Crusheen GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water bodies	Associated terrestrial ecosystems	Area (km^2)
27 - Fergus Catchment Clare and Galway Co. Co.'s	Rivers: Millbrook, Carheeny, Moyree, Drumandoora, Spancehill, Carrownanelly. Loughs: Inchicronan, Gortaphisheen, Nagall, Curraderra, Ardamullivan, Namugga, Nagilkagh, Carheeny, Red, Loughaundoongorey, Bunnahow, Island, Derreen, Beg, Skehanagh, Derroogh, Cloggahwood, Dromroon, Derroogh South, Attyquin, Doon, Nahaglish, Drumumna, Illauncronan, Ballinruan, Ballyglassan, Iscudda, Sunnagh, Cummeen, Knockreddan, Gortaphisheen, Derrynacrogg, Drumbonniv, Derrymore, O'Brien's Big, Holaun, Moyreisk, Finanagh.	Inchicronan Lough (000038), Derryhumma Wood (001005).	99

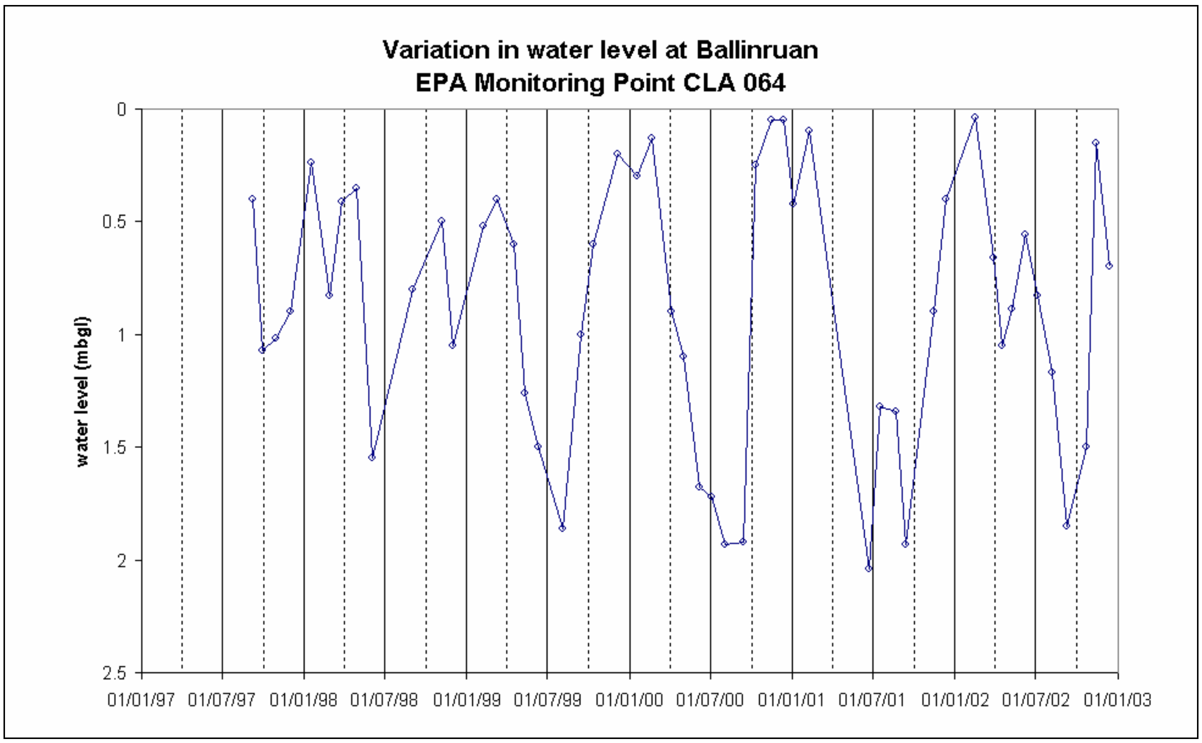
Topography		This groundwater body is elongated in a SW-NE direction. Elevation within the GWB ranges from 20-50 mAOD along much of the western boundary (i.e. at the contact with the karstified limestones of the Ennis GWB) to 400 mAOD at the Maghera peak of the Slieve Aughty, in the NE of the GWB. The topography is mountainous in the NE and east, which is underlain by the resistant sandstones and mudstones of the Devonian Old Red Sandstones and Silurian rocks; here, elevations are typically >100 mAOD. In contrast, the terrain is relatively flat-lying in areas underlain by impure limestones, where elevations are typically 20-60 mAOD, but up to 80 mAOD towards the surface water catchment divides in the north and south. Ground elevation decreases towards the west of the GWB, towards the karstified limestone lowlands. River flows radiate outwards from the upland areas, flowing generally westwards.
