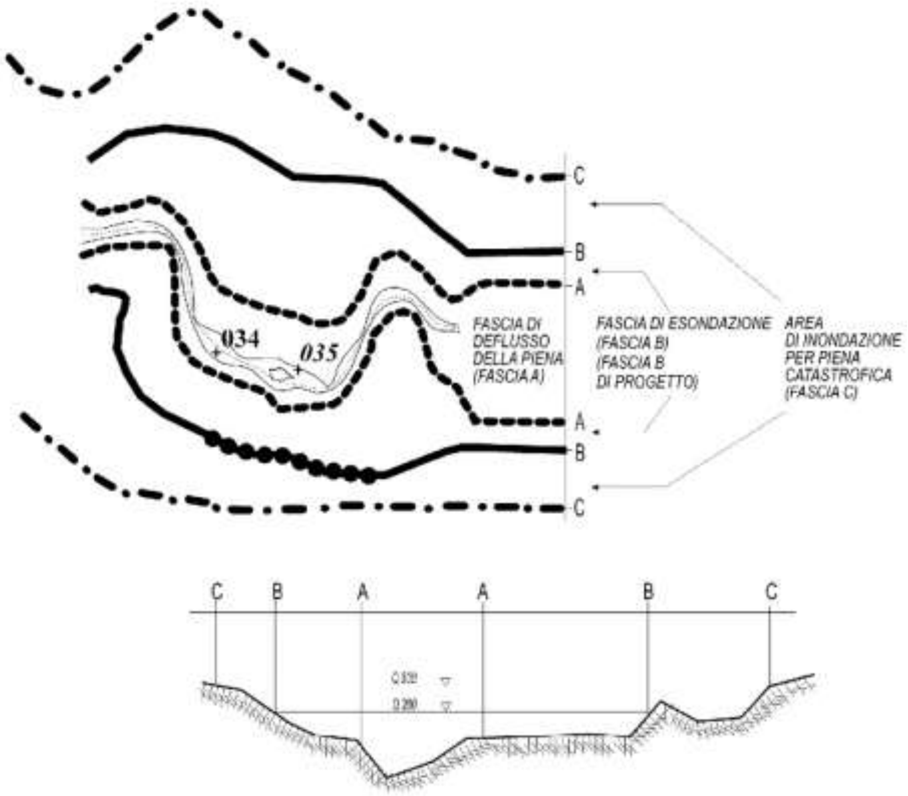
HYDRAULIC CRITERIA
LAYER 2: FLOOD HAZARD MAPS

Use of official flood hazard maps provided by the Po River Basin Authority assumed to be a proxy of the long-term floodplain frequency of inundation

Zone A: High frequency flooding area

Zone B: 200 yrs return interval flooded area

Zone C: 500 yrs return interval flooded area



Autorità di Bacino del Fiume Po, 1999

HYDRAULIC CRITERIA

LAYER 3: FREQUENCY OF INUNDATION 1948-2010

Activities

- Collection of 36 historical flood marks referred to the higher magnitude floods since 1948
- Reconstruction of historical evolution of hydraulic structures (levees, protection banks etc)
- Calibration of 2D hydrodynamic numerical model (CAESAR LISFLOOD[2]) using October 2000 flood event data
- Simulation of 21 historical floods (>1.5 year return interval)

