# Hydrogeology of Wales: Permo-Triassic and Jurassic aquifers - Vale of Clwyd

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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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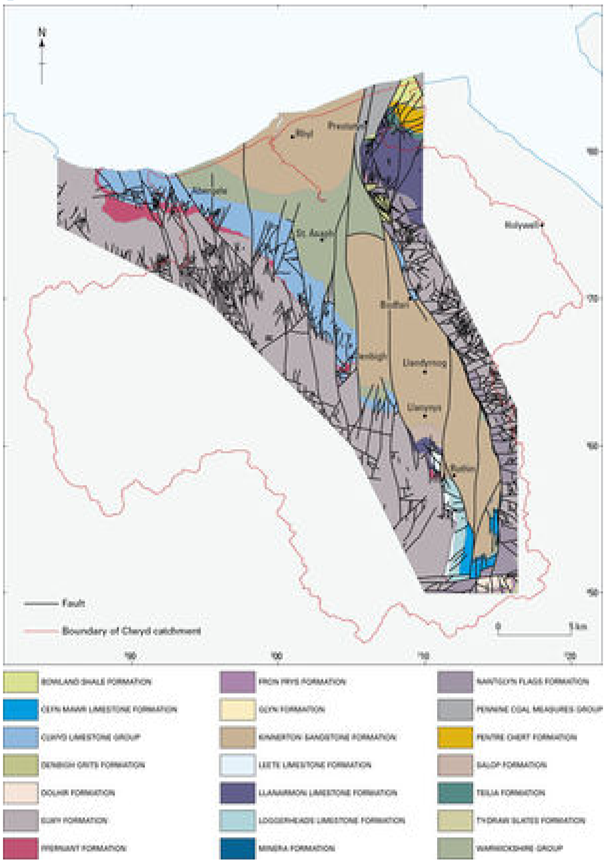



Vale of Clwyd—geological setting. P859277.

The Triassic sandstone aquifer is situated in the central part of the Clwyd catchment in north Wales. The catchment comprises some 800 km$^2$, and lies between the Conwy to the south and the Dee to the north and east. The Triassic aquifer occupies the central lowland area of the catchment with surface elevations rising to 115 m aOD inland towards its southern extremity. The sandstone is divided into two parts by a shoulder of Carboniferous strata: the northern block widens to 13 km at the coast and the southern block, which is twice as big in area, is 5 km wide and 22 km long, oriented north-north-west to south-south-east beneath the Afon Clwyd (**Figure P859277**).

The main aquifer unit is the Kinnerton Sandstone Formation of the Triassic Sherwood Sandstone Group. The principal lithology is a sequence of variously cemented fine- to medium-grained aeolian sandstones which are generally well laminated and in places cross-bedded. The northern block is fault bound to the east by the Denbigh Fault while the unconformity with Carboniferous strata forms the southern and western boundaries. The Vale of Clwyd Fault, with a downthrow to the west of 1500 m, forms the eastern boundary against the Carboniferous. The western boundary is mostly defined by an *en chelon* series of north–south trending faults, each with throws up to 300 m, the Triassic strata lying directly but unconformably on the Carboniferous (**Warren et al., 1984**). The aquifer continues offshore to the north. **Wilson et al. (2002)** suggest that the Kinnerton Sandstone Formation may be as thick as 350 m onshore although the greatest thickness proven is 152 m in a borehole at Foryd [SH 9945 3799]. **Wilson et al. (2002)** postulate that fault gouge along parts of the boundary faults may inhibit cross-flow. The sandstone crops out only in a small area towards Ruthin, being for the most part confined by the glacial cover material.

