Modeling Groundwater-Surface Water Interactions Using Influence Functions

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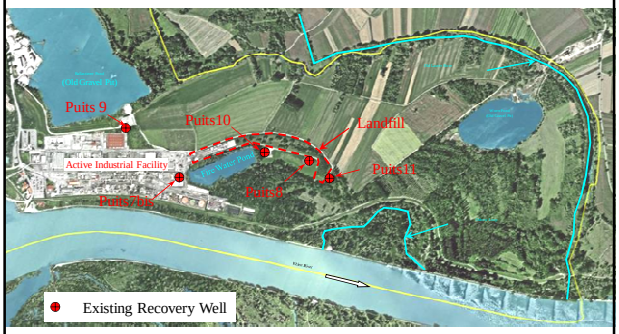
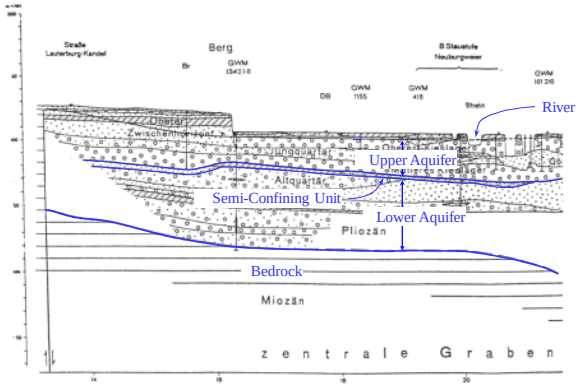
Site Location

Site Topographic Features



- The site is fairly flat.
- Rhine River levels fluctuate rapidly. Typical range is 2 to 4 meters.
- Old Lauter and the Oxbow Loop are connected to the Rhine.
- Pond levels are relatively stable.

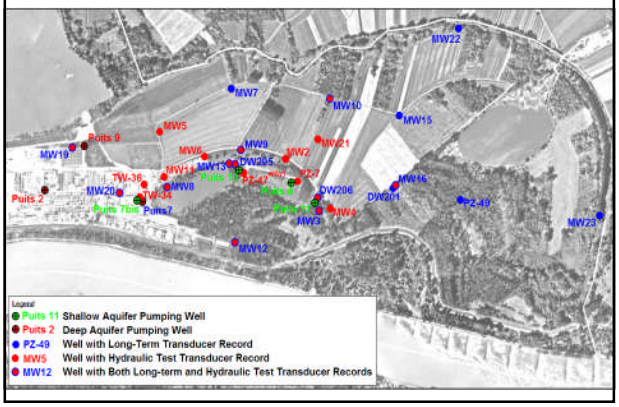
Regional Geologic Cross Section



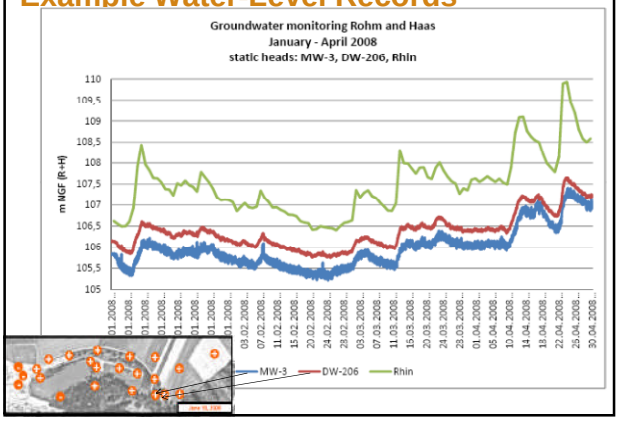
Project Objectives

- Demonstrate that the existing recovery wells achieve hydraulic capture of groundwater within 100 meters of the old internal landfill (regulatory requirement).
- Determine the optimal pumping rates to maintain capture under varying flow regimes caused by hydrologic changes, principally the Rhine River levels.

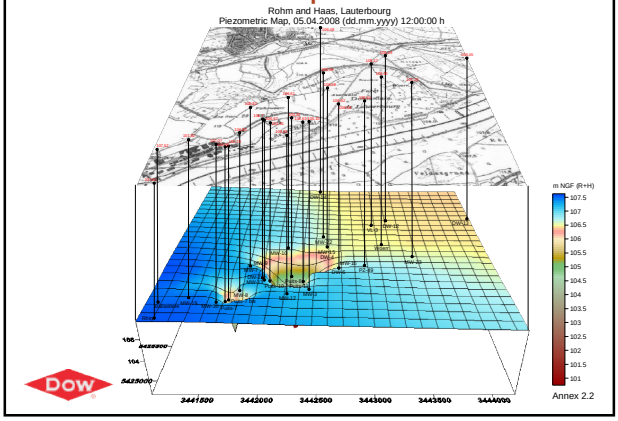
Available Groundwater Records



Example Water-Level Records



Visualization. GW table. April 2008.