[2] Coulthard *et al*, 2013

1977 flood

2015 photo

Flood marks

October 2000 flood

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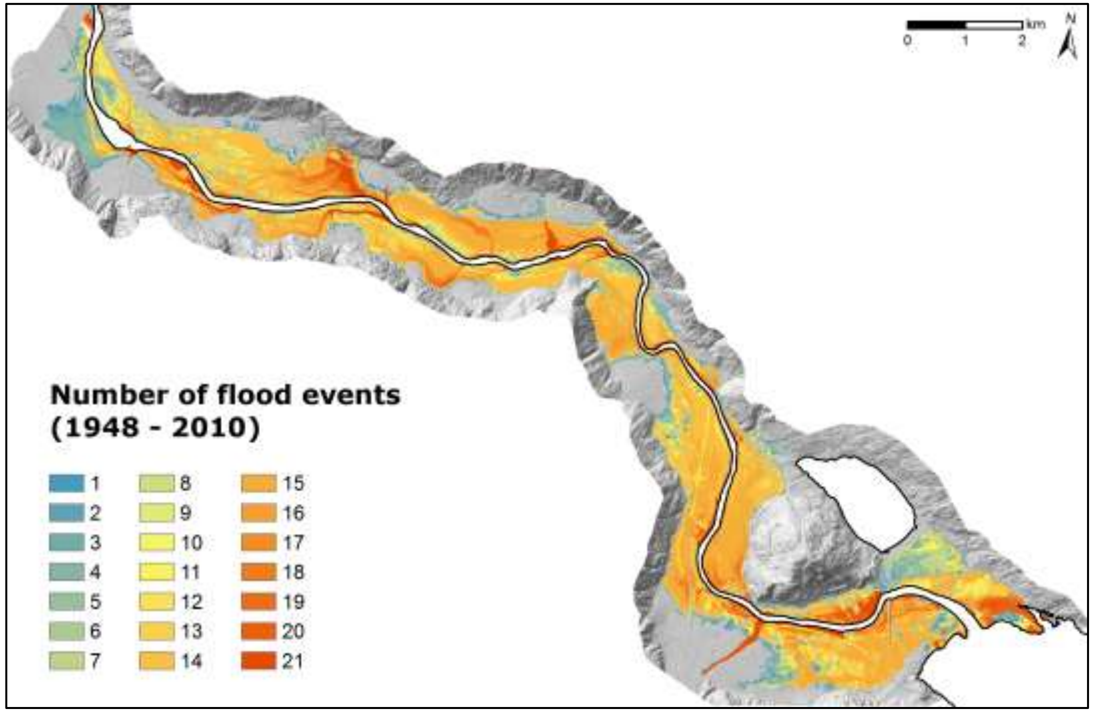
HYDRAULIC CRITERIA
LAYER 3: FREQUENCY OF INUNDATION 1948-2010

Results

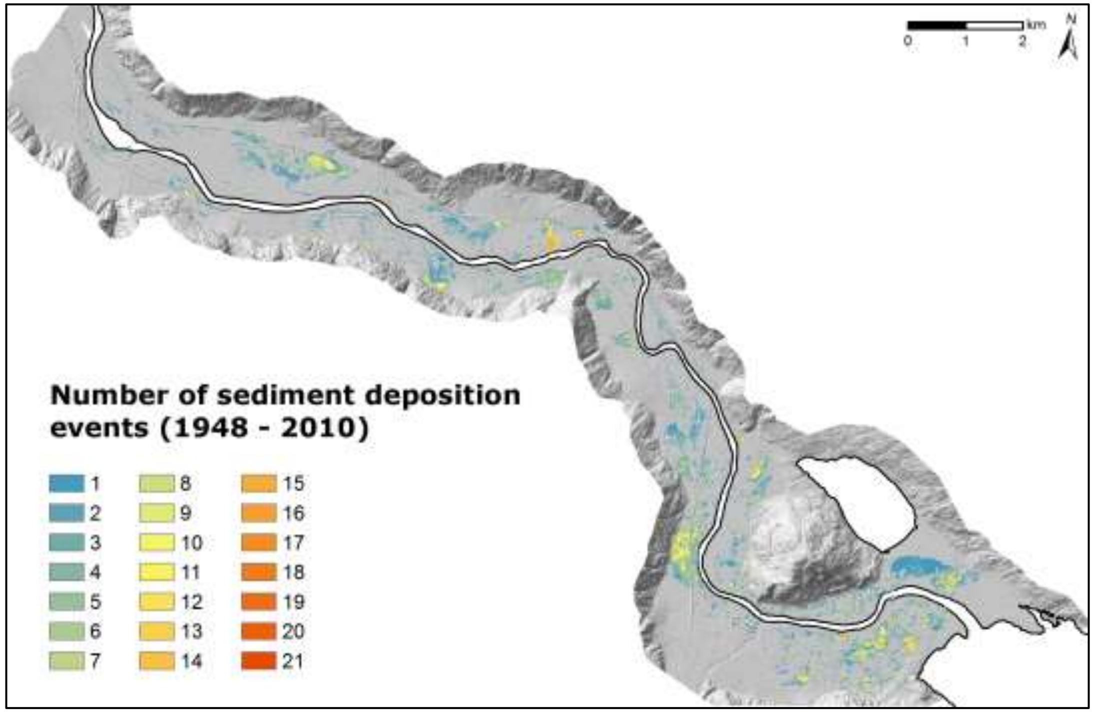
- Assessment of hydraulic model reliability: mean absolute residual between modelled and measured levels (estimated using flood marks) ~18 cm
- Map of frequency of inundation from 1948-2010



