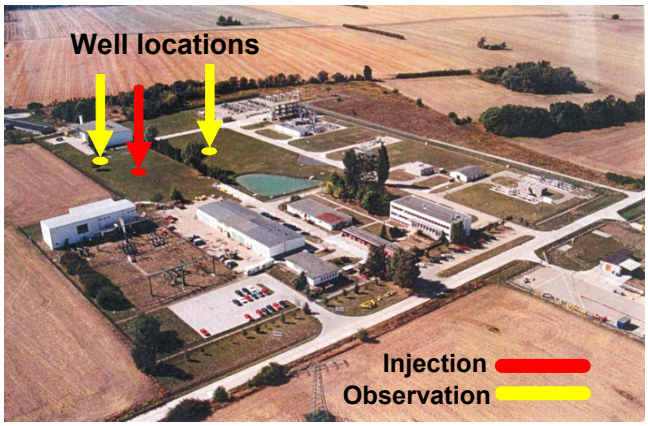
# $CO_2$SINK – Year Two

The $CO_2$SINK project has gathered momentum during its second year and valuable additional support has been provided by Government and industry. The proposed injection site at Ketzin is becoming an important magnet for research into Carbon Capture and Storage.

Major achievements have been:

- Permissions from mining authority
- 3D Seismic data acquisition
- Injection and observation well design
- Ordering of injection well tubulars
- Tender preparation for drilling, logging and coring
- Detailed analysis of caprock samples
- Verification of baseline geological model
- Funding and contract for $CO_2$ supply
- Surface baseline survey
- Dynamic flow modelling of injection
- Design of downhole sensing experiments and equipment




*The site showing planned well locations*

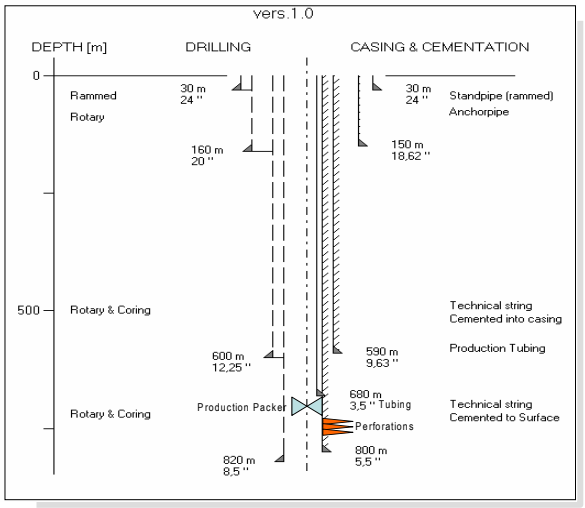
## Permits for drilling and injection

Obtaining permits for seismic data acquisition, the drilling and injection is a critical task. In Germany the Mining Authority is responsible for granting the necessary permissions and for identifying and obtaining any permissions needed from other authorities. Key documents which have been prepared in support of the permit applications have been a basic and a special schedule of operations for 3D seismic survey. A further "Basic Schedule Drilling, Logging, Coring" has been prepared and has verbal approval. These Schedules serve as a basis for further permitting documents which cover the injection activities at the $CO_2$SINK site. A lot has been learned about the permitting process as a result of this project.

## Well location

The injection and observation wells will be within the existing industrial site which used to serve the Ketzin gas storage facility. The wells will form an "L" with the injection well in the centre and spacings of 50m and 100m. This site is about 1km from the top of the anticline.

## Well design




*Design of the injection well*

Design and drilling of one injection and two observation wells is on the critical path of the project. It is also the largest financial commitment. Design is now complete and meets the requirements of the Mining Authority. Tubulars which are a major cost element have already been ordered and tenders have been prepared for the drilling operation. The design of the injection well is shown above. The observation wells are the same, with

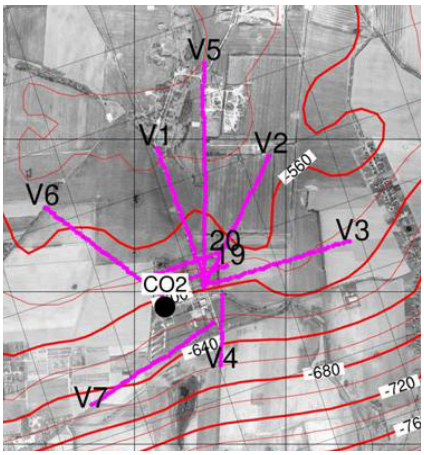
perforations, but without production tubing and packer

## Seismic survey

A successful 3D seismic survey campaign lasting 72 days took place in autumn 2005. A weight drop source was used for acquisition over a 4.2km by 3.4 km area extending up dip. About 7500 source points were recorded. The figure below shows the weight drop at work.