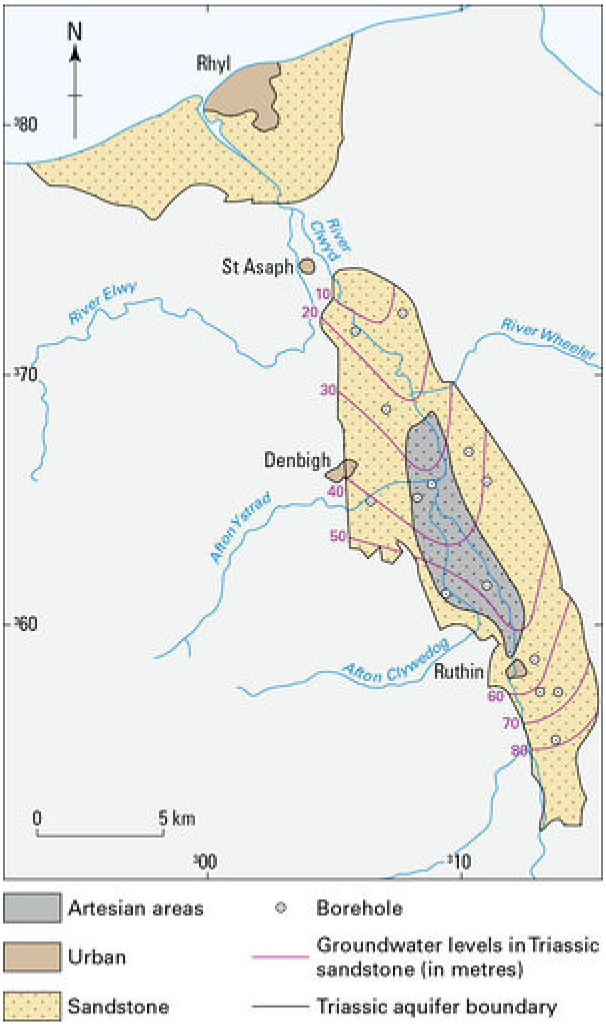
The Silurian stata to the east essentially comprise folded and cleaved mudstones with subordinate medium-grained sandstone.

The Carboniferous strata include the Warwickshire Group which for the most part underlies the Triassic sandstone aquifer. It comprises mudstone, siltstone, micaceous sandstone, seatearth and thin seams of coal. The older Carboniferous Limestone crops out to the east of the Coal Measures facies strata. The limestone includes cyclical sequences of thin- to thick-bedded limestone, the upper part also with thick sandstone at the top of each cycle of deposition. The lower part of the succession includes mudstone, siltstone and sandstone.

The lower part of the catchment is largely covered in glacial deposits, principally till, which may be up to 90 m thick. The superficial strata on top of the northern block lie in a broad steep-sided trough whereas the southern block is covered by infill of a broad palaeochannel of the Clwyd which was deepened by ice scour. The northern part of the aquifer lies beneath the Irish Sea Till while south of Denbigh the Welsh Till came down to meet it. Both ice sheets deposited fine-grained rock flour comprising silty and sandy clay although the sandy faces predominate in an area between Ruthin and Denbigh and outwash fan deposits are also present in the south, much of this, however, has been reworked into fluvial terraces. The river lies on a strip of alluvium and the lower part of the northern block also has postglacial marine clay above the till.

The Kinnerton Sandstone Formation comprises well-laminated and dune-bedded aeolian red, brown and yellow weakly cemented, fine- to medium-grained sandstones with subordinate coarser beds and silty horizons, although there are no coarse basal beds (**Warren et al., 1984**). Individual grains vary from well rounded to subangular and consist predominantly of quartz with subordinate feldspar and lithic grains. The sandstone is generally friable and borehole abstraction water is commonly turbid and red at the start of pumping.

The main aquifer is in the Ruthin and Denbigh area (**Figure P859278**) in which the central part of the aquifer was originally confined by till with an artesian head of about 6 m (**Lambert et al., 1973**). The sandstone aquifer is partly confined by overlying superficial deposits, causing artesian conditions in the centre of the southern basin. Confinement is not total, since leakage occurs elsewhere through the superficial deposits, which may be in hydraulic contact with some reaches of the river. Transmissivity was estimated at between 800 and 2000 $m^2 d^{-1}$ and storativity between $10^{-3}$ and $10^{-4}$. Coal Measures strata crop out to separate the upper part of the aquifer from the coastal area of Triassic sandstone centred on the town of Rhyl. Natural discharge from the upper aquifer to the surface-water system was estimated at 20 Ml $d^{-1}$ (**Lambert, 1981**).




The Vale of Clwyd Triassic aquifer (after ESI, 2003). P859278.

Boreholes at Llanerch Park [SJ 057 720], near St Asaph, confirm the upward flux of groundwater in the confined central portion of the aquifer. Test pumping undertaken in 1976 showed that the upward flux could be maintained by pumping at 7 Ml $d^{-1}$ and the water used for both public supply and for river augmentation in order to maintain a prescribed minimum flow for the benefit of fisheries in the River Clwyd (see also Section 8.2). Direct rainfall recharge to the sandstone aquifer was suggested by **Lambert et al. (1973**) with a likely focus via the gravel deposits and possibly also from cross-flow derived from the adjacent Carboniferous Limestone strata. **ESI (2003)**, however, report that cross-flow from the Carboniferous strata is likely to be limited to the western boundary of the aquifer as flow in the sandstone is unlikely beneath depths of about 200 m precluding upwelling from beneath much of the aquifer. In isolated locations where the Carboniferous Limestone is faulted against the sandstone some cross-flow may occur but the extent of the contacts is small and the potential cross-flow, if any, likely also to be small. Indeed borehole yields from the limestone are generally only modest.