HYDRO-SEDIMENTOLOGICAL CRITERIA
LAYER 4: DEPOSITION AREAS 1948-2010

Activities
Application of sediment transport module available in CAESAR LISFLOOD (previously calibrated hydraulic module) to estimate suspended solid deposition in floodplain area only

Results
Map of frequency of deposition between 1948-2010 related to the 21 major historical floods



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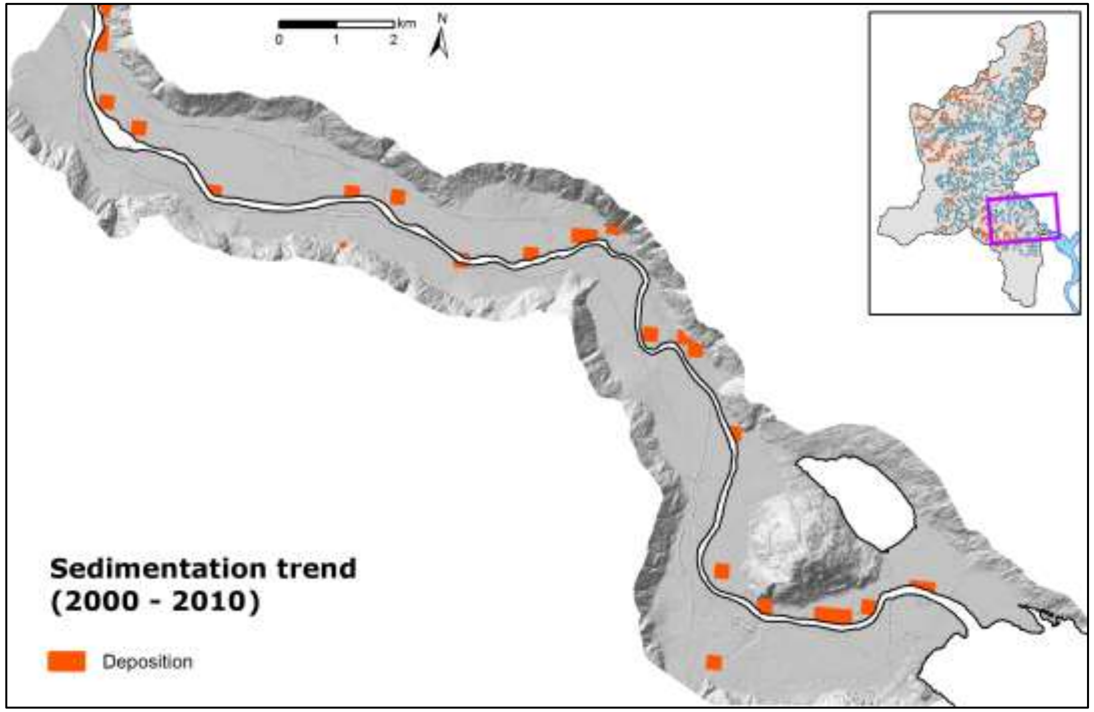
HYDRO-SEDIMENTOLOGICAL CRITERIA
LAYER 5: DEPOSITIONAL TRENDS

Activities
Application of hydro-sedimentological model FEST-WB[3]/ERODE[4] (spatially distributed and physically based) to investigate sediment yield processes at the Toce basin scale

Results
- Insights about short-term (2000-2010) depositional trend including all sediment related processes on hillslope and in river channel network
- Map of depositional trend from 2000-2010



