Note: there is an EPA Water Quality and Water Level monitoring point at Charleville RWS (CON026) drilled through the Ballysteen Limestone of the Mitchelstown GWB but drawing water from the confined portion of the Ballyhoura Kiltorcan GWB. Hydrograph and Durov plot for this data need to be added.

Ballyhoura Kiltorcan GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
18 Limerick, Cork and Tipperary Co. Co.	**Rivers:** Funshion, Sheep, Castlepook, Ogeen, Farahay, Geeragh, Attychrane, Behanagh, Bregoge, Awbeg.	Mountrussell Wood (002088) ?	29.3

Topography		At ground surface the GWB is represented as a narrow strip (300-1500 m wide) that winds around the southern, western and northwestern lower slopes of the Ballyhoura Mountains and the southern lower slopes of the Galtee Mountains. This body occurs at the transition from the uplands of the Ballyhoura and Galtee Mountains to the flat lowing valley of the Mitchelstown Syncline. The change in topography is linked to changes in the underlying geology. The topography is generally steeply sloping with a transition to some more gently sloping low lying areas at the outer margins of the body. Ground elevations range from 80-180 m AOD. The topography of the land surface is at times tightly incised by gullies of streams flowing off the mountains.
Geology and Aquifers	**Aquifer categories**	**Rf:** Regionally important fissured aquifer
	Main aquifer lithologies	Devonian Kiltorcan-type Sandstones.
	Key structures	The regional structural deformation of the Variscan (Hercynian) Orogeny (mountain building episode) created the characteristic South Munster sandstone ridge (anticline)-limestone valley (syncline) topography. The Devonian Kiltorcan-type Sandstones of this GWB are the uppermost unit of the Devonian Old Red Sandstone succession. They occur on the margins of the sandstone ridge that forms the Ballyhoora and Galtee Mountains. The outcrop area of the Kiltorcan-type Sandstones is limited (approx. 300-1500 m wide) however this GWB must be viewed in three dimensions. The Kiltorcan-type Sandstones dip underneath the overlying shales and limestones of the Mitchelstown GWB (Figure 1). Down-dip towards the middle of the synclines, the aquifer becomes progressively more confined by an increase in thickness of the overlying beds. Numerous north-south faults cross cut the GWB. As deformation is likely to be most intense along the fold axis of the anticline (Churchtown Anticline) the Kiltorcan-type Sandstones are likely to be most productive in the west of the body at the 'nose' of the anticline.
	Key properties	Results of aquifer testing undertaken in the Devonian Kiltorcan-type Sandstones throughout the country are very variable. Estimates of transmissivity range from 20-1850 m^2/day, the highest values likely to be associated with low-lying areas close to anticlines or faults. The permeability of these sandstones varies from 0.5 to 20 m/day, increasing up to 80m/day in localised areas (Daly 1988). It is expected that the permeability will be greatest in the upper part of the Kiltorcan Formation. Transmissivity will be reduced at depth, where the Kiltorcan Formation is thinner in the centre of synclines and permeability is reduced by the deep burial. Borehole yields of 50-4000 m^3/d have been encountered in the Kiltorcan Sandstone (typical yield of 500 m^3/d) with specific capacities of 5-400 m^3/d/m. Storage values range from 0.01-0.1; the higher storage coefficients are a result of a limited amount of intergranular porosity (the sandstone is susceptible to weathering). Boreholes drilled in this GWB as part of groundwater investigations for Charleville WSS at Ballynageragh (O'Sullivan 1980) 9km south of Charleville were artesian in nature and had well yields of 4582 m^3/d (BH1), 5673 m^3/d (BH2), and 1811 m^3/d (BH3). Specific capacities ranged from 200-400 m^3/d/m, transmissivity was estimated at 450 m^2/d and the storage coefficient was estimated at 2.4-5.6 x 10^{-4}. The aquifer can be tapped where it is confined and at considerable pressure. The resulting artesian flows can be quite large.
