Groundwater Circulation Wells for In Situ Remediation.
Validation of versatility and performance of the first field test in Italy.

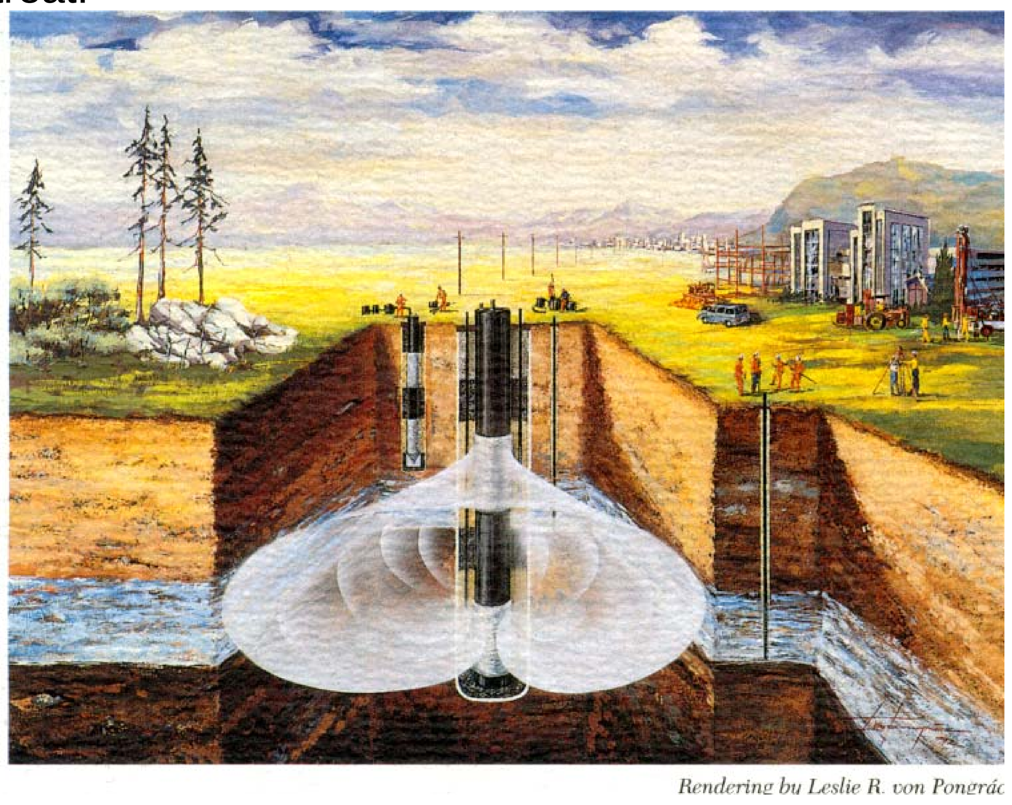
Mauro Fehervari(*), Eduard Alesi(**), Stefania Sgrigna(*), Gianrico Rossi(*), Leonardo Patata(*), Ernst Bartsch(***)

(*) Snamprogetti SpA – Environmental Remediation and Land Conservation; (**) IEG Technologie GmbH; (***) IEG Italia srl

Groundwater Circulation Well (GCW) Technology.

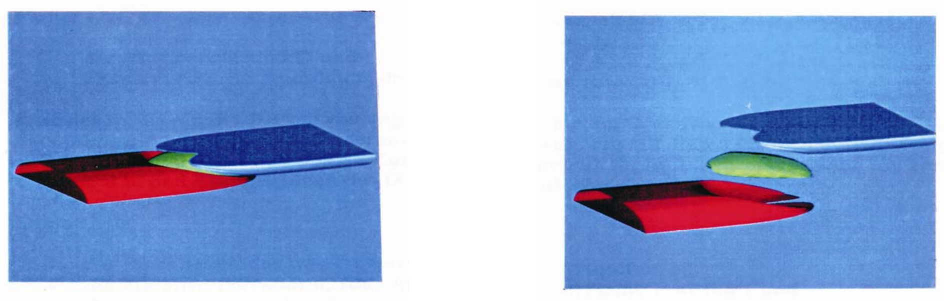
The conventional approach for remediating groundwater has been to extract the contaminated water, treat it above ground, and re-inject or discharge the clean water. Otherwise, it's becoming increasingly apparent that pump-and-treat technologies require considerable investment over extended periods of time, and that they have often been proven to be inadequate; in many cases, they do not actually clean up the source of groundwater contamination.