Geology and Aquifers	Aquifer categories	In the uplands in the NE and east of the GWB, the rock units are **Pl:** Poor aquifers which are generally unproductive except for local zones. In the west of the GWB, rock units are predominantly **Ll:** Locally important aquifers which are moderately productive only in local zones. The Dinantian (early) Sandstones, Limestones and Shales that form a narrow strip down the centre of the GWB are classified as **Pl**. The Pure Bedded Limestones along parts of the western margin are classified as an **Lm:** Locally important aquifer which is generally moderately productive.
	Main aquifer lithologies	Devonian Old Red Sandstones and Silurian Metasediments and Volcanics occupy nearly all of the NE and east parts of the GWB. The lowlands along the west and in the north and south of the GWB are underlain by Dinantian Pure Unbedded Limestones, Dinantian Lower Impure Limestones and Dinantian (early) Sandstones, Limestones and Shales.
	Key structures	The major structures affecting the distribution of rock types and hence aquifer types are large anticlinal and synclinal folds, and major faults. The older and more resistant rocks that form the Aughty Mountains occur within the cores of the ENE-WSW orientated anticline are found in the NW and west of the GWB. The younger impure and pure limestones are preserved on the limbs of the fold, and occupy the lower ground. Bedding dips are low, generally 5-15^o. There are several major fault sets crossing the GWB: those with a similar orientation to the fold axes, and also roughly NW-SE and NE-SW faults.
	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 Nenagh GWB, early time pumping test data indicate a transmissivity of around 5 m^2/d. The higher transmissivities quoted are probably only attained in limited circumstances; the Templederry pumping test results are probably most characteristic of this area. For the ORS in this GWB, there are no data; transmissivities will be very similar to the Silurian aquifers. Transmissivities may improve towards the junction with the Dinantian (early) Sandstones, Shales and Limestones. Within the Dinantian Lower Impure Limestones, transmissivities are likely to be in the range 2-20 m^2/d, with most values towards the lower end of the range. Dinantian (early) Sandstones, Shales and Limestones aquifer properties are less good than this. A pumping test in the Dinantian Pure Unbedded Limestones (Waulsortian limestones) at Shinrone in west Co. Offaly indicated a transmissivity of approximately 27 m^2/d. In the Tulla – Newmarket-on-Fergus GWB just to the south, transmissivity in the same rock unit at Tulla is estimated as 13 m^2/d. These values are probably in the middle of the range. Groundwater gradients in the upland areas may be steep (up to 0.06). In lower-lying areas, groundwater gradients on the order of 0.01 to 0.04 may be the norm. Storativities in all rocks are low. Porosity values of approximately 0.015 are likely to be representative of the ORS and Lower Impure Limestones in Co. Clare. *(data sources: Rock Unit Group Aquifer Chapters, GWPS Reports, Source reports, see references)*
	Thickness	The Silurian, ORS, Ordovician and Dinantian Lower Impure Limestone aquifers are more than several hundreds of metres thick at their maximum. However, most groundwater flow occurs within the top 15-20 m of the aquifer, in the layer that comprises a weathered zone of a few metres and a connected fractured zone below this. Permeabilities can be high in the upper few metres, but generally decrease rapidly with depth. Deeper inflows may occur where faults or significant fractures are intercepted by boreholes, however. 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. In the Pure Unbedded Limestones in the west of the GWB, there may be an epikarstic layer of around 1-2 m. Below this, the thickness of the bedding (around 5-10 m) and/ or jointing and faulting controls the inflow intervals. Most flow occurs within the top 10-20 m. Deeper inflows may occur where faults or significant fractures are intercepted by boreholes.

Overlying Strata	Lithologies	*[Information to be added at a later date]*
	Thickness	Topography across the GWB is varied, hence the subsoil thickness varies very widely. There are few data to assess subsoil thickness and its variation. Subsoil thickness variation within this GWB is described using the available data, and by analogy with the Tulla – Newmarket-on-Fergus GWB immediately to the south, which agrees with subsoil variations in this GWB. Over the Pure Unbedded Limestones that occupy the low-lands in the west of the GWB, subsoil is thin, with thicknesses typically in the range 1-3 m and plenty of outcropping rock. Occasional deeper subsoils (up to 10 m) are encountered. Subsoil thicknesses are generally similar over the Lower Impure Limestones, which are found in the area between the lowlands and the foothills of Slieve Aughty. However, over these rocks, there are fewer extensive areas of outcropping rocks, and subsoil thicknesses can reach 15-20 m in places. Over the Devonian Old Red Sandstone and Silurian aquifers, subsoil varies from very thin to absent on ridges and local topographic highs, to between 6-20 m in valleys or local depressions.
