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MODELING THE HYDROLOGIC EFFECTS OF LONGWALL MINING ON THE SHALLOW AQUIFER SYSTEM USING MODFLOW WITH TELESCOPIC MESH REFINEMENT

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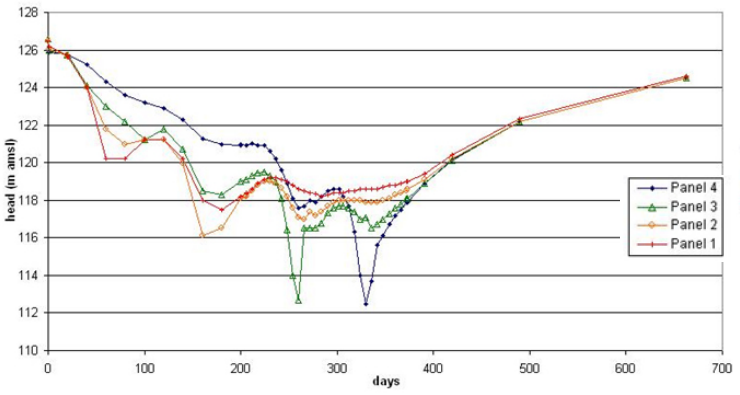
Project Description and Objectives:

The objective of this project was to develop an approach by which the familiar USGS model MODFLOW, operating through the Groundwater Vistas ® commercial interface, could be used to simulate the impact of longwall mining subsidence on the shallow aquifer system. Focusing on shallow aquifers avoids the problems of variably saturated flow, mine drainage and extreme fracturing that characterize the lower part of the overburden.

Three major issues had to be resolved. First, rapid spatial hydraulic variations that occur locally above the longwall panels were handled through telescopic mesh refinement (TMR). Second, rapid initial drops in water level due to sudden dilation of fractures and bedding planes were simulated using equivalent wells. Third, subsidence-related changes in hydraulic properties were addressed using stepwise discrete approaches. The model development was based on a well-documented case study in Illinois for which extensive field data were available.

Applicability to Mining and Reclamation:

Longwall coal mining may impair local water quality, affect well yields, and contribute to unease among the public in mining areas. Standard groundwater modeling tools can be effectively applied to the unique hydrologic problems of longwall mining. Accessible, documented modeling applications would help engineers and hydrogeologists make site-specific predictions and evaluations of hydrologic impacts during the coal-extraction phase or postmining hydrologic balance recovery. Although developed in a mid-continent setting, project techniques could be applied to longwall mining sites in other coalfields provided that site-specific geological and hydrological information is available to support the model development and calibration.



ABOVE FIGURE: Simulated heads at mid-points of longwall panels.

Methodology:

Model development and calibration were based on extensive monitoring from 1988–1995 of subsidence, subsurface strains, groundwater levels, and hydraulic properties. Overburden is predominately shale but includes a sandstone aquifer at a depth of about 25 m. Thin glacial drift covers the site. Local relief is 15 m. A 3-m-thick coal seam at depths around 220 m was mined by four longwall panels, producing about 2-m ground subsidence. Mine subsidence increased hydraulic conductivities in the sandstone by one to two orders of magnitude.

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Methodology (continued):

Groundwater levels in the aquifer dropped up to about 30 m to unconfined conditions during undermining but recovered fully about 5 years after mining ended.

The model represents the upper 60-70 m of overburden. A 53-km2 regional model of steady-state groundwater flow was developed from borehole records and hydrologic data and calibrated by adjusting hydraulic conductivities and boundary conditions. The TMR feature in Groundwater Vistas ® was then used to zoom down to a 7.3-km2 local model of 146,624 cells, each 20 m x 20 m, arranged in an 8-layer configuration. The local model was developed for transient conditions during mining and postmining recovery.

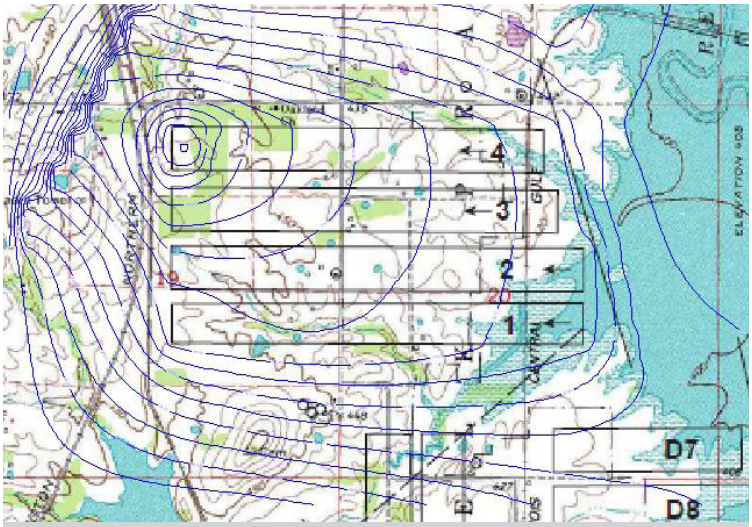
Early subsidence, with its dilation of fractures and bedding planes and rapid transient head drops, was simulated by the well-sink feature in MODFLOW using "pumping rates." Hydraulic property changes cannot be simulated dynamically. Instead, we represented them by discrete stress zones about the panel face that move in a stepwise fashion as the longwall panel advances. Values for K and S were manually reconfigured in each stress zone. The property zone feature of Groundwater Vistas ® was particularly useful for this operation. These property changes were combined with the well-sink simulations and run in transient mode for the discrete stress/advance period then reconfigured for the next advance step. The previous step's final solved heads were input as starting heads.

Highlights:

Modeling approaches developed in this project were built on a solid conceptual understanding of the hydraulic mechanisms involved in longwall mining. The well-sink approach successfully simulated the transient cone of depression that forms in the subsiding area. This is a simple way to represent a key hydraulic mechanism that had not been previously modeled for the longwall setting. Use of stress zones in discrete steps to modify hydraulic properties as the mine face advances is also new and was procedurally successful. It is a time-consuming but conceptually simple means of using readily available software to simulate a process that has been a challenge to previous modeling attempts.

Results/Findings:

The project demonstrated techniques that successfully simulated the effects of longwall mining on a shallow aquifer. These techniques were applied to the familiar MODFLOW groundwater flow model, interfaced with readily available commercial software. TMR allowed a detailed local model to be developed from a regional model. Well-sink and stress-zone approaches represented the critical mechanisms by which longwall mining affects aquifers. The model produced potentiometric levels through mining and recovery very similar in pattern to that observed in the field study. Future work may incorporate subsidence-related elevation changes into the discrete stepwise advances in the local model. While this can be done using the matrix editing properties built into the software, potential stability and inconsistency problems with boundaries and transferred heads would need to be resolved.



ABOVE FIGURE: Modeled aquifer potentiometric contours after mining panel 4.

Website Information:

The final project report can be found at **http://www.techtransfer.osmre.gov/NTTMainSite/appliedscience/2007appscience/CompletedProjects/ILLongwallMiningHicks07FR.pdf**

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