*The Vale of Clwyd is an important Welsh aquifer.* The Llannerch Park public supply boreholes have a collective abstraction licence of 3400 Ml $a^{-1}$. At Afon Clwyd to the south-west of Llannerch Park are five river augmentations boreholes with a collective licence of 2290 Ml/$a^{-1}$, and these are used seasonally as required.

Laboratory determined hydraulic conductivity on drill core samples ranges from $3x10^{-4}$ to 3.0 m $d^{-1}$ and a mean of 0.21 m $d^{-1}$ (**Allen et al., 1997**). The more permeable sands are the clean, well-sorted medium-grained sands, and the poorly sorted but laminated sands in which the coarse laminae have clean rounded grains. Well-cemented and compacted fine-grained sands are the least permeable (**Lovelock, 1977**).

**Lambert et al. (1973**) demonstrated that there is an inverse correlation between the degree of cementation and permeability but that there is little significant relationship between grain-size distribution and laboratory-determined physical properties. It was also noted that the median horizontal hydraulic conductivity, 0.29 m $d^{-1}$, was double the vertical median value, increasing to four to eight times vertical values in some borehole cores (**Lambert et al., 1973**). Fracture flow was demonstrated with downhole geophysical logging.

Pumping tests were conducted at eight sites as a component of the Groundwater Resources Study by the Dee and Clwyd River Authority and the Water Resources Board (**Lambert et al., 1973**). The mean tranmissivity is 130 $m^2$ $d^{-1}$, but values range from 20 to 1200 $m^2$ $d^{-1}$ depending on the degree of fracturing penetrated in each borehole. These values equate to bulk hydraulic conductivities of 0.17 m $d^{-1}$ to 20 m $d^{-1}$ with a mean value of 2.4 m $d^{-1}$. The minimum values are consistent with mean intergranular hydraulic conductivity values obtained from core samples but the higher values suggest that the borehole discharge is almost entirely derived from fracture flow drawing on intergranular storage in the sandstone matrix.

Core porosity data for the eight boreholes tend to a normal distribution within the range 19 to 31 per cent, with a mean of 23.6 per cent. This is higher than many other Triassic sandstones and reflects the generally low degree of cementation within the aquifer. Specific yield, determined from core samples by centrifuge techniques, is estimated as 4 to 17 per cent intermediate between confined storage values and the porosity values (**Lambert et al., 1973**).

Storage coefficients calculated from six pumping tests range from $1x10^{-4}$ to $2x10^{-3}$ with a mean of $3.8x10^{-4}$. The higher values reflect seepage from the weakly to moderately permeable superficial strata that overlie the sandstones.

The original water balance for the aquifer (**Lambert et al., 1973**) suggested a deficit was likely if abstraction exceeded leakage from the River Clwyd that could take place at the lower margins of the aquifer (see **Water balance table** ). Subsequently **ESI (2003)** suggested that the Clwyd and its main tributary the Afon Hesbin are hydraulically disconnected with bedrock except where they cross the Carboniferous Limestone at outcrop in the upper part of the catchment where some river loss may be occurring. The till cover controls the occurrence of direct rainfall recharge to the sandstone aquifer while the terrace sands and gravels in the south contain a significant shallow groundwater resource. Observations on the Llanerch Park well field showed that under static conditions the head on the sandstone is greater than that in the weakly permeable glacial sands and clays above. However, under pumping conditions the head declines in the sandstone aquifer so that water can be drawn down from the superficial deposits, principally from a basal gravel layer. It is possible that after extensive pumping the connection can be made via the gravel to the river. At Glan y Wern [SJ 090 695] there is a gravel layer in a borehole at 75 m depth which overflows, probably driven by the head in the underlying sandstone.

Water balance for the Vale of Clwyd sandstone aquifer (Ml $d^{-1}$) based on data from **Lambert et al. (1973)**.

| Inflow | | Outflow | |
|---|---|---|---|
| Infiltration to the Triassic sandstone aquifer | 15.2 | Base flow to the River Clwyd and tributaries at Pont-y-Cambyll gauge | 20.0 |

| | | | |
|---|---|---|---|
| Probable cross boundary flow to the sandstone aquifer from the Carboniferous Limestone aquifer | 4.2 | Base flow between Pont-y-Cambyll and Pont Dafydd | 5.0 |
| Leakage from storage in overlying superficial strata | ~7.0 | Groundwater abstraction minus effluent returns to surface waters | 1.5 |
| Leakage from River Clwyd | ?? | Abstraction | ?? |
| Total | ~26.4 | | 26.5 |