[3] Montaldo *et al*, 2007
[4] Ravazzani *et al*, 2012

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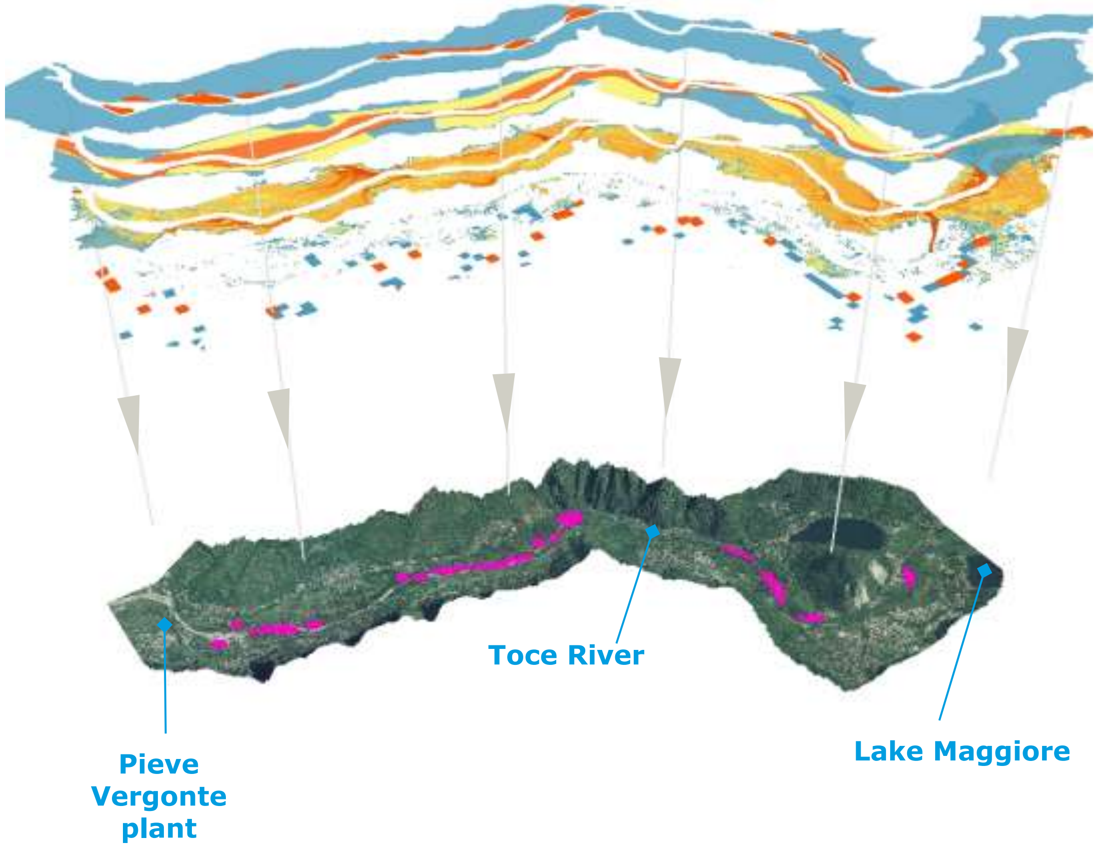
WEIGHTED LINEAR LAYER COMBINATION

	Layer value	Normalized and weighted value
1	$\begin{Bmatrix} 0\ [alluvial\ plan] \\ 1[recent\ or\ incipient\ fluvial\ terrace] \end{Bmatrix}$	$\begin{cases} i(0) = 0 \\ i(1) = 1 \end{cases}$
2	$\begin{Bmatrix} A\ [80\%\ RI\ 200\ yr] \\ B\ [\ RI\ 200\ yr] \\ C\ [RI\ 500\ yr] \end{Bmatrix}$	$\begin{cases} i(A) = 1 \\ i(B) = i\ (RI\ 200)/i(A) = 0.25 \\ i(C) = i\ (RI\ 500)/i(A) = 0.1 \end{cases}$
3	$\{0,1,2, \ldots, n\}$ $n \in N^+, \quad n = 21$	$\begin{cases} i\ (k) = 0 & k = 0 \\ i\ (k) = 0.1 & 1 \le k \le 2 \\ i\ (k) = 0.25 & 3 \le k \le 5 \\ i\ (k) = 0.75 & 6 \le k \le 15 \\ i\ (k) = 1 & 16 \le k \le 21 \end{cases}$
4	$\{0,1,2, \ldots, n\}$ $n \in N^+, \quad n = 21$	$\begin{cases} i\ (k) = 0 & k = 0 \\ i\ (k) = 0.1 & 1 \le k \le 2 \\ i\ (k) = 0.25 & 3 \le k \le 5 \\ i\ (k) = 0.75 & 6 \le k \le 15 \\ i\ (k) = 1 & 16 \le k \le 21 \end{cases}$
5	$\begin{Bmatrix} 0\ [depositional\ trend < 20\ mm/yr] \\ 1[depositional\ trend \ge 20\ mm/yr] \end{Bmatrix}$	$\begin{cases} i(0) = 0 \\ i(1) = 1 \end{cases}$

k = number of events

All layers normalised and linearly combined



Areas with the highest net deposition in 1948-2010 (1.16 km²)

