Note: The zone of contribution of the Holmshill water supply boreholes (Tullamore GWB) includes an area in the Geashill GWB – near Pallas Lough. Pallas Lough doesn't have any surface outlet and water is thought to discharge to groundwater. The lake and its catchment is part of the ZOC for Holmshill. 8/01/04

Geashill GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	**Associated surface water bodies**	**Associated terrestrial ecosystem(s)**	**Area (km^2)**
25 - Brosna catchment Offaly, Laois and Westmeath Co. Co.'s	Rivers: Silver, Clodiagh, Ballynacarrig, Tullamore, Black, Gorragh, Toberfin, County. Streams: Durrow Abbey. Loughs: Pallas, Poland's.	Screggan Bog (000921), Pallas Lough (000916), Annaghmore Lough Fen (Offaly) (000413), Clonaslee Eskers and Derry Bog (000859).	280

Topography	The groundwater body is very approximately rectangular, with the long axis orientated NE-SW, in line with the structural grain. The outline is irregular. Land within this GWB is relatively flat-lying; elevations range between 40 and 160 mAOD and most ground is between 70 and 100 mAOD. The lowest ground is along the course of the Tullamore River. The highest points occur along the southern boundary at the junction with the Clonaslee West GWB, along part of the SE margin, and also in the far SW, at Knockhill and Knockbarron. Ground elevation decreases overall to the northwest. The Tullamore, Clodiagh and Silver Rivers flow NW where the exit the GWB, but have different orientations in their headwaters.	
Geology and Aquifers	Aquifer categories	Nearly all aquifers within the GWB are **Ll:** Locally important aquifers which are moderately productive only in local zones. The thin band of Dinantian (early) Sandstones, Limestones and Shales in the south is a **Pl:** Poor aquifer which is generally unproductive except for local zones. There are small strips of diffusely karstified limestone in the centre of the GWB that are too small to be classified as 'Regionally Important'. The very small area in the NE of dolomitised limestone is classified as an **Rk^d**: Regionally important karstified aquifer dominated by diffuse flow.
	Main aquifer lithologies	Dinantian Upper Impure Limestones and Dinantian Lower Impure Limestones are the major rock unit groups within the GWB. There is a lesser proportion of Dinantian Pure Unbedded Limestones. Dinantian (early) Sandstones, Shales and Limestones are present along the south margin, whilst there are small strips of Dinantian Pure Bedded Limestone in the centre. There is a tiny area of Dinantian Dolomitised Limestone in the NE.
	Key structures	The major structures affecting the distribution of rock types are large folds and major faults. The rocks are on the northern limb of a major NE-SW anticline. The Dinantian (early) Sandstones, Shales and Limestones, Lower Impure Limestones and Pure Unbedded Limestones progress northwards in succession from the southern margin. The Upper Impure Limestones are predominant in the northern two-thirds of the GWB. Major NW-SE normal faults cross-cut the rocks. There are also major SW-NE (fold-parallel) faults crossing the GWB.
	Key properties	A pumping test in the Dinantian Pure Unbedded Limestones at Shinrone, to the south of this GWB, indicated a transmissivity of approximately 27 m^2/d. Most of the flow was through a fault zone at more than 50 mbgl. 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 of transmissivities for this rock unit group in this area. A pumping test at Lorrha WS in the nearby Nenagh GWB indicates an aquifer permeability of 5 m/d in the Upper Impure Limestones. The borehole there intercepts a large fissure, so this value is at the high end of what would be expected for this rock unit group, which typically has transmissivities in the range 2-20 m^2/d. The Banagher WS, abstracting from the same rock unit group in the Banagher GWB, has similar characteristics: a single large fault zone supplies the source, resulting in a transmissivity estimate of 45-70 m^2/d, but a thin flowing interval permeability estimate of 20 m/d. 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. The small areas of Dolomitised Limestones will have relatively high transmissivities. Within all rock units except the Dolomitised Limestones, storativities are low (probably about 0.015). Dolomitisation increases porosity and specific yield to up to 0.1. Groundwater gradients in the generally low-lying areas will be on the order of 0.002 to 0.02, but will be steeper (up to 0.04) in the highest areas of the GWB. *(data sources: Rock Unit Group Aquifer Chapters, GWPS Reports, Source reports, see references)*