In situ treatment technologies for contaminated groundwater such as Groundwater Circulation Well (GCW) technology are now considered to be fundamentally more efficient, cost effective and are significantly more sustainable alternatives to pump-and-treat.



Artist's 3-D impression of a GCW in operation

The pressure gradient between two hydraulically separated screen sections in the well induces a circulation flow in the aquifer. The groundwater moves through the treatment zone both horizontally and vertically before entering the influent screen. Groundwater flows into the lower screen to compensate for the water removal from the upper section (Standard Circulation). The direction of flow can be reversed by changing the direction of the pump (Reverse Circulation).



The 3-dimensional groundwater flow field pattern, the flow dynamics and the dimensions of the capture zone, circulation cell, and release zone can be calculated using design aids based on numerical simulations of the groundwater hydraulics.

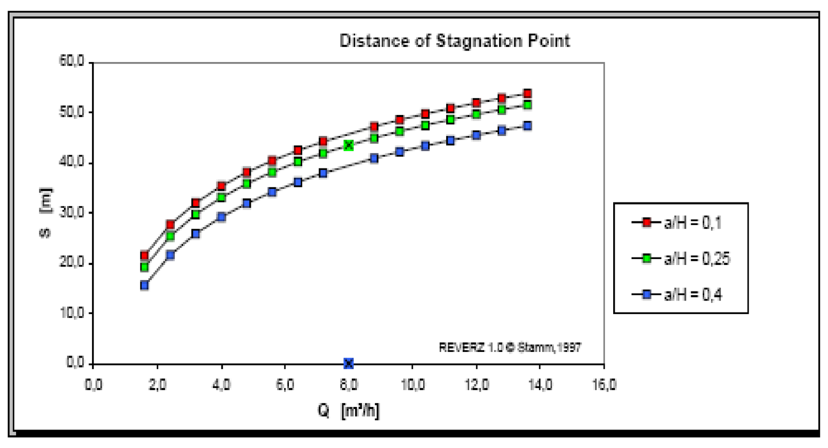
GCWs can be used in conjunction with other in situ remediation technologies to treat halogenated VOCs, semi-VOCs (SVOCs), pesticides, and petroleum products and their constituents such as benzene, toluene, ethyl benzene, and xylene (BTEX). They have been applied to a wide range of soil types, from fine silty clay to coarse sandy gravel. With at least two screen sections, GCWs are universally applicable remediation tools. They can be employed in several configurations, such as in well stripping (IWS), bioaugmentation, enhanced natural attenuation adding nutrients and/or electron acceptors for stimulating bioremediation processes, bioventing, soil vapour extraction, reactive nanoparticle dehalogenation, in situ denitrification and chemical oxidation (ISCO) or reduction (ISCR). They may also be combined with a LNAPL/DNAPL recovery system in the aquifer.

Finally, different well configuration and/or composition allows wide and versatile solutions, e.g. the vPRB (in situ Virtual Permeable Reactive Barrier) where several vertical circulation wells are arranged in one line perpendicular to the natural groundwater flow to obtain a curtain of overlapped circulation cells; such configuration could be promising to treat

The first field test in Italy.

The first field test of a GCW system consisting in an In Well Stripping system coupled with a reverse flow GCW and a LNAPL recovery system is currently being operated in Italy. The geology of the application site is a sandy aquifer 12 m deep. The groundwater is mainly contaminated by Organic Aromatic Compounds. Spots of LNAPL are present in the site. Initial concentrations were found to be in the range of 1 to 100 mg/l.

