Shinrone GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water bodies	Associated terrestrial ecosystem(s)	Area (km^2)
25 - Little Brosna catchment North Tipperary and Offaly Co. Co.'s	Rivers: Little Brosna, Camcor, Rock, Breaghmore, Bunow. Streams: Clareen, Golden Grove. Loughs: Roe, Valley Pond.	Sharavogue Bog (000585), Roscrea Bog (000583), Sharavogue Bog (000585), Drumakeenan, Eagle Hill and Perry's Mill (000900).	350

Topography		The groundwater body is roughly rectangular, with the longer axis oriented NNE-SSW. Elevation within the GWB ranges from about 40 mAOD along most of the NW flowing part of the Little Brosna to 455 mAOD at Benduff in the very south of the GWB. Overall, elevation decreases westwards and northwards northwestern and northern edges of GWB. The topography ranges from mountainous and hilly in areas underlain by the resistant sandstones and mudstones of the Devonian Old Red Sandstones and Silurian rocks (in the south and west of the GWB) to flat-lying in areas underlain by impure and pure limestones. Rivers flows are generally northwest-, west- and northwards.
Geology and Aquifers	Aquifer categories	The majority of the GWB comprises **Ll:** Locally important aquifers which are moderately productive only in local zones. A small area of Silurian rocks in the very south of the GWB, and thin strips in the south, west and east of Dinantian (early) sandstones, limestones and shales are **Pl:** Poor aquifers which are generally unproductive except for local zones. The thin bands of pure bedded limestones have the classification **Lm:** Locally important aquifers which are generally moderately productive. An area of pure bedded limestone in the very north of the GWB is classified as an **Rk^d**: Regionally important karstified aquifer dominated by diffuse flow.
	Main aquifer lithologies	Dinantian Lower Impure Limestones, Dinantian Pure Unbedded Limestones and Dinantian Upper Impure Limestones are the major rock unit groups within the GWB, and occupy the lowlands. There are small strips of Dinantian Pure Bedded Limestones in the west and north. Devonian Old Red Sandstones and Silurian Metasediments and Volcanics occupy the uplands in the south of the GWB and form the small inlier in the west of the GWB. The Dinantian (early) Sandstones, Shales and Limestones form thin strips around the Devonian ORS rocks, and occur in the east of the GWB at the junction with the Bredagh GWB.
	Key structures	The major structures affecting the distribution of rock types and hence aquifer types are large folds and major faults. The older and more resistant rocks that form the uplands in the south of the GWB occur within the core of an anticline, as are the rocks in the west of the GWB, around Knockshigowna. The younger impure and pure limestones are found preserved in the southern limb of the major syncline that trends NE-SW. There are several major faults crossing the GWB. The most notable is the NNE-SSW Knockshigowna fault, which has upthrown the older rocks that form the hill in the west of the GWB. This major fault runs along a >60 km sinuous, offset trace from Slieve Bernagh in Co. Clare to east of Tullamore in Co. Offaly. Another major fault juxtaposes ORS and Lower impure limestones in the south of the GWB. The dominant fault direction in the GWB is NNW-SSW, although there are numerous cross-faults with ENE-WSW orientations, and some orientated WNW-ESE. Compression during the folding also caused some fracturing and jointing of the rocks.