	Thickness	In drilling that has been done for water wells and core retrieval it has been established that productive fractures in the Kiltorcan Sandstone extend to depths of over 100 m (Dal, 1988). Where confined, active groundwater circulation is expected to be much more limited, but some deep flow has been inferred from mineral exploration boreholes at depths of over 200 m (Daly 1985). It is probable that the Kiltorcan Formation will be thinner in the centre of the synclines (e.g. in the Nore River Basin the Kiltorcan Formation is less than 40 m thick) and permeability will be reduced by the deep burial. In boreholes drilled at Ballynageragh.
Overlying Strata	**Lithologies**	This GWB is primarily covered by glacial till. The matrix is predominantly sandy but also contains some silt and clay. Subsoil permeability has not been mapped in detail in the North Cork region. Small amounts of alluvium deposits occur along some streams crossing the body and some small isolated areas of rock outcrop and shallow rock also occur. *Subsoil Types identified in Ballyhoura Kiltorcan GWB by Teagasc Parent Material Mapping (Draft): Alluvium (A); Rock outcrop and rock close to surface (Rck); Till – Devonian Sandstone Till (TDSs).*

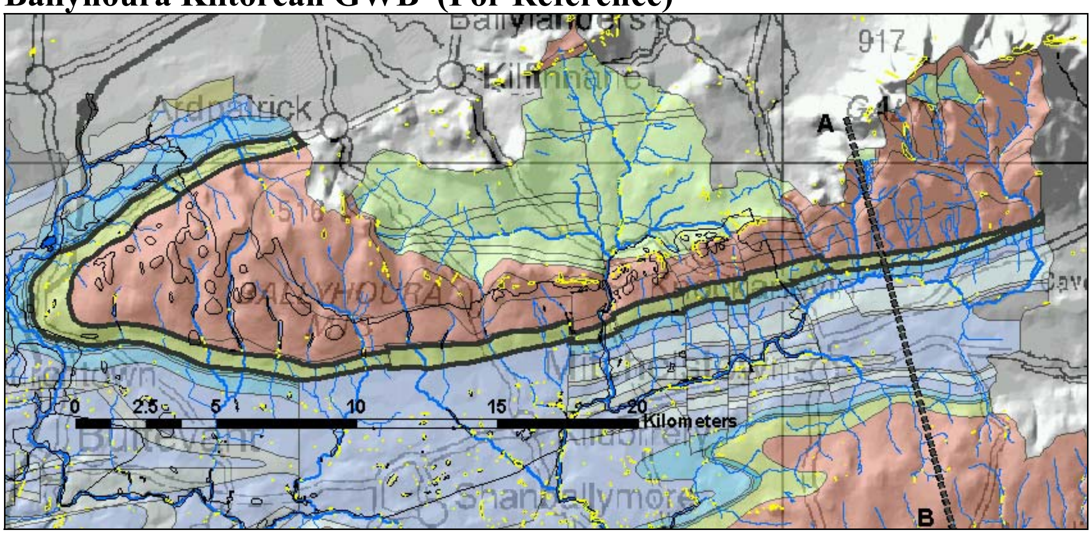
	Thickness	Few depth to rock data are currently available for this GWB. Subsoil depths are likely to be variable as this GWB lies in a transitional landscape from mountains to river valley. It is expected that subsoils will be thinner on the more elevated, steeply sloping parts of the GWB and along incising streams flowing across the GWB. Subsoil thickness is likely increase towards the more low-lying areas of the body in the valleys. At Ballynageragh, south of Charleville subsoil depths of 9-12 m were recorded.
	% area aquifer near surface	
	Vulnerability	A Groundwater Vulnerability Map is not currently available for the North Cork area. Based on data from similar areas in South Cork it is likely that most of this body will be of Extreme and High Vulnerability, however fully categorising areas of Extreme High, Moderate and Low Vulnerability is not possible at this time.
