Impact of sand and gravel mining in La Bassée alluvial plain, France

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1. Introduction

The alluvial plain of La Bassée in the middle reach of the Seine River (France) is a floodplain of national importance, as much for ecological interests as for its economic relevance (2). The area has a rural and peripheral character, mainly in its upstream part, an agricultural land still regularly submerged in the case of large floods. Downstream of the plain, the extensive exploitation of aggregates has shaped the landscape for decades.

Due to sand and gravel extraction, the area has experienced a drop in water table and the drying out of formerly inundated downstream wetlands.

We present a model-based approach using the EauDyssée platform for quantifying the impact of gravel pit lakes on groundwater resources at the plain scale. We first developed a lake package to describe gravel pit lake/aquifer interaction (3) and then applied it in a transient simulation over La Bassée (4).

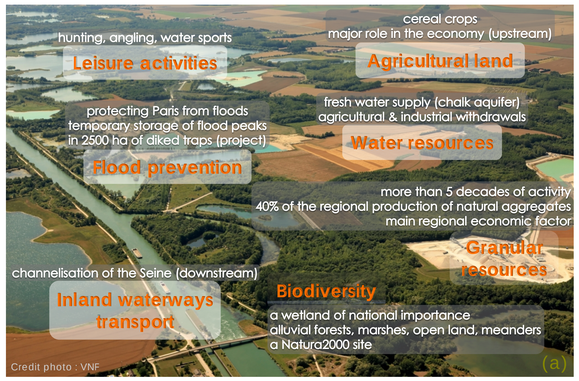
2. Natural resources and territorial challenges

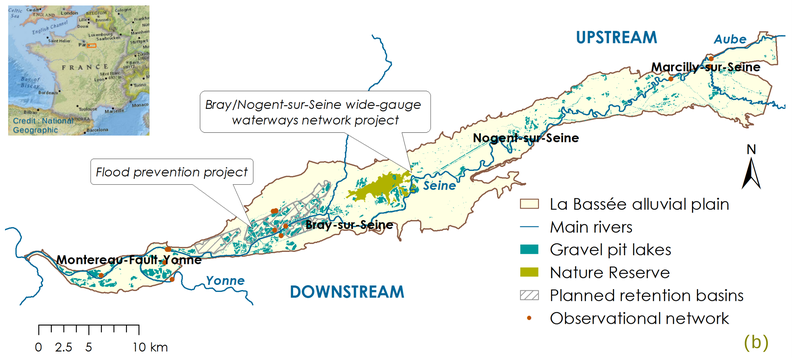
The alluvial plain of La Bassée is both of environmental importance as a major wetland and at the centre of strategic issues regarding inland waterways transport, flood prevention, water and granular resources.

Fig. 1 – The alluvial plain of La Bassée

(a) Strategic issues in the alluvial plain

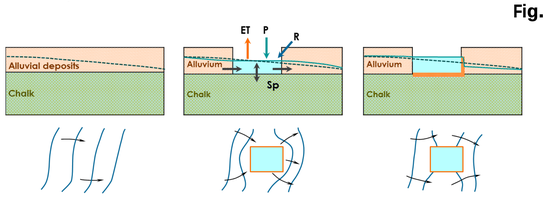
(b) Former and active gravel pits cover about 10% of the areal extent of the plain





Gravel pit lakes interact with groundwater from the surrounding alluvial aquifer and the underlying chalk aquifer. By exposing groundwater to the atmosphere, they can act as a sink/source for the groundwater system through atmospheric exchange (Schanen *et al.* 1998).

Fig. 2 – Hydrodynamic impacts of gravel pit lakes

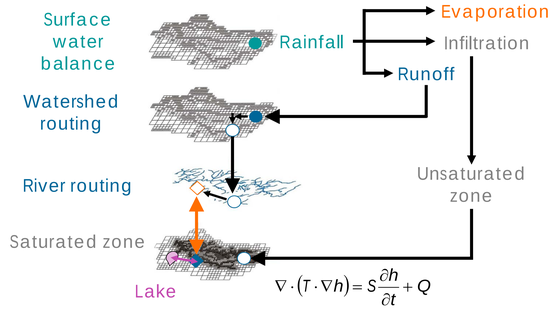


groundwater/atmosphere clogging layer

3. Including a lake module in the EauDyssée platform

EauDyssée (*e.g.*, Flipo *et al.* 2012) is a distributed model that allows the simulation of interacting components of the water cycle in a hydrosystem: surface, unsaturated and saturated zones.

Fig. 3 – The EauDyssée platform for hydrosystem modeling



To efficiently simulate lake-groundwater exchange, the modelling platform was extended by a lake module, LIBWET (Wang, 2016).