	Thickness	The Dinantian Pure Unbedded Limestones, and the Dinantian Lower and Upper Impure Limestone aquifers are more than several hundreds of metres thick. However, permeability tends to decrease rapidly with depth. Most 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 (early) Sandstones, Shales and Limestones is less than 100 m. Again, groundwater flow is confined to the top 15 m in the main. The Dolomitised Limestones will have an epikarstic layer, below which there is a diffusely-karstified network of fissures and collapse conduits down to around 30 m below rock head.
Overlying Strata	Lithologies	*[Information to be added at a later date]*
	Thickness	Depth to bedrock varies significantly over this relatively small GWB. In many areas of the GWB, subsoils are more than 10 m thick, rising to 97 m in some areas. The origin of the very thickest subsoils may be two-fold: the deepest depth to bedrock measurements (30-97 mbgl) are recorded along the valley of a tributary to the Tullamore River very near to the mapped Rahan (Tully) Gravels; there could be thick accumulations of glacial or post-glacial sediments in this vicinity. The other areas in which very thick subsoils (>25 m) are recorded are at the faulted junction with the Tullamore karstic limestone GWB along the Clodiagh River Valley and nearby. Areas where subsoil is less than 5 m thick are scattered across the GWB, also occurring along the fault zone on the NW edge of the GWB. These shallow measurements are usually nearby to outcrops, which are very few and isolated.
	% area aquifer near surface	*[Information to be added at a later date]*
	Vulnerability	Groundwater vulnerability ranges from Low to Extreme. The majority of the aquifers within the GWB are Moderately or Highly vulnerable. Vulnerability tends to be Moderate in the areas where there are small streams and drainage ditches, and High along the major rivers and where there are gravels. There are very small areas of Extreme vulnerability scattered across the GWB in between rivers and streams. There is an area of Low vulnerability in the SE, near to the Clonaslee West GWB.
Recharge	Main recharge mechanisms	Diffuse recharge will occur over the GWB via rainfall soaking through the subsoil only where subsoil is shallow or absent, or where subsoils are gravelly and high or moderate permeability. Thick, low permeability subsoils will cause rainfall to runoff, probably to another area within the GWB. In lowland areas where water tables are high, potential recharge may be rejected. A few swallow holes are known in the GWB; point recharge will occur via these features.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	Important springs and high yielding wells (m^3/d)	There is one Excellent (>400 m^3/d) yielding well in this GWB, at Coneygowan GWS (abstraction 1000 m^3/d, EPA database). This abstracts groundwater from the same unit that the Killeigh and Meelaghans GWS springs emerge from ('Intermediate' yield of 1182 – 1245 m^3/d) and the Geashill WS spring, which has an Intermediate (430 m^3/d < yield < 2160 m^3/d) spring (910 m^3/d). The aquifer comprises the Upper Impure Limestones. The remaining known boreholes in the GWB have Poor to Moderate yields (<100 m^3/d), with other springs having Low yields (< 430 m^3/d).
	Main discharge mechanisms	Groundwater discharges to gaining streams and rivers where subsoil thickness permits, and to the springs within the GWB, also where subsoil is sufficiently thin to let groundwater discharge to surface (such as Kelly (2001) proposes at Killeigh and Meelaghans springs). The one specific dry weather flow of 0.0 $l/s/km^2$ may be reflecting the properties of the subsoil rather than the bedrock aquifer, since the subsoil is thick along that stretch of the Clodiagh River.