Recharge	**Main recharge mechanisms**	The Ballyhoura and Galtee Mountains to the north and east of this GWB (Ballyhoura GWB) provide abundant runoff which supplies recharge to this GWB. A small amount of groundwater may also cross as through-flow from the sandstones of the Ballyhoura GWB into this GWB. Diffuse recharge will occur over the entire GWB via rainfall percolating through the subsoil. Due to the steep gradients that occur in some parts of this GWB, recharge to the body may be reduced due to rapid discharge to surface watercourses via the upper layers of the aquifer. Most of the recharge to the aquifer will take place in the unconfined portion of the GWB, where the subsoil cover is <5 m. In the confined portion of the GWB thick subsoils and low permeability shales and impure limestones will restrict recharge to the aquifer.
	Est. recharge rates	
Discharge	**Large springs and high yielding wells (m^3/d)**	*Note: Data on groundwater sources and abstractions needs to be updated and checked by RBD Project Consultants.* Data from GSI Well Database: Charleville (Rathluirc) Water Supply Scheme Ballynageragh No. 1 (4582 m^3/d); Ballynageragh No. 2 (5673 m^3/d); Ballynageragh No. 3 (1811 m^3/d).
	Main discharge mechanisms	In the unconfined portion of the GWB a large proportion of the recharge is likely to be discharged again quite rapidly to the many small effluent streams which cross the aquifer. Where the subsoil cover is thicker discharge will take place where the streams have cut down to bedrock or where the subsoil is of high permeability. Where the aquifer is mostly confined, artesian boreholes are common. Where the Kiltorcan Sandstones are overlain by low permeability shales, the aquifer is generally confined, and discharge can only occur near the 'sandstone'/shale boundary. Further down dip into the syncline where the Kiltorcan Sandstones are confined by an increasing thickness of strata there is no obvious outlet for deep groundwater movement. In studies of a similar situation in the Nore River Basin, it was concluded that the discharge of groundwater circulating at depth in the Kiltorcan Sandstones, via large faults and complex pathways, into groundwater of shallower aquifers, was the most likely mechanism (Daly 1988).
	Hydrochemical Signature	Groundwater from the Kiltorcan-type Sandstones is mainly a calcium/magnesium bicarbonate type water. In the recharge areas where the Quaternary deposits are absent or derived from non-Carboniferous strata the water is quite soft (<150 $CaCO_3$ mg/l). Where the aquifer is overlain by limestone derived drift the total hardness normally ranges from 150 – 250 $CaCO_3$mg/l. As the water moves down dip there is some evidence to suggest that ion exchange takes place with a decrease in hardness and the concentration of sodium bicarbonate increasing (Daly 1988). Iron and manganese levels are generally low although occasional high levels can be recorded. Hydrochemical analysis of groundwater from Charleville WS boreholes at Ballynageragh showed total hardness ranging from 176-196 mg/l as $CaCO_3$, total alkalinity 178-192 mg/l as $CaCO_3$, conductivity at 20^o, 362-372 µS/cm.

Groundwater Flow Paths	Groundwater flow occurs through faults and joints. The Kiltorcan-type Sandstones been found to be slightly friable due to weathering and may have a minor component of intergranular porosity, although there is no evidence that this occurs in this GWB. In general groundwater flow is concentrated in the upper 30 m of the aquifer, although deeper inflows can be encountered. Where the sandstones outcrop the aquifer is unconfined but becomes confined as it dips beneath increasing thickness of glacial till and the Dinantian (early) Sandstones, Shales and Limestones, Dinantian Lower Impure Limestones and Dinantian Pure Unbedded Limestones at the margins of the synclinal valleys. Groundwater flow is influenced by topography and groundwater flow will be to the south and west away from the higher ground towards the valleys. In studies of a similar occurrence of Kiltorcan Sandstones in the Slieve Bloom area Daly (1988) divided groundwater flow conditions into four zones (Figure 2). Groundwater circulation is most active in the more elevated parts of the GWB where the overburden cover is < 5 m and the aquifer is unconfined (Zone I). Moving down dip where the GWB is covered by increasing thickness of till the aquifer is mostly confined and artesian boreholes are common. There is not much groundwater movement (Zone II). Where the aquifer is overlain by low permeability shales (Dinantian (early) Sandstones, Shales and Limestones, the aquifer is generally confined and not much natural groundwater circulation takes place (Zone III). In the final zone (Zone IV) the aquifer is capped by an increasing thickness of strata. Significant artesian flows have been hit in this zone which means that groundwater can be induced to move at reasonable depth (over 100 m) in this aquifer. Evidence from temperature logs run in deep mineral exploration boreholes suggests that there maybe movement in reasonable quantities down to 200m and possibly 300 m. It has been suggested that groundwater circulating at depth in the Kiltorcan Sandstone aquifer may be the vehicle for carrying heat from depth to some of the warm springs active in the overlying Carboniferous limestones (Daly 1988), with faults feeding warm groundwater to some of the warm springs. However the link between groundwater circulating in the Kiltorcan Sandstones at depth, and geothermal springs and boreholes has yet to be conclusively proven. Large faults may also retard the circulation of groundwater in the Kiltorcan Sandstones, either by isolating all or part of one block of the aquifer another (fault at right angles to the strike of the aquifer) or by isolating the recharge area from the deeper parts of the aquifer (fault parallel to the outcrop) (Daly, 1988).