	% area aquifer near surface	*[Information to be added at a later date]*
	Vulnerability	Vulnerability is High to Extreme in areas underlain by Pure Unbedded Limestones, Lower Impure Limestones and Dinantian (early) Sandstones, Limestones and Shales. On the western and NW slopes of Sleive Aughty, vulnerability is predominantly Moderate or High, although small areas of Extreme and Low vulnerability occur. In the highest ground, vulnerability is generally Extreme.
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. Due to the generally low permeability of the aquifers within this GWB, a high proportion of the recharge will then discharge rapidly to surface watercourses via the upper layers of the aquifer, effectively reducing further the available groundwater resource in the aquifer. In lowland areas where water tables are high, recharge may be rejected.
	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) or Good (100 m^3/d < yield < 400 m^3/d) yielding boreholes known in this GWB. There are 8 public, private and commercial sources that are within the GSI 'Poor' (2.7 m^3/d < yield < 40 m^3/d) and 'Moderate' (40 m^3/d < yield < 100 m^3/d) yield categories however.
	Main discharge mechanisms	Groundwater discharges to the gaining streams and rivers crossing the GWB. The aquifer within this GWB have low storage capacity and cannot sustain high summer baseflows to the rivers. Springs within the GWB tend to have low to intermediate yields, and may dry up in summer.
	Hydrochemical Signature	There are limited hydrochemical data available for this GWB. From available data and by analogy with the similar Nenagh and Slieve Felim GWBs, it is likely that groundwaters from all aquifers within this groundwater body have a calcium-bicarbonate signature. Hardness, alkalinity and electrical conductivities will vary between the aquifers, however. Groundwaters from the Silurian strata are likely to range from Slightly Hard to Hard (90–360 mg/l $CaCO_3$), with alkalinities ranging from 60 to 270 mg/l (as $CaCO_3$) and electrical conductivities from 260–600 µS/cm. pHs will be neutral. At springs, or other systems where throughput is rapid, groundwaters have limited dissolved solids and are at the lower end of the ranges quoted above. In the Old Red Sandstone aquifers, groundwaters are Moderately Hard (145-235 mg/l as $CaCO_3$) with moderate alkalinities (140-225 mg/l as $CaCO_3$) and electrical conductivities (310-440 µS/cm), and neutral to slightly acidic pHs. The groundwater is characterised by relatively low calcium and magnesium concentrations, but elevated iron and magnesium. 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). In the Dinantian (early) Sandstones, Limestones and Shales, the Impure Limestones and the Pure Limestones, groundwaters will be hard to very hard (typically ranging between 380–450 mg/l), with high electrical conductivities (650–800 µS/cm) often observed. Alkalinity is also high, but less than hardness (250-370 mg/l as $CaCO_3$). Within the Impure and mixed 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. 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.

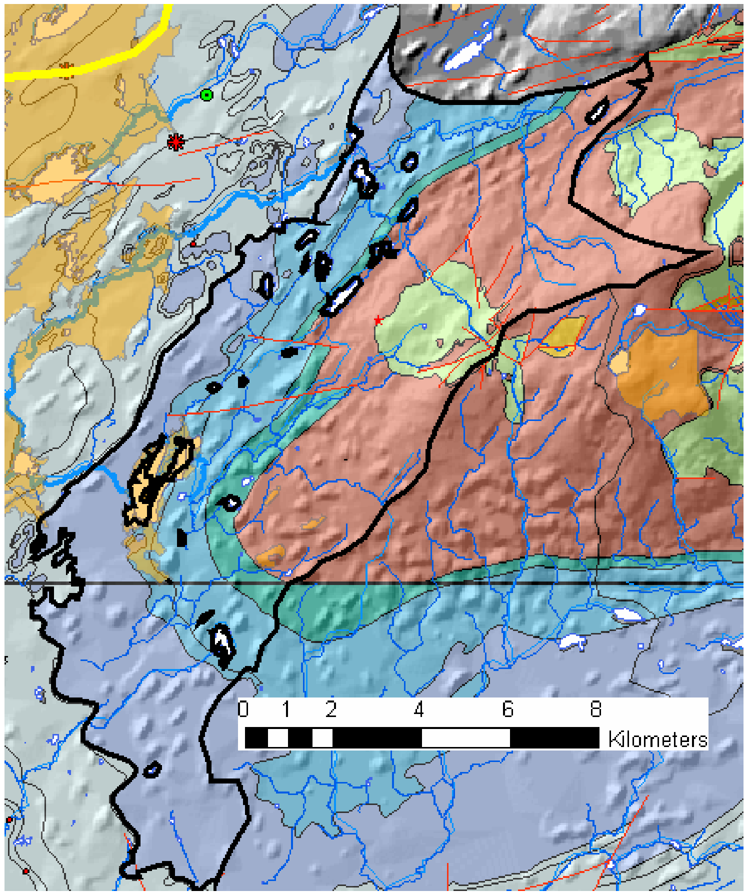
Groundwater Flow Paths	These rocks are devoid of intergranular permeability; groundwater flow occurs in fractures and faults. In the main, the rocks are dependent on fracturing and fissuring to enhance their permeability. Permeabilities in the upper few metres are often high although they decrease rapidly with depth. Most of the flow occurs in the shallow zone near the top of the aquifer, although faulting in certain areas can act as high transmissivity zones that concentrate groundwater flow. The pure limestones may have had their transmissivity enhanced further by dissolution of calcium carbonate along fracture and bedding planes. Zones of high permeability can be encountered near fault zones and in areas of intensive fracturing. Evidence of the generally low permeabilities is provided by the drainage density and flashy runoff response to rainfall in areas underlain by Silurian, Devonian and Impure Limestone rocks. Areas underlain by Pure Unbedded Limestones are generally better-drained. This is due to the probable presence of an epikarstic layer. In the adjacent Tulla – Newmarket-on-Fergus GWB, water levels in Silurian rocks are shallow, usually less than 8 m below surface. Water levels within the ORS unit are also generally less than 8 m below ground surface although deeper water levels of > 20 mbgl are recorded. Seasonal water level variations recorded by the EPA in Devonian Sandstones