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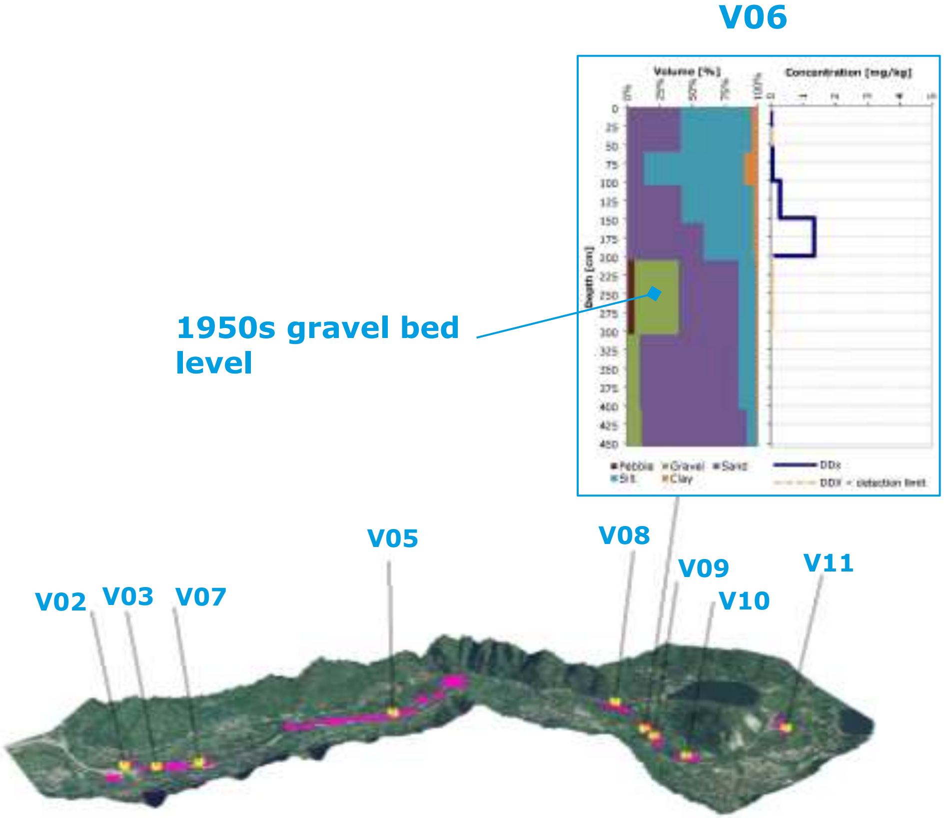
ENVIRONMENTAL INVESTIGATION

Activities

Nine geognostic boreholes (grain size measurements and chemical analysis) performed in 2014 and 2015

Results

- Validation of geomorphological conceptual evolution model. Gravel strata dated to 1950s (corresponding to channel bed level before incision started), has been found in all the investigated points with only a few exceptions
- DDT low concentrations (0.01-0.039 mg/kg) detected in soils along upstream portion of the reach. Higher concentrations detected only in three soil samples in downstream portion, about 2-3m below the ground surface, consistent with historical deposition in this area



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CONCLUSIONS

- Multi-criteria approach allowed the identification of the areas with highest historical net deposition tendency (a small part of the whole alluvial plain ~3%) and evaluate geomorphological conceptual evolution model
- Due to morphological adjustments since 1950/60 (channel narrowing and bed incision), recent terraces were filled by suspended solids during major floods
  Upstream portion of river: DDT low concentrations
  Downstream portion of the river, less dynamic than the upstream portion: vertical sedimentation profile is lake-like, higher concentrations of DDT (related to 1970s) are buried 2-3m below ground level
- Long-term monitoring plan proposed to observe suspended solid load and environmental condition (chemical concentrations and ecology) of the river-lake system

THANK YOU

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[1] Rinaldi, M, N Surian, F Comiti and M Bussettini (2015), A Methodological Framework for Hydromorphological Assessment, Analysis and Monitoring (IDRAIM) Aimed at Promoting Integrated River Management, Geomorphology, 251, 122-136

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