*Weight drop source at work*

In addition a VIBSIST source was used for a pseudo 3D survey with a "star" geometry over the injection site. The layout of the seismic lines for this survey is shown below.




*Receiver lines for pseudo 3D seismic survey*

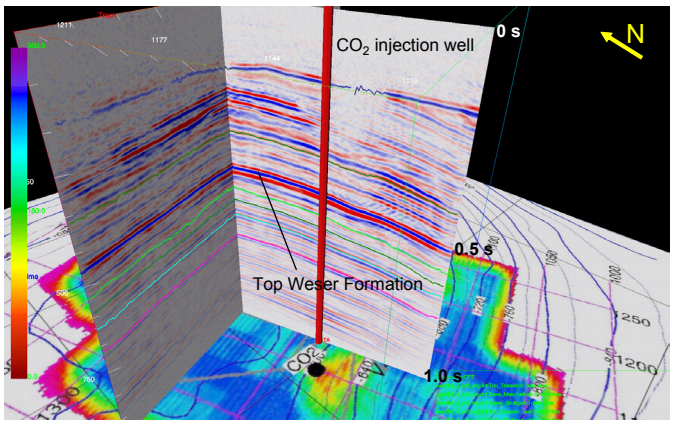
Seismic in a volume near the injection site has been processed and a report released. In the figure opposite a preliminary perspective view of two time sections which pass almost directly over the injection site shows the K2 (anhydrite) horizon at 0.5 seconds and illustrates the quality of the imaging. This horizon corresponds to the Weser formation which is the cap-rock for the target $CO_2$ storage formation. The nominal fold, a measure of the number of seismic traces at each location, is 25. As shown on the colour coded map at the bottom of the sections, the actual subsurface coverage of the seismic measurements varies over the area due to the presence of nature preserves, housing in the village of Neu Falkenrehde, as well as equipment and buildings on the former gas distribution site.

## Geological model

To enable development of geological models a comprehensive collection of data has been incorporated into a $CO_2$SINK information system (CO2SIS). This includes structural, lithological, petrophysical, hydrogeological and thermal data. This information is made available to all consortium members at the project website and has been used, for example, in support of permit applications.

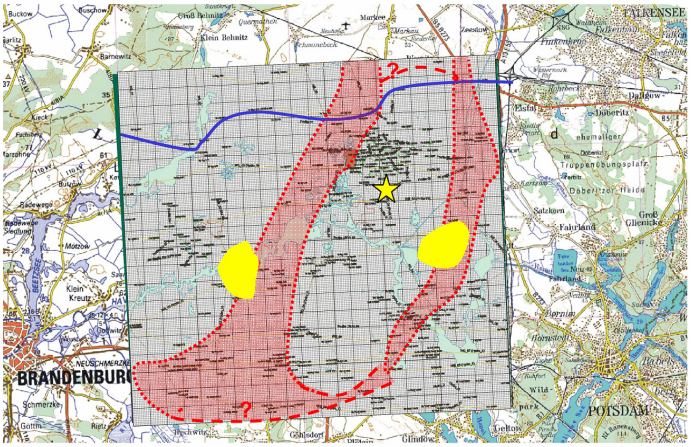
The geological field model of the Ketzin anticline has been further refined. The latest data incorporated are from the 3D baseline seismic survey.

A geological model of the shallow subsurface has also been developed to study the Quaternary aquifer system and how it is sealed off from the deeper saline aquifers. The model comprises 17 layers covering sequences from the Quaternary to Jurassic covering an area 22 km x 20 km as shown below. The red areas bounded by stippled lines are Quaternary incision troughs that may serve as pathways for saline fluids towards the surface as




*Perspective view of two perpendicular seismic sections from the 3D seismic measurements. The top of the Weser Formation can be identified as a strong continuous horizon. The location of the CO2 injection well is denoted by a red tube. The color coded map below the seismic sections shows the subsurface coverage of the seismic measurements*

observed in areas indicated by yellow patches. The yellow star marks the location of the $CO_2$SINK injection site. Based on this hydrogeological model, scenarios of $CO_2$ leakage will be evaluated.