Annex 2.2

Technical Approach

- Use existing site hydraulic data to develop polynomial **Influence Functions** that empirically describe aquifer behavior.
- Assemble these "Influence Functions" into a spreadsheet model that predicts water levels at selected points.
- Map the predicted water levels to identify capture zones.

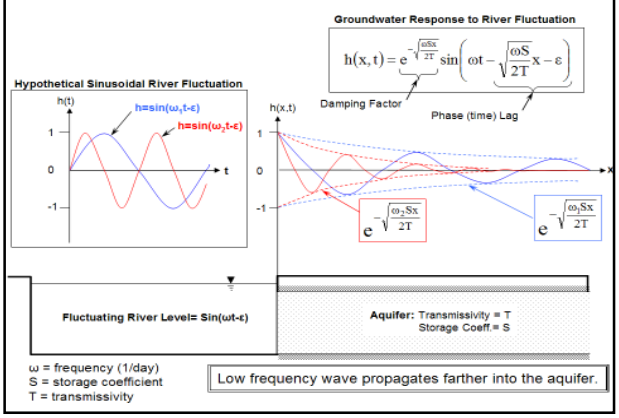
Basic Assumptions

-

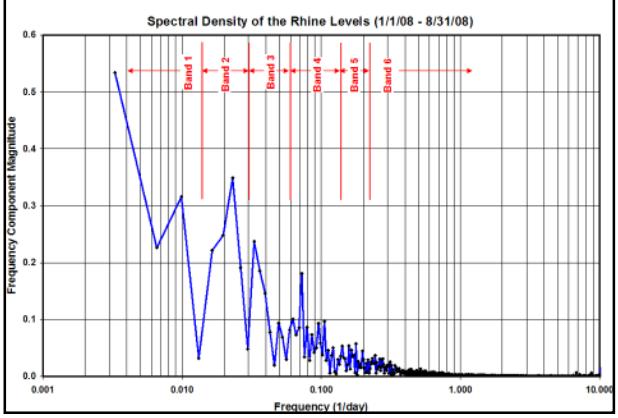
$$W(t,Q) = H(t)-S(Q)$$

where,
W(t,Q) = Water level at any location in the aquifer
H(t) = Response to river (river response function)
S(Q) = Sum of drawdown influences (pumping response function)

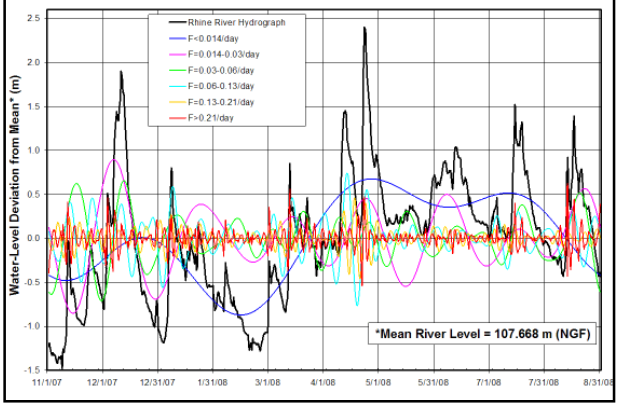
River-Aquifer Interactions: 1-D



Decomposition of Rhine Hydrograph



Decomposed Rhine Hydrograph



Polynomial Form of River Response Functions

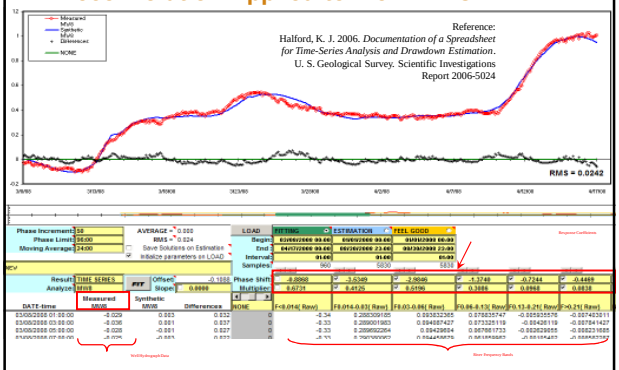
- Assume that the river's time-varying influence on water levels in a given well can be characterized as the sum of six time-dependent terms in a polynomial.
- Each of these terms quantifies the damping factor and time lag for one of the six frequency bands, as follows:

$$H(t) = H_{ave} + a_1 R_1(t-\varepsilon_1) + a_2 R_2(t-\varepsilon_2) + \ldots + a_6 R_6(t-\varepsilon_6)$$

where:

$H(t)$ = the predicted water-level at time, t, for a given well
H_{ave} = the long-term average water level at the well
$R_n(t)$ = the filtered river-level fluctuation for frequency band n at time, t
a_n = the amplitude reduction coefficient at the well for frequency band n
ε_n = the propagation lag time at the well for frequency band n

Deconvolution Applied to Well MW-8



$$H_{MW8}(t) = 107.127\text{ m} + 0.6731\,R_1(t-0.8868\text{ days}) + 0.4125\,R_2(t-3.5349\text{ days}) + 0.5196\,R_3(t-2.9846\text{ days}) + 0.3086\,R_4(t-1.3740\text{ days}) + 0.0968\,R_5(t-0.7244\text{ days}) + 0.0838\,R_6(t-0.4469\text{ days})$$

Pumping Response Functions

- At any point (a) in the aquifer assume that the total drawdown is the sum of the drawdowns produced by each of the four wells.

$$S_a = D_{a1}Q_1 + D_{a2}Q_2 + D_{a3}Q_3 + D_{a4}Q_4$$

- Response is a function of position and pumping rate, only.
- Aquifer tests were run to determine the hydraulic response coefficients (D_{ij}).

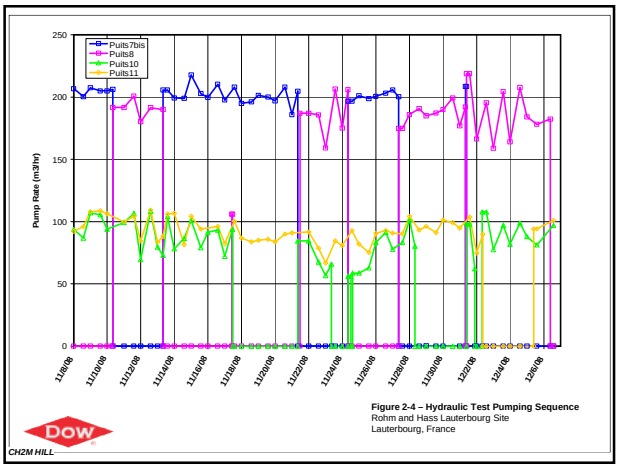


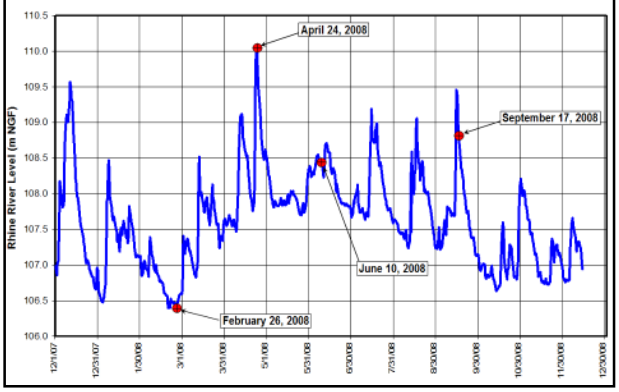
Figure 2-4 – Hydraulic Test Pumping Sequence
Rohm and Hass Lauterbourg Site
Lauterbourg, France

Model Application

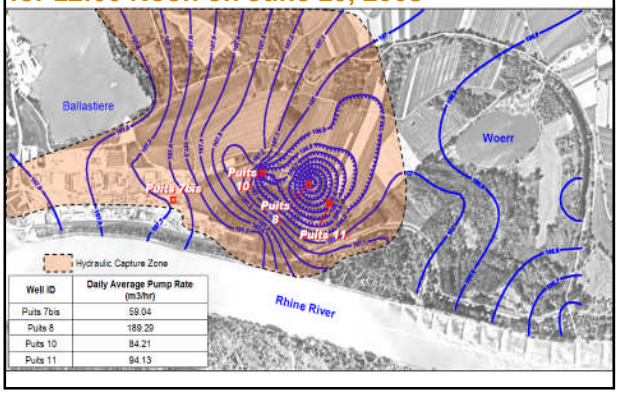
To apply the model:

1) Select a date and time from the period covered by the Rhine River hydrograph.
2) Enter the desired combination of extraction well pumping rates.
3) The model predicts aquifer levels at 27 points in the upper aquifer, 17 points along the river bank, and vertical gradients at 23 points.
4) Contour the potentiometric surface in the upper aquifer.
5) Delineate capture zones from the potentiometric surface map.
6) Map the locations of upward and downward gradients.

