Hydrogeology of Wales: Carboniferous aquifers - modelling the South Wales Coalfield

From Earthwise

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This page is part of a category of pages that provides an updated review of the occurrence of groundwater throughout Wales.

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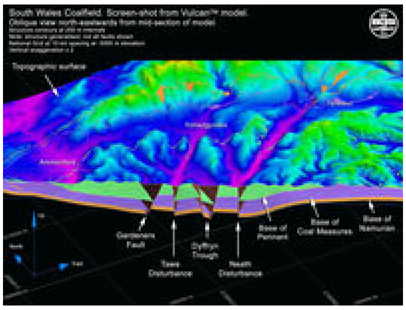
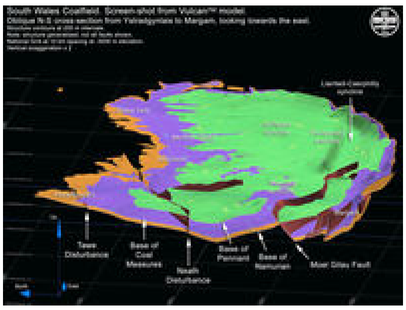
In order to determine the overall groundwater flow patterns within the coalfield and given its complex structure, **Robins et al. (2008**) created a 3D visualisation model (see blue box below: 3D visualisation techniques). The model was constructed from the BGS digital 1: 250 000-scale geological geoline dataset which was draped over the digital terrain model for the area (**Figure P859290**). The model incorporated cross-sections from the 1: 50 000-scale geological map sheets and base of Marros Group, South Wales Coal Measures Group and the Warwickshire Group data derived partly from interpreted geophysical data and partly from available borehole data.

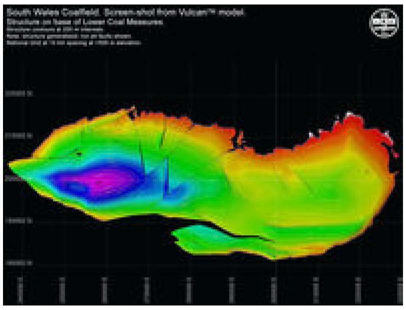
The basic geological model reinforces understanding of two key aspects of the coalfield, firstly the significance of major structural divides across the region, and secondly the different nature of the coalfield east and west of the Neath Disturbance (**Figures P859291 and P859292**). The shallow coalfield of the eastern area contrasts with the much deeper coalfield in the west, itself illustrating why the partly metamorphosed low-sulphur anthracite coals are only available in the deeper part of the coalfield. It is also apparent that the deep western coalfield pinches out towards the west, and that it does not connect with the South Wales Coal Measures Group in Pembrokeshire beneath Carmarthen Bay.



Oblique west–east screen shot from VULCAN model along national grid northing 200000 looking towards the north-west. P859290.

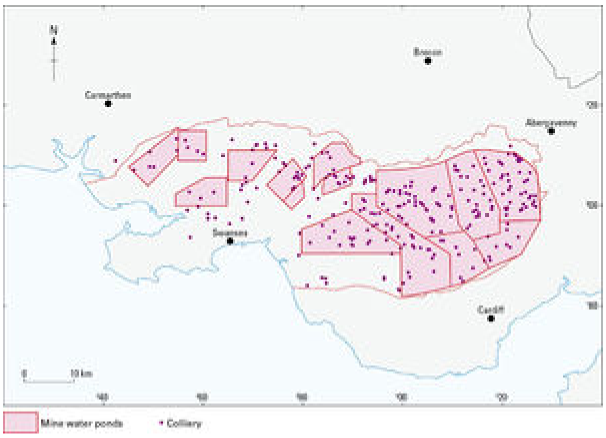


Screen shot showing an oblique north-south section through Margam looking west and illustrating the low angle Moel Gilau fault. P859291.



Screen shot showing the structure on the base of the South Wales Lower Coal Measures Formation with contours at 200 m intervals: dark purple -2500 m OD; green -1000 m OD; orange 0m OD. P859292.