	Hydrochemical Signature	Data for this GWB are limited. Groundwaters from all aquifers within this groundwater body will have a calcium-bicarbonate signature. By analogy with nearby similar GWBs, bedrock aquifer groundwaters are Very Hard (typically ranging between 380–450 mg/l as $CaCO_3$), with high electrical conductivities (650–800 µS/cm). Alkalinity is also high, but less than total hardness (250-370 mg/l as $CaCO_3$). These values are typical of groundwater from limestone rocks and typical of groundwater across Co. Offaly (Cronin, 1999). pH is generally neutral. At springs, or other systems where throughput is rapid, groundwaters have lower dissolved solids. For example, at Toberfin (Killeigh and Meelaghans GWS), which is situated in the Upper Impure Limestones, spring water is hard to very hard, with alkalinity values of 292-344 mg/l, total hardness values of 288-457 mg/l (as $CaCO_3$) and electrical conductivity (EC) values of 579-820 µS/cm. EC values are and the coefficient of variation of conductivity is 7.7% which indicates that diffuse recharge is the dominant type of recharge (Doak, 1995), but also, that there is an element of point recharge picked up by the springs, and this is likely to be recharge from the swallow hole. There are occasional peaks in iron concentrations, which seem to be coincident with pollution events and may signify temporary oxygen deficient conditions allowing iron to be brought into solution. 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 in the Lower Impure Limestones (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). Groundwaters in the overlying gravel deposits and gravel aquifers have similar compositions to pure limestone bedrock aquifers, but may contain less total dissolved solids if throughput is rapid.
Groundwater Flow Paths		Most of these rock units are devoid of intergranular permeability; groundwater flow occurs primarily in fractures and faults. In the main, the rocks are dependent on fracturing and fissuring to enhance their permeability. Zones of high permeability can be encountered near fault zones and in areas of intensive fracturing. There is limited karstification in the Upper Impure Limestones, as indicated swallow holes and by complex, karst-like connections at the Toberfin springs of the Killeigh and Meelaghans GWS. The Pure Unbedded Limestones may also have had their transmissivity enhanced further by dissolution of calcium carbonate along fracture, joint and bedding planes. There is probably an epikarstic layer of 1-2 m at the top of the pure unbedded limestones. Dolomitisation in the Waulsortian Limestones will have created void spaces such that intergranular flow is possible, and also some conduit flow where cavities have been created by volume reduction during dolomitisation. Within the fissure-permeability rocks, 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. Significant yields can be encountered where fault zones are intercepted by boreholes. Often, these flowing intervals behave in a confined way and, when the water level falls beneath the inflow level, yields decrease and drawdowns increase rapidly. Generally speaking, these rocks are unconfined where subsoils are thin or gravelly. Groundwater may be locally confined where subsoils are thick and low permeability or where it flows beneath the low permeability bases of the raised bogs. The Dinantian (early) Sandstones, Limestones and Shales rock unit of this GWB itself confines the partly-underlying Clonaslee West GWB aquifer immediately to the south. Examination of data in the GSI well database shows that water levels are usually less than 15 m below surface. In the low-lying areas underlain by impure limestones, groundwater levels are between 2 and 10 mbgl. Next to the rivers, water levels will be closer to ground level. Water levels in the Upper Impure Limestones on the NW GWB boundary at Adams Villas typically range between 4-6 mbgl, and vary by up to 3 m annually. At Kilmanmun in the south of the GWB, a well in the Lower Impure Limestones measures a typical annual variation of about 1-1.5 m. In the bedrock aquifers, 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 and to small springs. Local groundwater flows are determined by the local topography. High permeability zones in bedrock or subsoil may determine the locations of spring points. There is no regional flow system in these aquifers. There are several locally important ***potential*** gravel aquifers and gravelly deposits overlying this bedrock GWB: These are: part of the Rahan (Tulla) Gravels, in the NW of the GWB; mapped gravel deposits between Killeagh-Meelaghan and Geashill, in the north of the GWB.
Groundwater & Surface water interactions		The streams and rivers crossing the aquifer are likely to be gaining, and groundwater comes to surface as springs. Due to the shallow groundwater flow in these aquifers, the groundwater and surface waters may be closely linked where subsoils are thinner. There are several fens and wetlands in the area that are dependent on groundwater. For example, Annaghmore Lough Fen (Offaly) (000413) is shrinking – it is not clear whether the lake shrinkage has been purely the result of the natural process of sediment accumulation, or whether this has been accelerated by drainage. However, the area once occupied by the lake, is now a peat accumulating, calcareous fen and is probably sensitive to water level changes. The Derry Bog fens (000859) located at the foot of the gravel ridges (eskers) are fed by springs coming from the base of the esker.