Dates Chosen for System Optimization

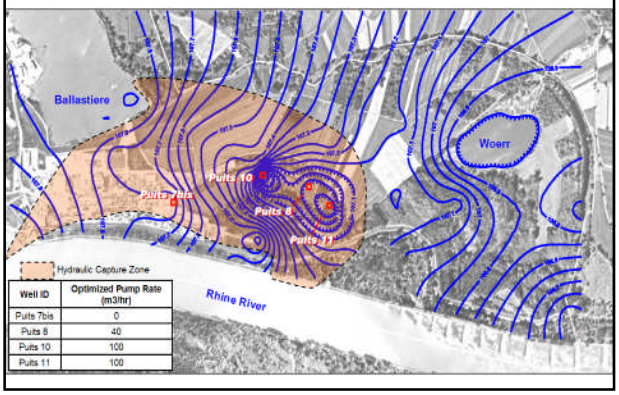


Simulated Water Levels and Capture Zone for 12:00 Noon on June 10, 2008



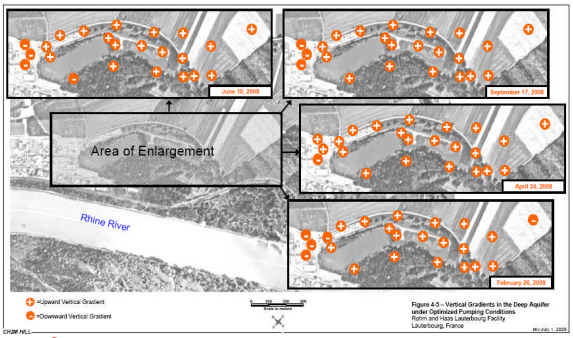
Well ID	Daily Average Pump Rate (m3/hr)
Puits 7bis	59.04
Puits 8	189.29
Puits 10	84.21
Puits 11	94.13

Optimized Water Levels and Capture Zone for 12:00 Noon on June 10, 2008

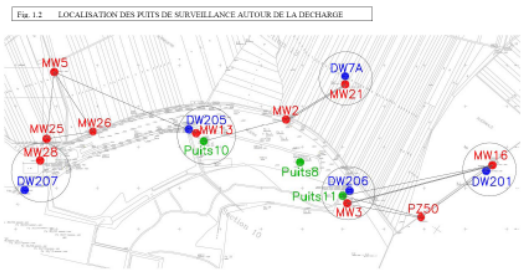


Well ID	Optimized Pump Rate (m3/hr)
Puits 7bis	0
Puits 8	40
Puits 10	100
Puits 11	100

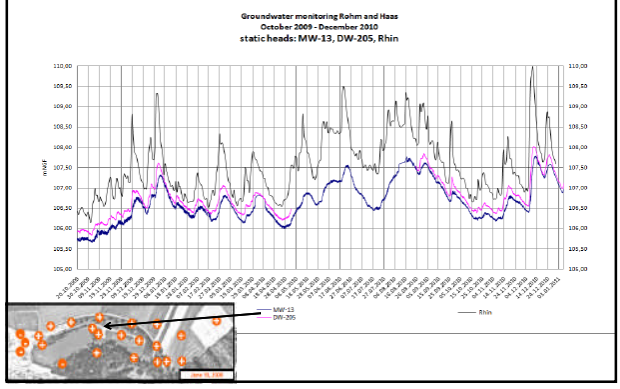
Optimization of vertical gradient.



Model and GW level monitoring. Network of monitoring wells equipped with pressiometers.

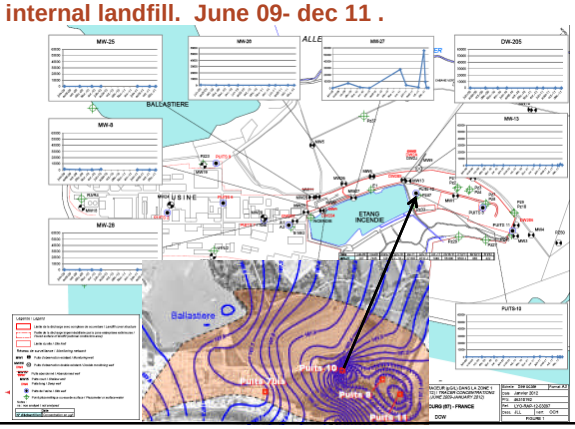


Model (vertical gradient) and GW level monitoring. Oct. 09-Dec. 11.



Zone 1. New monitoring network (mai 09).

Model and GW monitoring of tracer (µg/l) around internal landfill. June 09- dec 11 .



Summary and Conclusions

- Influence functions showed that existing wells achieve hydraulic capture. In fact, it is often excessive.
- Optimized pumping rates were developed using the influence function spreadsheet model.
- The results were well received by the regulators. They were persuasive because they were based directly on measured hydraulic data.
- Influence functions are not based on the equations of groundwater flow. Instead, they empirically describe observed aquifer behavior.
- The procedure used a lot of data, but even more would have been required for a persuasive numerical model.
- The confinement around the internal landfill predicted by the model at optimized pumping rates was confirmed hydraulically and chemically over a 16 months period.