	Key properties	In the Silurian rock unit in the Slieve Felim mountains to the south of this GWB, a site investigation undertaken for a proposed landfill found that permeabilities in the top 30 m of rock ranged from 0.00036 to 0.76 m/d. A zone of higher permeability, 150-200 m wide, 12-14 m deep and 2.2 km long was delineated on the site. The transmissivity estimated for this zone was 27-82 m^2/d (Deakin, Daly and Coxon, 1998). At Templederry, in the adjacent Nenagh GWB, early time pumping test data indicate a transmissivity of around 5 m^2/d. There are no data for the ORS in this area; transmissivities will be low, but better than in the Silurian rocks, especially toward the top of the ORS succession. Within the Dinantian Lower Impure Limestones, transmissivities are likely to be in the range 2-20 m^2/d, with most values at the lower end of the range. Dinantian (early) Sandstones, Shales and Limestones aquifer properties are less good than this: Kelly (in prep.) gives permeability estimates of 0.5 m/d for unfaulted rock, and 5-10 m/d in fault zones. A pumping test in the Dinantian Pure Unbedded Limestones (Waulsortian limestones) at Shinrone indicated a transmissivity of approximately 27 m^2/d. At Tulla in Co. Clare, transmissivity in the same rock unit is estimated as 13 m^2/d. These values are probably at the middle to higher end of the range. Within all rock units, storativities are low. Groundwater gradients in the upland areas may be steep (up to 0.1). In low-lying areas, groundwater gradients on the order of 0.02 to 0.05 may be the norm. *(data sources: Rock Unit Group Aquifer Chapters, GWPS Reports,source reports, see references)*
	Thickness	The Silurian, Devonian ORS, the Lower and Upper Impure Limestone, and the Pure Unbedded aquifers are more than several hundreds of metres thick at their maximum thickness. However, permeability tends to decrease rapidly with depth from the surface. Most groundwater flow occurs in the upper ≤ 15 m, in the zone that comprises a weathered layer and a connected fracture zone below this, although deeper flows may occur along faults or significant fractures, or occasionally bedding-parallel dissolution planes within the Pure Unbedded Limestones. In the Pure Unbedded Limestones east of Lough Derg, epikarst has been observed that has a thickness of up to 1-2 m. There is likely to be epikarst in the region of this GWB also. The maximum thickness of Dinantian Sandstones, Shales and Limestones is less than 100 m. Again, groundwater flow typically is concentrated in the top 15 m in the main. The Pure Bedded Limestones will have an epikarstic layer, below which there is a diffusely-karstified network of fissures and conduits down to around 30 m below rock head.

Overlying Strata	Lithologies	*[Information to be added at a later date]*
	Thickness	The groundwater body has varied topography due to underlying rock units' varying resistance to weathering. In addition, the area was near the ice margin during the ice age. Hence subsoil thicknesses vary widely across the GWB. Thicknesses are generally less in the northern half than the SE. Subsoil thickness in the very SE of the GWB ranges between 10-60+ m. In the rest of the GWB, subsoil thickness typically ranges between 5-15 m. Outcrops and areas of shallow rock are mainly found over the ORS and Silurian rocks. There are areas of outcrop in other areas of the GWB, however, particularly in areas underlain by the Pure Unbedded Limestones that have hilly topography.
	% area aquifer near surface	*[Information to be added at a later date]*
	Vulnerability	Groundwater vulnerability ranges from Extreme to Moderate. The majority of the GWB has High vulnerability. Extreme vulnerability areas mainly occur in the north, NE and NW of the GWB, and are typically relatively small areas. There is also an Extreme vulnerability area along the SE GWB boundary. Moderate vulnerability areas occur in low-lying poorly drained areas and along rivers.
Recharge	Main recharge mechanisms	Diffuse recharge will occur via rainfall percolating through the subsoil. The proportion of the effective rainfall that recharges the aquifer is largely determined by the thickness and permeability of the soil and subsoil, and by the slope. In general, due to the generally low permeability of the aquifers within this GWB, a proportion of the recharge will discharge rapidly to surface watercourses via the upper layers of the aquifer, effectively reducing further the available groundwater resource in the aquifer. However, the permeable gravelly subsoils covering parts of the aquifer will act as a 'store' of groundwater and somewhat mitigate this rapid through-flow. In low water table conditions, the one known turlough will accept point recharge from surface waters.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	Important springs and high yielding wells (m^3/d)	There are no Excellent (> 400 m^3/d) yielding wells known in this GWB. At Shinrone, groundwater can be pumped at a higher rate than this, but it is not sustainable. There are three known Good yielding boreholes (100 m^3/d < yield < 400 m^3/d): Shinrone WS (196 m^3/d, GSI database) Ballingarry WS (200 m^3/d, EPA database) An Offaly Co. Co. borehole at Ballylonan (GSI database) At the Lisduff-Dunkerrin Well (650 m^3/d), most water is abstracted from gravels overlying bedrock, with some contribution from stream flowing nearby and also bedrock groundwaters. This is also the situation at the Intermediate yield (430 m^3/d < yield < 2,160 m^3/d) spring at Moneygall WS. The Roscrea Bacon Factory abstracts 318 m^3/d from the gravel aquifer at Roscrea.