<table>
<tr><td>Conceptual model</td><td>

The groundwater body is roughly rectangular and orientated NE-SW. Surface water catchment divides define the S, SE and NE edges of the GWB, the latter two of which are coincident with the RBD boundary. It is bounded on NW by the contact between the low transmissivity rock units of this GWB and the karstified Pure Bedded Limestones of the adjacent Tullamore GWB. Topgraphy ranges from flat-lying to hilly.
The groundwater body is comprised of generally low transmissivity and storativity rocks. Where gravel deposits or potential gravel aquifers overlie the bedrock aquifer, this can contribute to the storage.
Flow occurs along fractures, joints and major faults. Flows in the aquifer are typically concentrated in a thin approximately 15 m zone at the top of the rock although deeper groundwater flow in hydraulically isolated fault zones can occur. Within the pure limestones, transmissivity may have been enhanced further by dissolution of calcium carbonate along fracture and bedding planes. An epikarstic layer of 1-2 m is likely to exist at the top of the Pure Unbedded Limestones. Limited karstification has also taken place in the Upper Impure Limestones, as evidenced by flow tracing at Killeigh/ Meelahans GWS springs.
Diffuse recharge occurs across the parts of the GWB not covered by thick and low permeability subsoils or raised bogs, but particularly where rock outcrops or where subsoils are thin or are high permeability. Where the water table is close to the surface potential recharge may be rejected.
The aquifers within the GWB are unconfined where subsoils are thin or high permeability. Aquifers are confined or semi-confined beneath thick, lower permeability subsoils, or beneath the raised bogs. The deep, isolated fault zones also can behave in a confined manner. Depending upon the local topography, the water table can vary between a few metres up to 15 m below ground surface. Flow path lengths are short (≤ 30-300 m). Groundwater flows to the surface water bodies and to springs, with local flow directions controlled by local topography. High permeability zones in bedrock or subsoil may determine the locations of spring points. A regional flow system does not exist.
In the south of the GWB, the Dinantian (early) Sandstones, Limestones and Shales rock unit of this GWB confine the partly-underlying Clonaslee GWB aquifer.
There are several ecosystems in the GWB dependent on groundwater, including mineralised flushes. Groundwater and surface water interactions require special attention where terrestrial ecosystems are dependant on a sustainable balance between the two.
There are several gravel aquifers or potential gravel aquifers overlying this bedrock GWB. These are: part of the Rahan (Tulla) Gravels, in the NW of the GWB; mapped gravel deposits between Killeagh-Meelaghan and Geashill, in the north of the GWB..