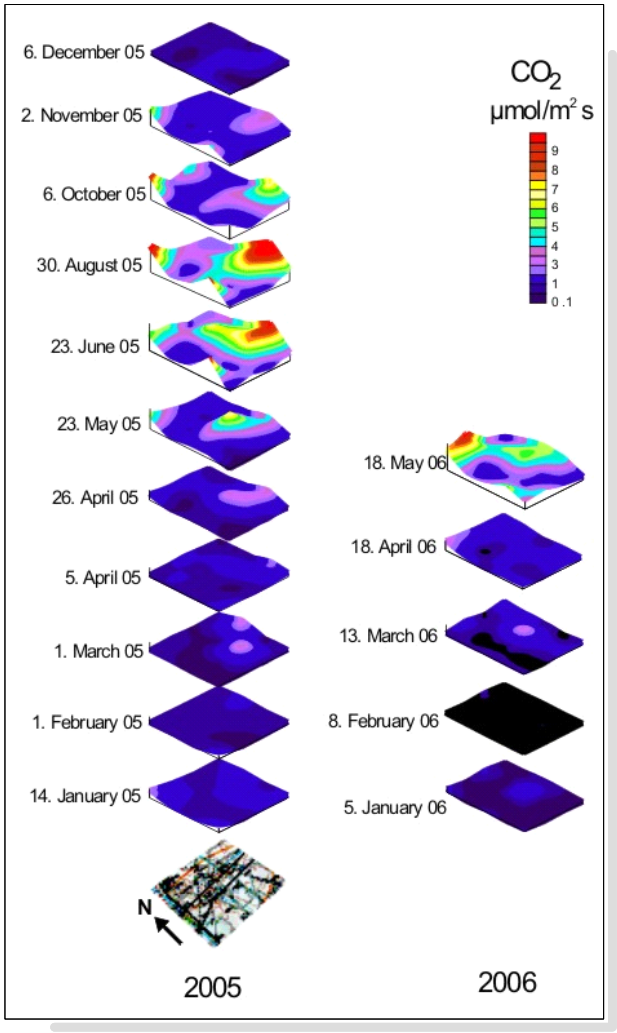

*Ground water flow model – extent of grid*

First in-depth lithological analyses of caprocks have been made in cooperation with the Geological Survey of Brandenburg. Samples analyzed covered mudstones, silty mudstones, and fine-grained clayey sandstones, which are typical for the Weser and Arnstadt formations constituting the immediate overburden of the Stuttgart formation reservoir. Techniques used included SEM, EMPA, XRD, XRF, DTA and TGA.* The studies show that the caprocks have excellent sealing properties. Flow experiments with water and $CO_2$ have been performed in various sandstones types to prepare for the $CO_2$SINK reservoir rock study. Permeability, electrical resistivity, and sonic wave velocities have been measured under simulated in-situ conditions and their change with saturation and time was analyzed.

## Surface baseline

Measurements were taken throughout the year in 20 surface boreholes and 2 shallow groundwater wells. Samples were also taken from a well in the incised channel and subjected to isotopic analysis. $CO_2$ and methane in these samples proved to be of biogenic origin. This helps to demonstrate the integrity of the seal above the former gas storage reservoir.

Soil $CO_2$ fluxes were observed and mapped as shown opposite. This shows that fluxes normally rise in the warmer months due to increased bio-activity in the growing season. A meteorological station was set up to gather data to assist in revealing possible correlations with the planned injection activity.




*Soil $CO_2$ flux baseline during 2005/6*

## Permanent downhole sensors

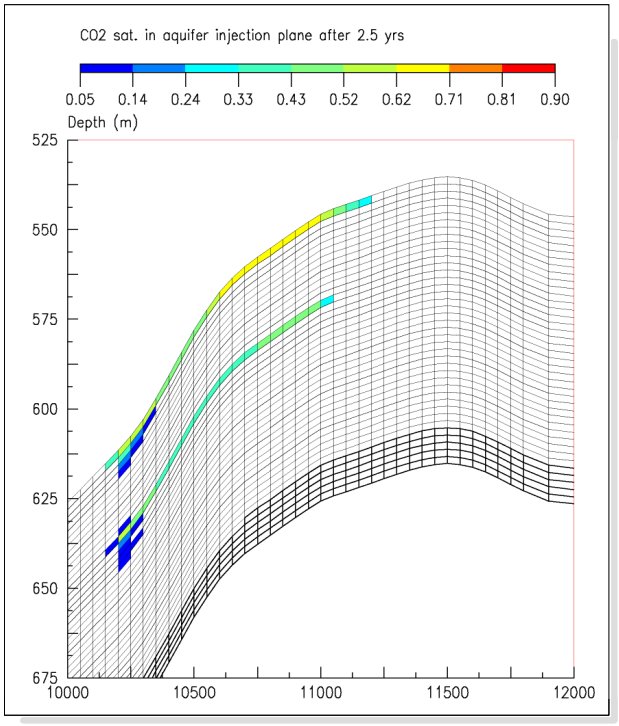
Down hole monitoring will consist of distributed optical fibre Temperature Sensing (DTS), pressure sensing and Electrical Resistance Tomography (ERT). These sensors will be installed and cemented behind the casing. The DTS cable has been procured and is currently undergoing tests. The ERT experiment is funded under the International COSMOS (Community Earth System Models) program.