The available piezometry, derived largely from pumping water levels in working shafts for the pre-1990 era when intensive mining still took place, and from limited borehole monitoring data for the more recent period illustrates two significant points. The first is that the piezometric surface, both during mining and subsequent to abandonment of the coalfield, is relatively flat compared with the topography and is largely controlled by the elevation of valley bottoms. The second is that the regional influence from mine dewatering on the water table in the South Wales Coal Measures Group and the Warwickshire Group was negligible, i.e. mine dewatering affected the immediate area around a mine or group of interconnected mines, and there was a steep hydraulic gradient away from the mined area over a limited area of influence. This is known to be case elsewhere (*Whitworth, 2002*) as the transmissive properties of the undisturbed coal measures are small, the horizontal permeability derived from sandstone and grit bands being considerably higher than the vertical permeability. Undermining generally increases the vertical permeability of the strata as a result of collapse and fracturing of otherwise weakly permeable fine-grained but brittle horizons (*Booth, 2002*).



The discrete drainage ponds within the former operational South Wales Coalfield (after Lewis et al., 2000). P859274.

The hydraulic interconnection of mine workings has been investigated, and a set of discrete 'ponds' defined from historical pumping and water level data in former mine workings (**Lewis et al., 2000**). Each pond represents a cluster of voids which have a common water level and overflow at a single lip. Much of the shallow eastern coalfield falls into one of eight hydraulic systems whereby abstraction in one mine ultimately affects levels in adjacent mines in the same pond (**Figure P859274**). In the deeper coalfield to the west of the Neath Disturbance the pond effect is lessened due largely to the smaller number of mines and their more dispersed distribution. The work demonstrates that the hydraulic interconnection is generally of limited scale with the normal area of each pond, typically only about 10 x 10 km. This contrasts with the much larger scale interconnections found, for example, in the South Nottinghamshire Coalfield where interconnections typically exceeded a distance of at least 20 km (*Dumpleton et al., 2001*).

Overlaying the ponds onto the 3D geological and topographical visualisation model showed that the controlling hydraulic boundaries within the eastern part of the coalfield are all topographical divides. Structure seems to play no part in separating the various ponds other than prescribing the courses of the rivers. From west to east the ponds fall within the catchments of the Afon, Rhondda, Taff, Rhymny and Lwyd with the three eastern catchments divided into subcatchment ponds on either side of the axis of the Pontypridd Anticline.

The ponds suggest that much of the groundwater transport in the coalfield is limited to the catchment and subcatchment scale. Mass exchange of groundwater, by definition, has never been observed between one pond and another, although transport of water from one colliery to another within the same pond can occur freely. This partly reflects the interlinking between different pits by roadways and adits which may be used to transport water from one area to another, but it also reflects the prevailing groundwater flow system within a given pond or catchment.

Although the historical dewatering information for the coalfield indicates short catchment-scale flow paths within much of the eastern part of the coalfield, there is only limited evidence that this is the case in the deeper western coalfield. This is due to the smaller number of mines and their uneven distribution. Nevertheless it is likely that the same is the case in this area and that the dominant shallow groundwater system is limited to the catchment scale throughout the whole coalfield.

Taff's Well - a warm spring rising from faulted Avon Group strata on the bank of the Taff, now housed in an enclosed bath. P802426.

A small proportion of the groundwater in circulation may adopt a deeper and longer flow path via suitable discontinuities offered by the complex structure of the region. Deeper flow may emerge down-gradient to discharge as base flow to rivers and streams. However, it will be mixed with shallow groundwater and any chemical or isotopic signature it may have gained is obscured by the time it reaches the surface. Such older and deeper circulation is, therefore, difficult to locate, although Taff's Well [ST 120 836] is one such example (**Plate P802426**).

Rae (1978) calculated a water balance for the coalfield based on returns made for 1975 under the Water Resources Act 1963 and a survey of mine drainage carried out by the National Coal Board in 1972. He calculated annual outflow from effective precipitation on the South Wales Coal Measures Group to be 988 mm or 2100 $Mm^3\ a^{-1}$ but did not attempt to separate base flow and run-off. He did, however, provide values for intercepted groundwater flow as:

abstraction from wells, boreholes and springs	= 16 $Mm^3\ a^{-1}$
drainage from abandoned mines	= 62 $Mm^3\ a^{-1}$
drainage from disused mines	= 25 $Mm^3\ a^{-1}$