in the centre of the GWB are about 2 m at a monitoring point in which the SWL is approximately 0-2 mbgl. This large variation in a discharge zone indicates low aquifer storage. The deeper water levels indicate that there are zones within the aquifer that are hydraulically isolated. In the low-lying areas underlain by Pure Unbedded and Lower Impure limestones, groundwater levels are typically between 4 and 6 mbgl. Next to the rivers, water levels will be closer to ground level. The aquifers in the GWB are mainly unconfined. Where vulnerability is Low on the slopes of Slieve Aughty, the ORS aquifer may be confined. Where the ORS aquifer passes underneath the Dinantian (early) Limestones, Sandstones and Shales, it may become confined. The ORS rock unit group is not considered as an aquifer in the areas where it passes underneath other rock units. 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. There is no regional flow system in these aquifers. Surface water drainage is ultimately westwards.
Groundwater & Surface water interactions	Due to the shallow groundwater flow in this aquifer the groundwater and surface waters are closely linked. The streams crossing the aquifer are gaining although, since aquifer storage is low, significant summer baseflows to the rivers cannot be sustained in most areas. Groundwater also discharges to springs. A number of ecosystems within the GWB are groundwater-dependent, including Inchicronan Lough (000038), which is a medium sized lake with some wet grassland and marsh to the south, and Derryhumma Wood (001005), which is small deciduous woodland (oak) with wet birchwood area. Surface water running off this GWB contributes to the groundwater flowing from the large spring (>10,000 m^3/d discharge) at Pouladower in the Ennis GWB.
Conceptual model	• The GWB is elongated SW-NE and is roughly rectangular. It is bounded to the NW and SW by its contact with the karstic limestones of the Ennis GWB. Topographic and implied groundwater divides define the northern, NE and SE boundaries. The terrain ranges between mountainous in areas underlain by Silurian and Devonian rocks to undulating or gently hilly 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 Lower Impure Limestones (i.e. younger rock units) will have better flow properties. Where gravels or gravelly tills overlie the bedrock aquifer this can contribute to the storage. • Flow occurs along fractures, joints and major faults. Faults within the rocks may act both as groundwater flow conduits and barriers. Flows in the aquifer are typically concentrated in a thin zone at the top of the rock. Within the pure limestones, transmissivity may have been enhanced further by dissolution of calcium carbonate along fracture and bedding planes. An epikarstic layer may exist at the top of the Pure Unbedded Limestones. • Recharge occurs diffusely through subsoils and outcrops. The amount of recharge is a function of slope, subsoil thickness and permeability, and aquifer properties. Where the water table is close to the surface in upland or lowland areas, potential recharge may be rejected. • Aquifers within the GWB are generally unconfined. Where the ORS aquifer passes underneath the lower transmissivity Dinantian (early) Sandstones, Limestones and Shales, it may be confined in some areas. Over the GWB, the water table is generally < 8 mbgl, but can be > 20 mbgl in parts of the ORS aquifer. This indicates that there are zones that are not connected to the rest of the aquifer by a fracture network. • Locally, groundwater flows to the surface water bodies and flow directions are determined by local topography. Flow path lengths in the upland and lowland areas are short (30-300 m). There is no regional flow system. The increased hydraulic gradient, due to the sloping topography in the upland areas, will allow groundwater to flow faster than if it were flowing through a similar rock type in low-lying land. • Groundwater discharges to the numerous streams and rivers crossing the aquifer. There will be a small volume of cross-flow from this GWB to the karstic Ennis GWB to the west. Surface water flowing off this GWB will recharge the adjacent karstic 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. Groundwater and surface water interactions require special attention where the terrestrial ecosystems within this GWB are dependent on a sustainable balance between the two. • Surface water running off this GWB contributes to the groundwater flowing from the large spring (>10,000 m^3/d discharge) at Pouladower, which is in the Ennis GWB.