Prototypes of fibre optical accelerometers were developed by the University of Kent and were tested successfully in an abandoned mine in Freiberg, Germany. Further development of triple axis accelerometers for permanent micro-seismic monitoring at Ketzin based on these prototypes has been abandoned because of the time constraints of the drilling programme.

* *SEM Scanning electron microscope, EMPA Electron Microprobe Analysis, XRD X-Ray Diffraction*, XRF *X-Ray Fluorescence*, DTA *Differential Thermal Analysis, TGA Thermogravimetric Analysis.*

## Dynamic flow modelling

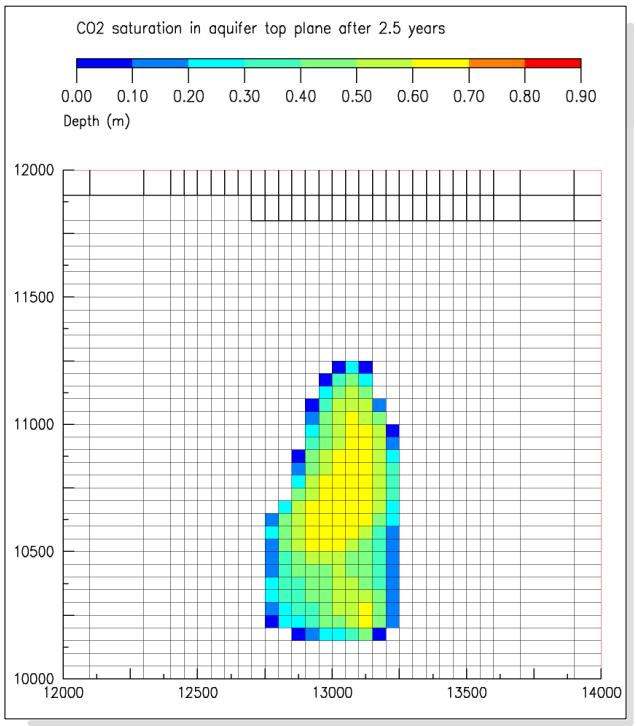
A base case model has been set up with the best estimates of the parameters which can be made prior to drilling. This model will be updated as new data is acquired. The model has been used to examine the injection of $CO_2$ and the flow near the well bore. This was initiated by the request of the mining authority which required a simulation using industry standard software. The base case shows that with 60,000 tons injected over 2.5 years an elliptical plume with a major axis of about 250m would form. This is illustrated below.




*Base case $CO_2$ saturation after 2.5 years*
*North South profile*

The model has also been used to explore the possibilities for detection of the plume using seismic, electric and thermal monitoring techniques and has been able to suggest appropriate quantities and time scales for injection and monitoring.

Work is in progress to model the water-rock chemical interactions. This is so far based on a variety of compositions with varying amounts of quartz, k-feldspar, illite and calcite because detailed composition cannot be determined until cores are available from the injection site. Two codes, TOUGHREACT and SHEMAT are under comparison, the former being based on a kinetic model and the latter an equilibrium model. None of the models yet incorporates any faults or fractures as these can only be added once the seismic data is interpreted.




*Base case $CO_2$ saturation after 2.5 years*
*Plan view*

## Risk Assessment

A comprehensive risk identification, based on a series of workshops, has been completed for all aspects of the project and a total of 69 risks are documented in the risk database. Responsibility for follow up for all but 2 of these has been assigned. Further work has to be done on long term storage integrity modelling and risk analysis and is scheduled for the summer of 2006.

## $CO_2$ injection

Linde Gas AG will supply the $CO_2$ for the injection. They were chosen on the basis of an EU-wide call for tender. They will supply the $CO_2$ by road tanker and the on site storage and conditioning facility which delivers $CO_2$ to the well head at the required temperature and pressure.

It is anticipated that drilling will occur late 2006/early 2007 and that injection can start soon thereafter.

Further information is available at
www.co2sink.org