	Main discharge mechanisms	Groundwater discharges to gaining streams and rivers crossing the GWB, and to springs. The locations of faults and juxtaposed rock units may contribute to the locations of spring points in some areas (such as at Moneygall WS). Specific dry weather flows in rivers crossing Lower Impure Limestone aquifers are low (0.27 and 0.52 $l/s/km^2$ in the Bunow and Little Brosna Rivers). A DWF of 1.52 $l/s/km^2$ in the Camcor River, which traverses an Upper Impure Limestone aquifer is probably supported by gravels along the river's course rather than being reflective of the storage capacity of the bedrock aquifer.

	Hydrochemical Signature	Groundwaters from all aquifers within this groundwater body have a calcium-bicarbonate signature. Hardness, alkalinity and electrical conductivities vary between the different rock unit group aquifers, however. There are limited data for this GWB, so data from the nearby Slieve Phelim GWB are also considered. Groundwaters from the Silurian strata range from slightly hard to hard (90–360 mg/l $CaCO_3$). In association, alkalinities range from 60 to 270 mg/l (as $CaCO_3$) and electrical conductivities from 260–600 µS/cm. pHs are neutral, with lab. pHs in the range 7.12–7.33. The majority of samples are at the upper end of the ranges given. At springs, or other systems where throughput is rapid, groundwaters have limited dissolved solids. In Old Red Sandstone aquifers, groundwaters are similar, but all parameters are elevated compared to the Silurian rocks, i.e., groundwaters are moderately hard to hard. In other areas, alkalinity ranges from approximately 14 to 200 mg/l (as $CaCO_3$) and hardness ranges from approximately 50 to 270 mg/l. Groundwater in the Old Red Sandstone rock units is generally considered to range from moderately soft to moderately hard water (Kelly and Wright 2000). Groundwater conductivities are relatively low ranging from approximately 150 to 500 µS/cm. A typical range for pH in groundwater from the Old Red Sandstone rock units is 6–7. In the Dinantian (early) Sandstones, Limestones and Shales and the Lower and Upper Impure Limestone aquifers, groundwaters are Hard to Very Hard (typically ranging between 380–450 mg/l), and high electrical conductivities (650–800 µS/cm) are often observed. Alkalinity is also high, but less than hardness (250-370 mg/l as $CaCO_3$). High iron (Fe) and manganese (Mn) concentrations can occur in groundwater derived from ORS, due to the dissolution of Fe and Mn from the sandstone/shale where reducing conditions occur. Within the Impure Limestones, iron and manganese concentrations frequently fluctuate between zero and more than the EU Drinking Water Directive maximum admissible concentrations (MACs). Hydrogen sulphide can often reach unacceptable levels (E.P. Daly, 1982). These components come from the muddy parts of these rock units and reflect both the characteristics of the rock-forming materials and the relatively slow speed of groundwater movement through the fractures in the rock allowing low dissolved oxygen conditions to develop. It has been demonstrated that at low pumping rates water does not reside long enough in the well for oxidation to occur, thereby resulting in elevated Fe and Mn in small domestic supplies (Applin *et al*, 1989).