Base-flow indices derived from low-flow calculations (Centre for Hydrology and Ecology/British Geological Survey, 2003) allow an approximate separation of run-off. Base-flow indices for the major rivers traversing the coalfield (e.g. the Rhymney at Llanedeyrn [ST 224 821], the Ogmore at Bridgend [SS 896 790] and the Ebbw at Rhiwderyn [ST 263 881]) are all 0.48 suggesting that some 48 per cent of total outflow leaves the system as base flow, i.e. some 1008 $Mm^3\ a^{-1}$. This also represents the likely volume of recharge, given that there is no long-term change in groundwater storage. The recharge volume is equivalent to a depth over the area of just less than 500 mm a^{-1}. This estimate compares well with the long-term rainfall data and monthly MORECS data for the area which indicate that the long-term average annual rainfall ranges from 1200 to 2000 mm across the coalfield, of which some 400 to 600 mm is lost to evaporation. The effective rainfall thus ranges from 600 mm to 1600 mm, of which 48 per cent, or between 290 and 770 mm, again represents recharge depending on the exact location within the coalfield. This method suggests a likely overall value of about 530 mm essentially similar to the value derived from Rae's historical data.

The overall water balance for the area of the coalfield can be approximated to:

Rainfall	= Evaporation + run-off + recharge ± change in storage
1500 mm	= 500 mm + 520 mm + 480 mm ± change in storage

The water balance is currently at equilibrium with input balancing output. This reflects the present-day status of mine water rebound still taking place in the coalfield with little additional demand on recharge needed for additional storage.

Hydraulic connection with the underlying Avon Group is feasible in a number of localities most notably where the South Wales Coal Measures Group thins towards the northern and eastern boundaries of the coalfield. Reports of water breaking through the floor of some passageways in these parts of the coalfield suggest an inrush of confined groundwater contained in the Avon Group below. Away from the margins of the coalfield the risk of water inrush is less but may still occur where faulting or other discontinuities allow hydraulic contact between the workings and basal sandstones in the South Wales Lower Coal Measures Formation. Flow rates of inrushes generally diminished quite rapidly reflecting limited storage. Roof and wall inrushes have also occurred in the coalfield margins due to connectivity with surface waters in some of the shallower mines. However, rising groundwater from the Avon Group through the Marros Group is unlikely to affect significantly the water balance of the South Wales Coal Measures Group in its present postmining, near-equilibrium state.

3D visualisation techniques

Given the complex structural setting of the overall coalfield, 3D visualisation techniques provide a useful platform with which to investigate the available geological and piezometric data. The key benefits of the visualisation process were summarised by **Robins et al. (2008)**. The process:

- provides a formalised means of assembling diverse and complex datasets into a comprehensive and tangible model
- can be added to and improved upon, as new data become available
- provides a data platform on which subsequent analytical models can be developed
- allows analysis of the geometric logic of planes between lithostratigraphical units
- allows visual inspection of the data in 3D format and assists in graphical presentation of data for reporting and demonstration and for informing nongeologists
- can accentuate and help identify structural features for analysis by exaggerating the vertical scale
- allows the investigation of the relationship between lithostratigraphy and piezometric surfaces.

A variety of software is available to the user including VULCAN, EARTHVISION and GoCAD. VULCAN was selected as the most appropriate for the south Wales analysis as it incorporates various mining specific tools that may be required in some future study.

VULCAN is a complex suite of software modules that allow the creation, assimilation, manipulation and visualisation of varied datasets within a common 3D environment. The VULCAN 3D visualisation software not only provides a platform for data assembly, but also a means of inspecting spatial configuration.

The software was developed by Maptek/KRJA Systems Limited for the Australian mining industry, in order to portray mineral deposits in 3D, to assist in the creation of the optimum underground design, but the software is now also used to solve groundwater problems. The VULCAN Modeller is the core of the toolkit. It includes a Graphical User Interface and 3D graphics environment, CAD and visualisation options. Triangulation and grid mesh modelling and contouring tools allow the creation and modelling of most terrain. Geological and block modelling tools augment the Modeller package for geologists. Lithological, analytical, structural and hydrogeological data are all stored and co-ordinated, available to be displayed, manipulated and analysed.

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