Seepage between gravel pit lake and aquifer (L/T)

$$Q = \frac{KA}{\Delta l}(h_a - h_l) = C(h_a - h_l)$$ C conductance (L²/T)

Net rate of seepage (L³/T)

$$S_p = \sum_m^M C_m \left(h_{am}{}^n - h_l^{n-1}\right)$$

Gravel pit lake budget

$$h_l^n = h_l^{n-1} + \Delta t \frac{P - E + R + S_p}{A_s}$$

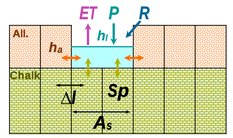
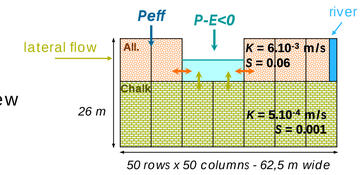


Fig. 4 – Gravel pit lake/aquifer interactions

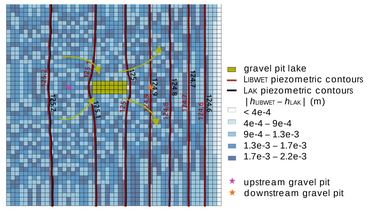
Numerical results of our gravel pit lake module and the lake package LAK of MODFLOW (Merritt & Konikow 2000) are compared using a benchmark validation test: gravel pit lake and aquifers reach equilibrium under time-invariant conditions.

Fig. 5 – Benchmark validation test

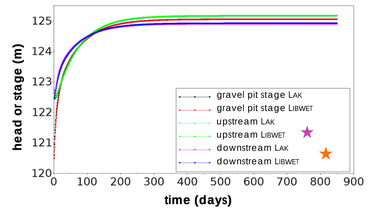
(a) Cross-sectional view



(b) Calculated steady-state heads LIBWET vs. LAK : Δh < 2 mm



(c) Selected heads in the aquifer and gravel pit lake stage computed by LIBWET and LAK: Δh < 0,023 m for Δt = ¼ day



- ✓ Head discrepancies between the two codes using lake package are on the order of magnitude of simulated head differences without lake.
- ✓ LIBWET shows higher convergence ability than LAK for decreasing time steps.
- ✓ A validated & operational lake module

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Acknowledgements

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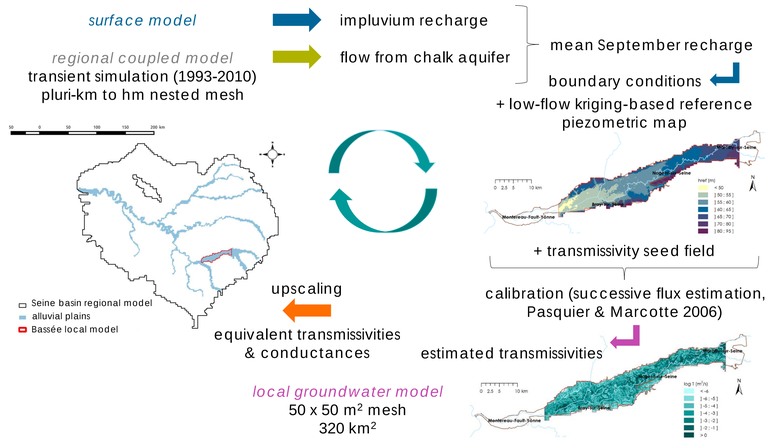
4. Quantifying the gravel pit lakes hydrodynamic impacts

Over the alluvial plain of La Bassée a local model is built, which takes the heterogeneity of its hydrodynamic parameters from an inverse calibration procedure and its boundary conditions from a coarser regional model run on the whole Seine basin (Labarthe 2016).

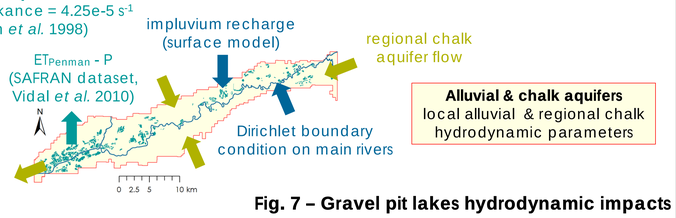
Fig. 6 – Multiscale modelling strategy



The effet of gravel excavation is investigated by quantifying the gravel pit lakes water budget over almost two decades (1994-2010).

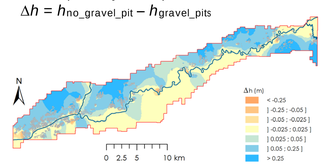
Fig. 7 – Gravel pit lakes hydrodynamic impacts

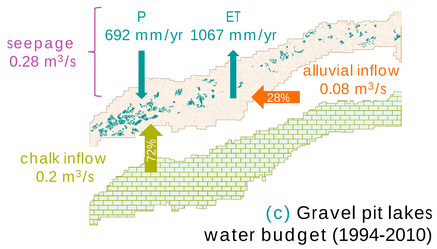
(a) Local groundwater model including gravel pit lakes



(b) Gravel pit lakes piezometric impact: ~ 0.1-m water level drop (steady-state)

$\Delta h = h_{no\_gravel\_pit} - h_{gravel\_pits}$





(c) Gravel pit lakes water budget (1994-2010)

- ✓ Gravel pits are fed by groundwater, discharging into the lakes especially over dry summer season. Recharge from lakes to aquifers only occurs during particularly wet springtime conditions (*e.g.*, March to May 2001).

5. Conclusion and perspectives

- ✓ A first attempt to estimate the global effect of sand and gravel extraction on groundwater budget in a major wetland
- ✓ Data-model comparison is required to better constrain our modelling results: we have already started collecting head pressure and temperature data in gravel pits as well as in the chalk and alluvial aquifers (see Fig. 1).
- ✓ Future research may investigate the impact of gravel pit lakes on groundwater quality in the area.