Attachments	Groundwater hydrograph (Figure 1).
Instrumentation	EPA Water Level Monitoring boreholes: Ballinruan (CLA 064).

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. Kelly, C. *Shinrone Public Supply-Groundwater Source Protection Zones*. Geological Survey of Ireland Report to Clare Co. Co., in preparation. Deakin, J. and Daly, D. (2000) *County Clare Groundwater Protection Scheme*. Geological Survey of Ireland Report to Clare Co. Co. (draft), 71 pp. Hunter Williams, N., Motherway, K. & Wright, G.R. (2002) *Templederry WS, Groundwater Source Protection Zones*. Geological Survey of Ireland, 18 pp. Aquifer chapters: Dinantian Pure Unbedded Limestones; Dinantian Lower Impure Limestones; Devonian Old Red Sandstones; Silurian Metasediments and Volcanics; 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



NB: this monitoring point is at the boundary between Devonian Old Red Sandstones and Silurian Metasediments (both Pl aquifers).



Rock units in GWB

Rock unit name and code	Description	Rock unit group
Ayle River Formation (AR)	Mudstone, siltstone, conglomerate	Devonian Old Red Sandstones
Old Red Sandstone (undifferentiated) (ORS)	Red conglomerate, sandstone, mudstone	Devonian Old Red Sandstones
Scalpnagown Formation (SG)	Conglomerate & sandstone, nodular	Devonian Old Red Sandstones
Lower Limestone Shale (LLS)	Sandstone, mudstone & thin limestone	Dinantian (early) Sandstones, Shales and Limestones
Ballymartin Formation (BT)	Limestone & dark-grey calcareous shale	Dinantian Lower Impure Limestones
Ballynash Member (BAbn)	Wavy-bedded cherty limestone, thin shale	Dinantian Lower Impure Limestones
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones
Ballycar Formation (BC)	Dark grey fine cherty limestone	Dinantian Pure Bedded Limestones
Cregmahon Member (TUcm)	Crinoidal limestone with cherts	Dinantian Pure Bedded Limestones
Waulsortian Limestones (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones
Finlough Formation (FL)	Dark grey shaly & cherty fine limestone	Dinantian Upper Impure Limestones
Broadford Formation (BF)	Fine to conglomeratic graded greywacke	Silurian Metasediments and Volcanics
Broadford Formation & Greywacke sandstone (gwBF)	Fine to conglomeratic graded greywacke	Silurian Metasediments and Volcanics
Cornagnoe Formation (CE)	Green, mottled siltstone & mudstone	Silurian Metasediments and Volcanics
Cratloes Formation (CR)	Laminated siltstone & sandstone	Silurian Metasediments and Volcanics
Derryfadda Formation (DF)	Greywackes, siltstone and mudstone	Silurian Metasediments and Volcanics
Glennagross Member (CRgc)	Conglomeratic sandstone	Silurian Metasediments and Volcanics
Greywacke sandstone (gw)		Silurian Metasediments and Volcanics
Kilanena Formation (KA)	Greywacke, siltstone & shale	Silurian Metasediments and Volcanics
Slieve Bernagh Form & Conglom & coarse greywacke (cgSB)	Fine & some coarser greywacke	Silurian Metasediments and Volcanics
Slieve Bernagh Formation (SB)	Fine & some coarser greywacke	Silurian Metasediments and Volcanics
Slieve Bernagh Formation & conglom & coarse greywa (cgSB)	Fine & some coarser greywacke	Silurian Metasediments and Volcanics