Groundwater Flow Paths		These rocks are devoid of intergranular permeability; groundwater flow occurs in fractures and faults. In the main, the rocks are dependent on fracturing and fissuring to enhance their permeability. The pure unbedded limestones may have had their transmissivity enhanced further by dissolution of calcium carbonate along fracture, joint and bedding planes. Zones of high permeability can be encountered near fault zones and in areas of intensive fracturing. In the very northern part of the GWB, groundwater flows through a diffusely karstified pure bedded limestone aquifer. Permeabilities in the upper few metres are often high although they decrease rapidly with depth. In general, groundwater flow is concentrated in the upper 15 m of the aquifer. Evidence of the relatively low permeabilities is provided by the drainage density and flashy runoff response to rainfall in areas underlain by Silurian and Devonian rocks. Areas underlain by Pure Unbedded Limestones are generally well-drained. This is due to the probable presence of an epikarstic layer. Areas underlain by Lower and Upper Impure Limestones are less well drained, reflecting their generally low transmissivities. Examination of data in the GSI well database shows that water levels are shallow; they are less than 15 m below surface and typically less than 6 mbgl. Next to the rivers, water levels will be closer to ground level. Water levels in Dinantian Pure Unbedded Limestones in the flat-lying area around Gurteen Agricultural College vary by up to 2.5 m annually. At Laughran, the groundwater level variation in Lower Impure Limestones is almost 3.5 m despite being less than 200 m from a stream and being situated in an area overlain by gravelly deposits. This indicates a low aquifer storativity. Groundwater flow paths are generally short, on the order of 30-300 m, with groundwater discharging to the streams and rivers that traverse the aquifer. Groundwater flow directions are expected to approximately follow the local surface water catchments. There is no regional flow system in these aquifers. Generally speaking, these rocks are unconfined where subsoils are thin or gravelly. Confined conditions will exist under the raised bogs, and in areas where subsoils are thick and low permeability. There are several gravel aquifers overlying this bedrock GWB: The Roscrea Gravels in the SE, the gravel deposits around Lisduff/Dunkerrin and Moneygall in the SW, the Birr Gravels in the NW, and several small deposits along the eastern boundary of the GWB. Gravel deposits overlying the bedrock aquifers can confuse the impression of drainage densities, can contribute storage to the bedrock aquifers, and can also focus flow and influence the locations of springs in some cases.
Groundwater & Surface water interactions		The streams crossing the aquifer are generally gaining. Due to the shallow groundwater flow in this aquifer the groundwater and surface waters are closely linked. There are several fens and wetlands in the area that are dependent on groundwater. At Sharavogue Bog (NHA000585) is underlain by low permeability limestone and limestone till. However, groundwater upwells at the base of the ridge on the eastern side of the site at a species-rich spring-fen. Roscrea Bog (NHA000583) is not a true bog, but a fen (high calcium status), developed on poorly drained glacial drift over limestone and shales. There is also a narrow strip of wet woodland. Drumakeenan, Eagle Hill and Perry's Mill (000900) includes calcareous esker ridges covered in grassland with spring-flushed slopes, rich wet meadows and an extremely wet calcareous fen with wet flushes. The stream passing the Lisduff-Dunkerrin WS spring is both gaining and losing, depending upon water levels.

Conceptual model	• The groundwater body is bounded on the northwestern edge by the contact between the low transmissivity rock units of this GWB and the karstified Pure Bedded Limestones of the adjacent Birr GWB. Surface water catchment divides define the remainder of the boundary. The terrain ranges between mountainous in areas underlain by Silurian and Devonian rocks to flat-lying or gently undulating in areas underlain by the impure and pure limestones. • The groundwater body is comprised of generally low transmissivity and storativity rocks. The older rock units (i.e., Silurian and Devonian) are likely to have the lowest transmissivities, whereas the Pure Unbedded, and Upper and Lower Impure Limestones (i.e. younger rock units) will have slightly better flow properties. The small area of karstified limestone in the very north of the GWB has high transmissivity. Where gravels, extensive alluvium or very sandy till overlies the bedrock aquifer, this can contribute to the storage. • Flow occurs along fractures, joints and major faults. Within the pure limestones, transmissivity may have been enhanced further by dissolution of calcium carbonate along fracture and bedding planes. This is particularly the case in the pure bedded limestones in the north of the GWB. Flows in the aquifer are typically concentrated in a thin zone at the top of the rock. An epikarstic layer of 1-2 m is likely to exist at the top of the Pure Unbedded Limestones. • Diffuse recharge occurs across the entire GWB, but particularly where rock outcrops or where subsoils are thin. Much of the potential recharge runs off in the upland areas. Where the water table is close to the surface in upland or lowland areas, potential recharge may be rejected. • The aquifers within the GWB are generally unconfined. Areas where confined conditions occur include beneath raised bogs. Groundwater levels are less than 15 mbgl, and are typically less than 6 mbgl. Flow path lengths are short (≤ 30-300 m). Groundwater flows to the surface water bodies, with local flow directions controlled by local topography. There is no regional flow system in the aquifers comprising this GWB. • Groundwater discharges to springs and to the numerous streams and rivers crossing the aquifer. • Due to the shallow groundwater flow in this aquifer the groundwater and surface waters are closely linked. There are several ecosystems in the GWB dependent on groundwater, including mineralised flushes. • There are several gravel aquifers overlying this bedrock GWB: The Roscrea Gravels in the SE, the gravel deposits around Lisduff/Dunkerrin and Moneygall in the SW, the Birr Gravels in the NW, and several small deposits along the eastern boundary of the GWB.