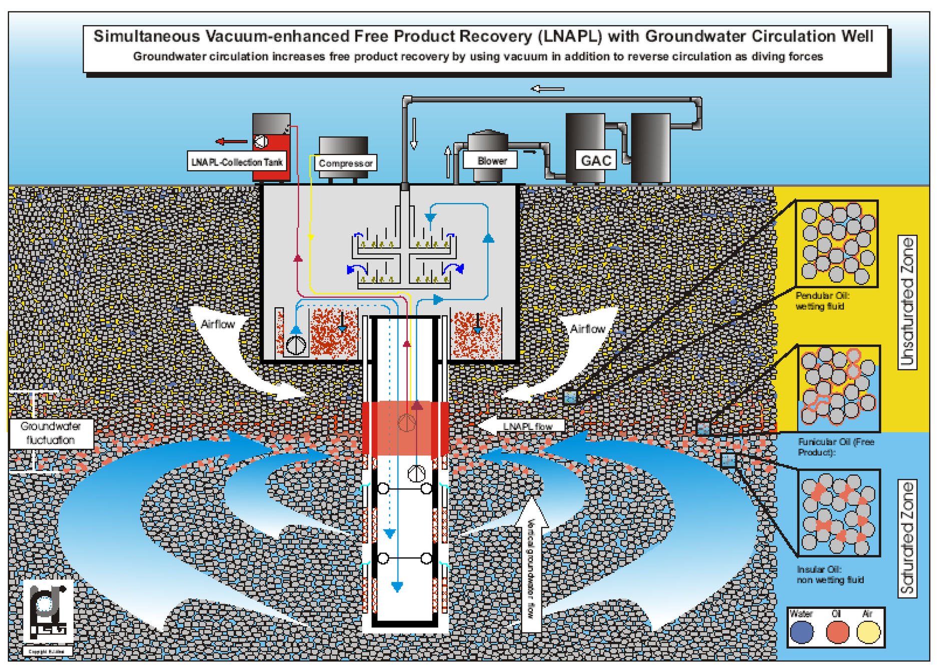
Groundwater flow modeling calculations estimate a radius of influence of GCW equal to 30 m using a flow rate extraction of 4 m^3/h.



Two multilevel wells each located 15 m up-gradient and down-gradient of the main well were installed to monitor the long range effects of the induced groundwater circulation cell. A few months after the drilling operations and the installation of all the equipment, the system was commissioned in March 2006.

The GCW drilling phase, the IWS equipment installation and the stripping in progress.

The chosen location was initially expected to be free of LNAPL. Unfortunately, during the first week several centimetres of free product accumulated in the well. Consequently, an automated LNAPL recovery system was added and the system restarted in May 2006. The final design of the system is shown in the sketch below.



During these months, some maintenance and setting operations were done. Operational parameters and physical-chemical properties of all the liquid and gaseous streams were monitored weekly and recorded. Additionally, the groundwater was sampled periodically from the multilevel monitoring wells and submitted to an extensive programme of laboratory analysis in order to achieve a detailed characterisation of the changing groundwater quality conditions from the well to the edge of the sphere of influence of the GCW.