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<tr><td>Attachments</td><td>Groundwater hydrograph (Figure 1), Hydrochemical signature (Figure 2).</td></tr>
<tr><td>Instrumentation</td><td>Stream gauges: 25007*, 25129, 25203, 25208, 25209, 25223, 25225, 25301. (Stations marked with * have specific dry weather flows calculated.)
EPA Water Level Monitoring boreholes: Kilmanum (LA 068), Adams Villas (OFF 059).
EPA Representative Monitoring points: Geashill GWS (OFF 013).</td></tr>
<tr><td>Information Sources</td><td>
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Cronin, C. and Daly, D. (1997) A Water Quality Assessment of the Mountbolus Public Supply. Geological Survey of Ireland Report to Offaly Co. Co., 8 pp.
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Doak, M., 1995. The Vulnerability to pollution and hydrochemical variation of eleven springs (catchments) in the karst lowlands of the west of Ireland. M Sc. Thesis, Sligo RTC, 52 pp.
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Kelly, C. Shinrone WS – Groundwater Source Protection Zones. Geological Survey of Ireland Report to Offaly Co. Co., in preparation.
Motherway, K., Hunter Williams, N. & Wright, G.R. (2002) Lorrha WS, Groundwater Source Protection Zones. Geological Survey of Ireland, 15 pp.
Aquifer chapters: Dinantian Upper Impure Limestones; Dinantian Pure Unbedded Limestones; Dinantian Lower Impure Limestones; Dinantian (early) Sandstones, Limestones and Shales; Dinantian Pure Bedded Limestones; Dinantian Dolomitised Limestones.
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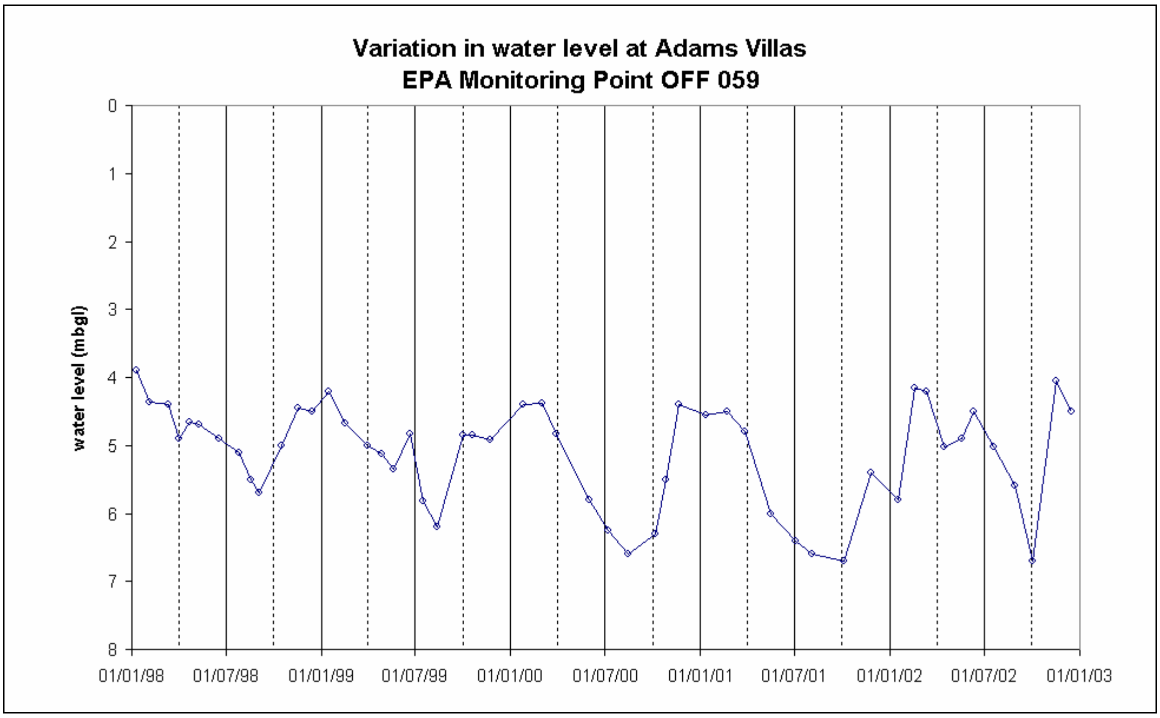
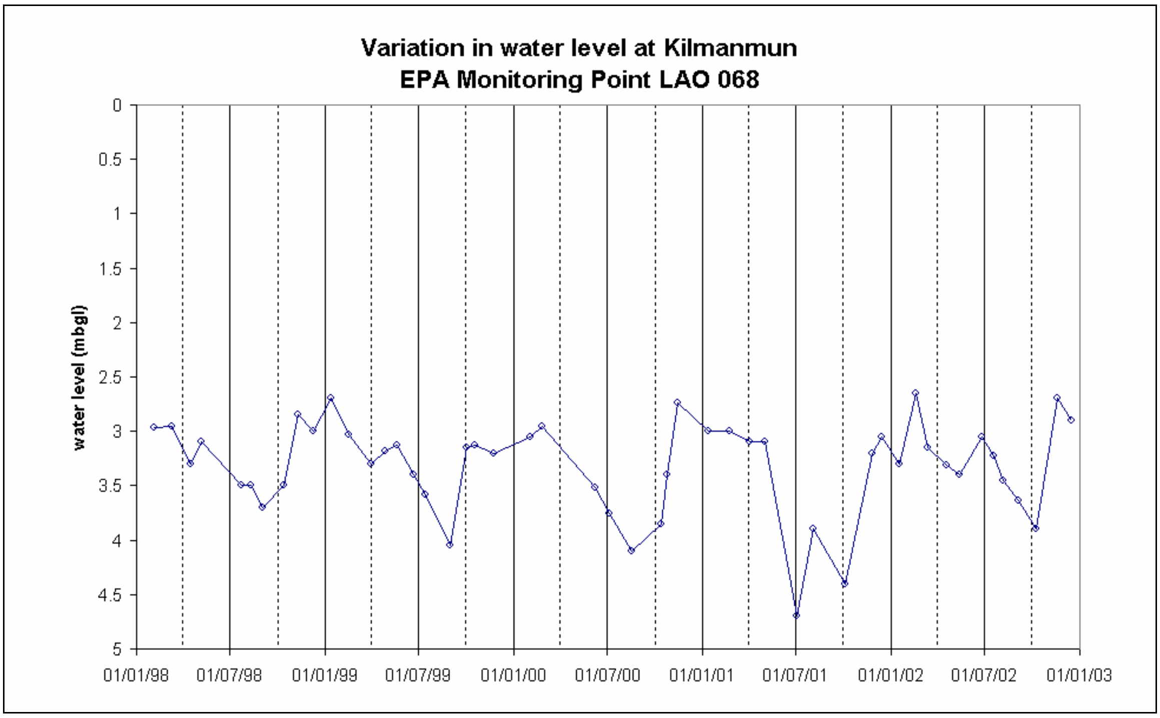
<tr><td>Disclaimer</td><td>Note that all calculations and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae</td></tr>
</table>