Attachments	Groundwater hydrographs (Figures 1 and 2).
Instrumentation	Stream gauges: 25022*, 25023*, 25040*, 25111, 25112, 25121, 25122, 25127, 25244, 25245, 25253. *(stations marked with * have specific dry weather flows calculated.)* EPA Water Level Monitoring boreholes: Laughran (OFF62), Gurteen Agricultural College (TIN107, TIN151, TIN152). EPA Representative Monitoring Points: Dunkerrin WS (OFF10).
Information Sources	Applin, K. R. and N. Zhao (1989) The Kinetics of Fe(II) Oxidation and Well Screen Encrustation. *Ground Water*, Vol 27, No 2. Daly, D., Cronin, C., Coxon, C. and Burns, S-J (1998) *County Offaly Groundwater Protection Scheme.* Geological Survey of Ireland Report to Offaly Co. Co., 54 pp. Gately, C., Kelly, C. (2001) *Lisduff-Dunkerrin Water Scheme (Lisduff Well), Groundwater Source Protection Zones*. Geological Survey of Ireland Report to Offaly Co. Co., 11pp. Hunter Williams, N., Motherway, K. and Wright, G. (2002) *North County Tipperary Groundwater Protection Scheme (draft)*. Geological Survey of Ireland Report to North Tipperary Co. Co., 58 pp. Hunter Williams, N., Motherway, K. & Wright, G.R. (2002) *Templederry WS, Groundwater Source Protection Zones*. Geological Survey of Ireland, 18 