Borehole hydrographs in the sandstone show annual variation up to 1.5 m, with a long-term but slow downward trend in the vicinity of the Llanerch Park boreholes. Pumping in these boreholes also induces a reduction in water level in the overlying glacial deposits in the vicinity (**ESI, 2003**). The greatest seasonal range in water level occurs on the eastern edge of the aquifer, 5 m at Pentre Mawr, which is likely to be a reflection of recharge through the local granular superficial material. Groundwater chemistry data also suggest that the groundwater on the eastern side of the aquifer is youngest with nitrate concentrations greater than 40 mg $l^{-1}$ whereas concentrations of only about 4 mg $l^{-1}$ persist elsewhere. Intermediate concentrations occur south of Ruthin. Available piezometry in the southern block shows an overall hydraulic gradient falling away to the north, varying from 0.01 to the south of Ruthin to 0.003 north of Ruthin.

Transmissivity appears to increase from 20 $m^2$ $d^{-1}$ in the south increasing to 100 $m^2$ $d^{-1}$ near Ruthin, and increasing again to the north where values of between 660 $m^2$ $d^{-1}$ and 2200 $m^2$ $d^{-1}$ have been demonstrated at and around Llanerch Park (**ESI, 2003**). Laboratory analyses of core material consistently yield permeability values less than field values reflecting the important role of fracture flow in the system. Transmissivity values in the older strata surrounding the sandstone are small, consistently less than 10 $m^2$ $d^{-1}$, supporting the hypothesis that there is little likelihood of any significant cross-flow from these strata to the sandstone aquifer.

**ESI (2003)** describe a conceptual model and water balance for the southern block aquifer. However, it was not feasible to isolate the sandstone baseflow component to surface waters to establish a recharge volume. The recharge estimate was based on the likely processes and recharge mechanisms prevalent within different typological zones within the catchment, for example, the principal recharge zone is taken as the eastern periphery of the aquifer. Elsewhere the aquifer is divided between unconfined and confined zones in which recharge can and cannot normally occur. **ESI (2003)** indicate that the long term depth of water passing beneath the soil zone above the superficial strata is equivalent to 340 mm $a^{-1}$ or 84 Ml $d^{-1}$. However, only a small component of this will access the sandstone aquifer. **ESI (2003)** suggest that longitudinal flow in the essentially confined aquifer could be as little as 2.1 Ml $d^{-1}$ at Ruthin and between 2 and 7 Ml $d^{-1}$ further to the centre of the aquifer. In perspective this is tiny compared to the river flow which ranges between 133 and 584 Ml $d^{-1}$.

The water balance assumes an upwelling of groundwater from the confined sandstone which discharges as base flow. This flow may amount to only 10 per cent of the overall base flow component in the river which includes spring discharges from the older strata within the entire catchment area and base flow from the superficial strata. **ESI (2003)** further conjecture that the likely recharge rate to the southern sandstone aquifer block is about 22 Ml $d^{-1}$ with some three times that value recharging the superficial deposits and discharging directly as base flow. They further determine that the current long-term average abstraction for the sandstone aquifer is about 10 Ml $d^{-1}$, suggesting that the aquifer is currently underutilised. The recharge estimate (22 Ml $d^{-1}$) compares favourably with the 26.4 Ml $d^{-1}$ postulated by **Lambert et al. (1973)**.

Three different groundwater types have been identified in the southern block of the aquifer

(**Fahrner et al., undated**): Ca/Mg-$HCO_3$ type occurs in the north, Ca-$HCO_3$/Cl type in the central western part of the aquifer with the more common Ca-$HCO_3$ type, generally associated with a dynamic actively recharged system, in the central eastern part of the southern block. Major ion concentrations, with the exception of higher concentrations of $NO_3$ in the east, remain reasonably consistent across the aquifer. $HCO_3$ concentrations range from 160 mg $l^{-1}$ to 350 mg $l^{-1}$, and the specific electrical conductivity varies from 336 to 978 µS $cm^{-1}$.

# Hydrogeology of Wales - contents

- Hydrogeology of Wales

# Navigation menu

## Personal tools

- Not logged in
- Talk
- Contributions
- Log in
- Request account

## Namespaces

- Page
- Discussion

☐

## Variants

## Views

- Read
- View source
- View history
- PDF Export

☐

## More

## Search

Search Go

## Navigation

- Main page
- Recent changes
- Random page
- Help about MediaWiki

## Tools

- What links here
- Related changes

- Special pages
- Permanent link
- Page information
- Cite this page
- Browse properties

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- Privacy policy
- About Earthwise
- Disclaimers
- 
- 