Figure 1: Groundwater hydrograph

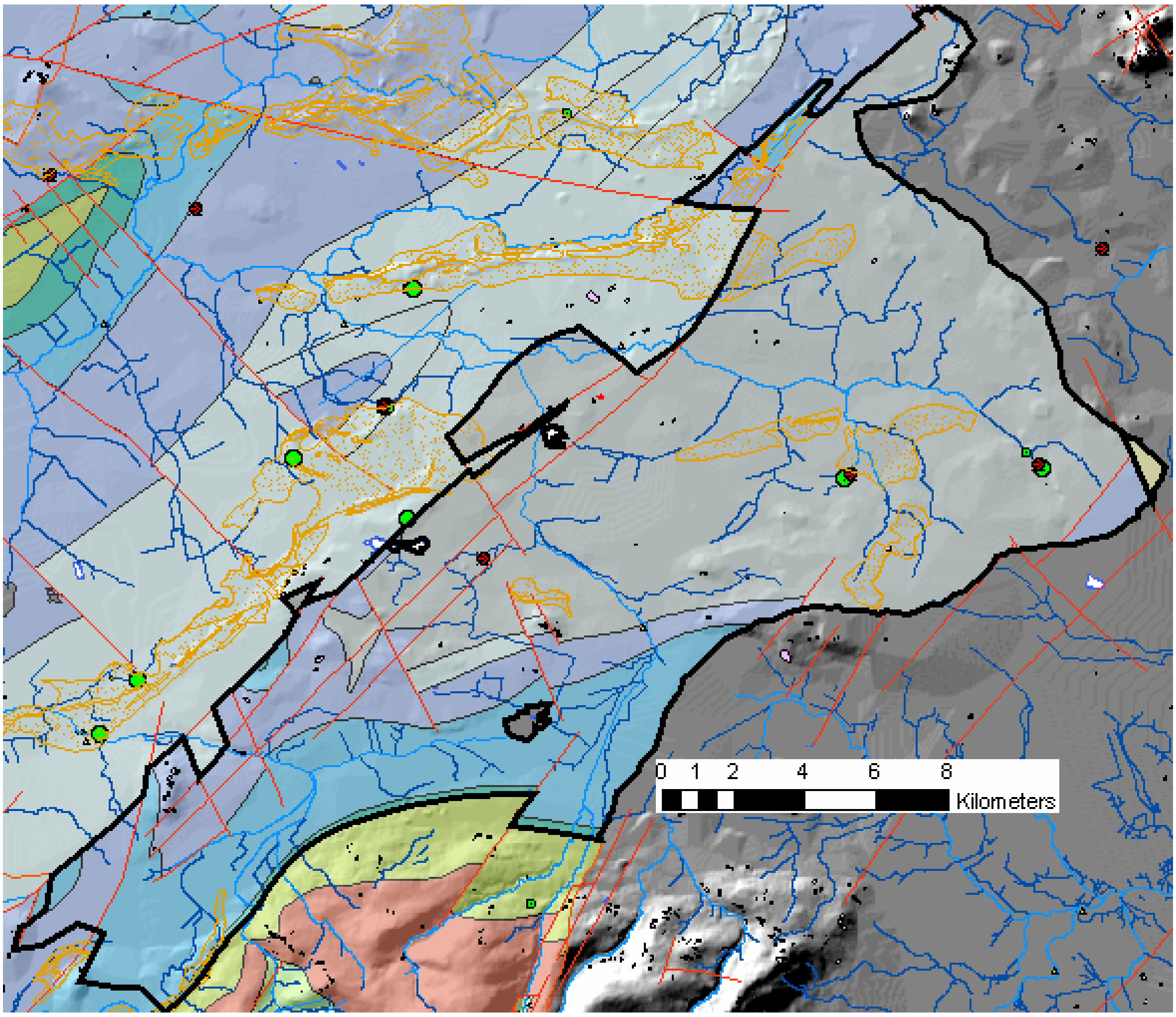


NB: Monitoring point is in Dinantian Upper Impure Limestones next to shallow rock.

Figure 2: Groundwater hydrograph



NB: Monitoring point is in Dinantian Lower Impure Limestones in Low Vulnerability setting, and adjacent to faulted contact with high transmissivity rocks of the Clonaslee GWB.



Rock units in GWB

Rock unit name and code	Description	Rock unit group
Lucan Formation (LU)	Dark limestone & shale (`Calp)	Dinantian Upper Impure Limestones
Ballysteen Formation (BA)	Dark muddy limestone, shale	Dinantian Lower Impure Limestones
Waulsortian Limestones (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones
Lower Limestones Shales (LLS)	Sandstone, mudstone and thin limestone	Dinantian (early) Sandstones, Shales and Limestones
Allenwood Formation (AW)	Thick-bedded limestone, locally peloidal	Dinantian Pure Bedded Limestones
Dolomitised Waulsortian Limestones (WAdo)	Dolomitised massive unbedded lime-mudstone	Dinantian Dolomitised Limestones