pp. Kelly, C. *Moneygall WS (Busherstown springs) – Groundwater Source Protection Zones*. Geological Survey of Ireland Report to Offaly Co. Co., in preparation. Kelly, C. *Shinrone WS – Groundwater Source Protection Zones*. Geological Survey of Ireland Report to Offaly Co. Co., in preparation. Kelly, D. and Wright, G.R. (2000) *An Assessment of Groundwater Quality in County Cork (Southern Division)*. Geological Survey of Ireland Report to Cork County Council (Northern Division). Aquifer chapters: Dinantian Lower Impure Limestones; Dinantian Upper Impure Limestones; Dinantian Pure Unbedded Limestones; Devonian Old Red Sandstones; Silurian Metasediments and Volcanics; Dinantian Pure Bedded Limestones; Dinantian (early) Sandstones, Limestones and Shales.
Disclaimer	Note that all calculations and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

Figure 1: Groundwater hydrograph

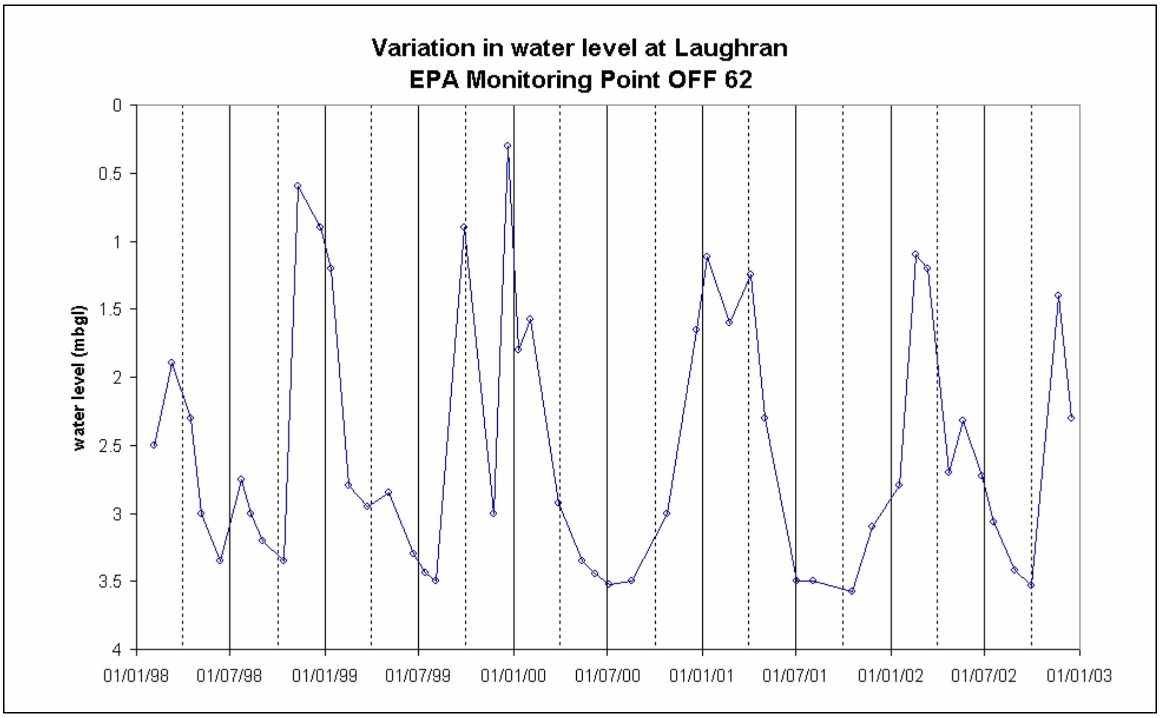
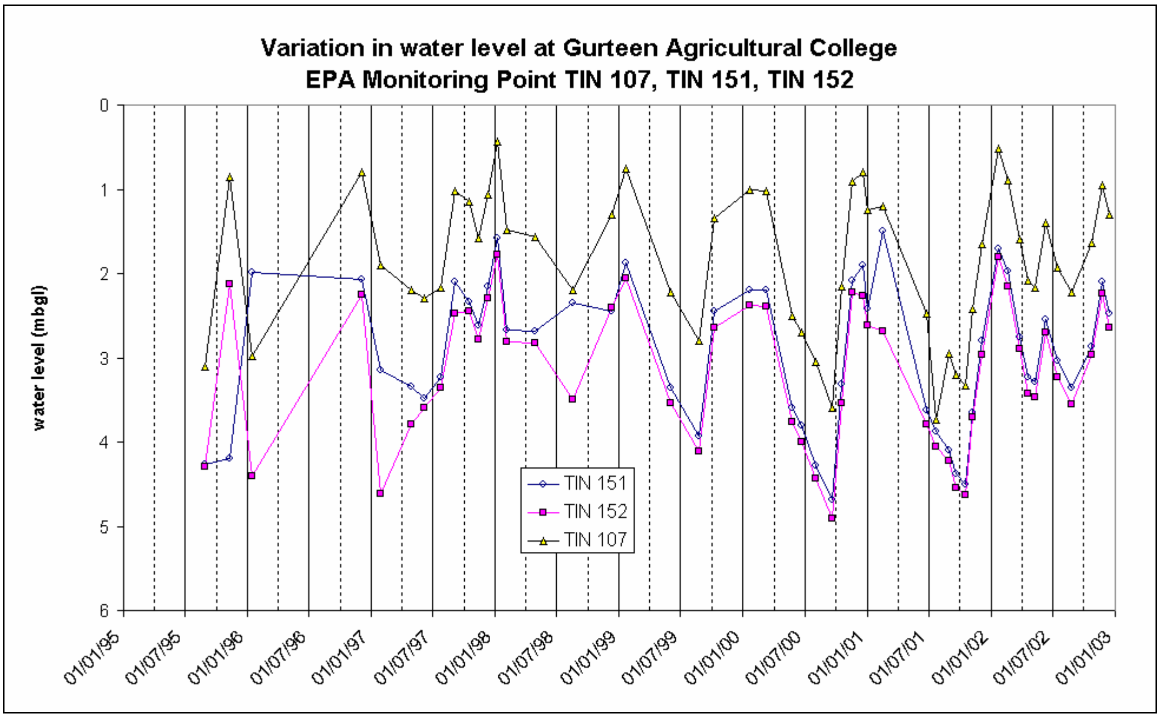
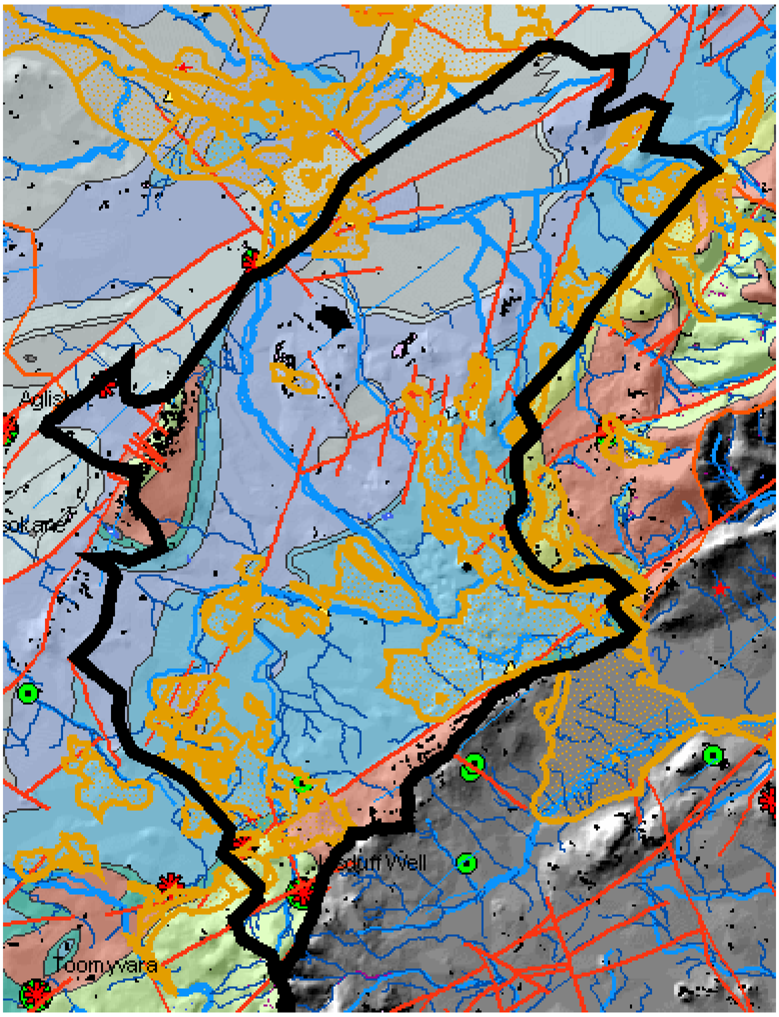


Figure 2: Groundwater hydrograph





Rock units in GWB

Rock unit name and code	Description	Rock unit group
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones
Ballynash Member (BAbn)	Wavy-bedded cherty limestone, thin shale	Dinantian Lower Impure Limestones
Visean limestones, undifferentiated (VIS)	Undifferentiated limestone	Dinantian Pure Bedded Limestones
Waulsortian Limestones (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones
Lucan Formation (LU)	Dark limestone & shale (Calp)	Dinantian Upper Impure Limestones
Lismaline Micrite Formation (LM)	Medium-grey micritic limestone	Dinantian Pure Bedded Limestones
Oldcourt Cherty Limestone Formation (OC)	Grey limestone & dark chert	Dinantian Pure Bedded Limestones
Terryglass Formation (TS)	Grey calcarenitic & oolitic limestone	Dinantian Pure Bedded Limestones
Lower Limestone Shale (LLS)	Sandstone, mudstone & thin limestone	Dinantian (early) Sandstones, Shales and Limestones
Cadamstown Formation (CW)	Pale & red sandstone, grit & claystone	Devonian Old Red Sandstones
Lacka Sandstone Formation (LA)	Conglomerate, sandstone & marl	Devonian Old Red Sandstones
Fairy Hill Conglomerate Formation (FC)	Chert, sandstone & quartz conglomerate	Silurian Metasediments and Volcanics
Hollyford Formation (HF)	Greywacke, siltstone & grit	Silurian Metasediments and Volcanics
Knockshigowna Formation (KG)	Greywacke sandstone, siltstone & slate	Silurian Metasediments and Volcanics