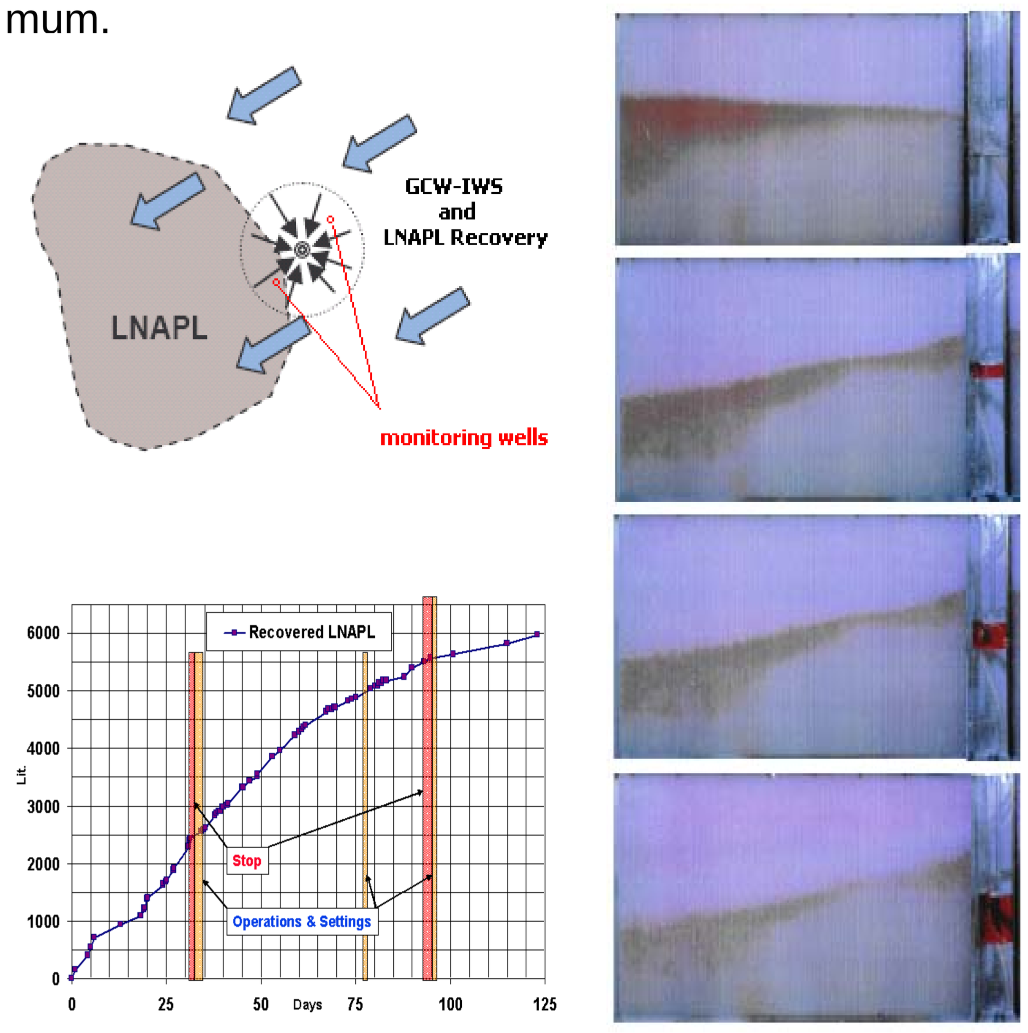
The system runs with the following setting parameters: flow rate of groundwater circulation between between 4-10 m^3/h, water/air ratio for negative pressure stripping 1: >200.

Preliminary results.

After 18 months of operation, the GCW extended its influence to a volume of 30.000 m^3 of saturated soil; 50.000 m^3 of groundwater were treated and recirculated. In addition, approximately 18.000 kg of hydrocarbon compounds have been recovered. The LNAPL recovery system has removed 90% of hydrocarbons as free oil product and 10% has removed as off-gases rich in VOCs by means of the in-well stripping. Furthermore, as re-injected groundwater is saturated with oxygen introduced by the in-well stripping unit, in situ bioremediation has been promoted leading to degradation of hydrocarbon compounds in the aquifer. The amount of this degradation remains to be quantified.

Trends observed and expected.

Radial attraction of free phase product from the down gradient zone has been demonstrated. The cohesive transport of LNAPL is proven by down gradient multilevel well observations: for the initial three months free phase product was present in the shallow sampling level, whilst all of the monitored concentrations in the deeper sampling levels passed through a maximum.



GCW radius of influence, recovered LNAPL and vacuum-enhanced free product with GCW a lab-test.

After approximately three months during which the LNAPL was recovered at a constant rate of 70 litres/day, depletion of free product reserve was observed. This trend is expected to continue until the drainable LNAPL reserve within active GCW remediation zone is exhausted. Initially, LNAPL removal has masked the groundwater remediation effect. The trends in groundwater contamination concentration shown by the extracted groundwater and the down gradient multilevel samples is consistent with the hypothesis of the initial arrival of LNAPL to the central GCW followed by collection of highly contaminated groundwater from the peripheral remediation zone.

Increasing concentrations are expected in the influent groundwater up to a maximum, followed by a reducing trend. Furthermore, vertical homogenisation of groundwater concentrations are expected (as shown by the up-gradient monitoring well early on), followed by a generalised decreasing concentration throughout the vertical profile.

In conclusion, the system reacts as expected: the radius of influence is extended to thirty metres; the length of the aquifer is completely included in the circulation cell; the drainable LNAPL was recovered from a large area; the in well-stripping achieves an efficient volatilisation (97-99,5%) of the dissolved VOCs from the pumped groundwater.

The GCW-IWS & LNAPL Recovery system test remains operational. Consolidated results of the remediation are expected by the end of 2007.

Contacts: ***Eduard Alesi:*** *eduard.alesi@ieg-technologie.de*
Mauro Fehervari: *mauro.fehervari@snamprogetti.eni.it*