Groundwater & Surface water interactions	Based on data from other areas with similar rock type the aquifer is expected to contribute a relatively high baseflow to streams and rivers directly underlain by rock.

Conceptual model	• This GWB occurs as a narrow strip on the ground surface (300-1500 m wide) that winds around the southern, western and north-western flanks of the Ballyhoura and Galtee Mountains. The body occurs at the transition from the uplands of the Ballyhoura and Galtee Mountains to the generally flat low-lying Mitchelstown Syncline. The topography is generally steeply sloping with a transition to some more gently sloping low lying areas to the south and west. Ground elevations range from 80-180 mAOD. • The GWB is composed of productive fissured sandstone classed as a regionally important fissured aquifer. • The GWB is bounded to the north and east by the contact with the low permeability sandstones of the Ballyhoura GWB. The Kiltorcan-type Sandstones of this GWB dip to the west and south and become confined beneath the low permeability shales and impure limestones of the Newtown Butler GWB (west), and the base of the karstic Mitchelstown GWB (south), which forms the southern and western boundary of the body at ground level. At either end of this elongated GWB there is a groundwater divide that coincides with the SWRBD boundary. • The GWB is made up of an unconfined portion where the Kiltorcan-type Sandstones outcrop, and a confined portion where the sandstones become confined beneath thick glacial till and the overlying shales and impure limestones of the Mitchelstown Syncline. Where the aquifer is mostly confined, artesian boreholes are common. The aquifer is expected to be most productive in the west of the body along the axis of the anticline, where deformation is likely to have been most intense. • Groundwater flow generally occurs through faults and joints. • In general groundwater flow is concentrated in the upper 30 m of the aquifer, although deeper inflows can be encountered. The upper half of the Kiltorcan Sandstones is generally the most permeable. Groundwater flow is influenced by topography and groundwater flow will be to the south and west away from the higher ground towards the valleys. • The GWB is recharged diffusely via rainfall percolating through the subsoil over the GWB and by runoff from the Ballyhoura and Galtee Mountains to the north and east. Most of the recharge to the aquifer will take place in the unconfined portion of the GWB, where the subsoil cover is <5 m and where the aquifer is most vulnerable to pollution. In the confined portion of the GWB thick subsoils and low permeability shales and impure limestones will restrict recharge to the aquifer. • It has been suggested that groundwater circulating at depth in the Kiltorcan Sandstone aquifer may be the vehicle for carrying heat from depth to some of the warm springs active in the overlying Carboniferous limestones (Daly, 1988), with faults feeding warm groundwater to some of the warm springs. However the link between groundwater circulating in the Kiltorcan Sandstones at depth, and geothermal springs and boreholes has yet to be conclusively proven.

Attachments	Figure 1 Schematic Cross Section through the Mitchelstown Syncline; Figure 2 Conceptual Model of Groundwater Flow in the Slieve Bloom area; Daly EP (1988) *The Kiltorcan Sandstone Aquifer*. Paper presented at the 8th Annual Groundwater Seminar held in Portlaoise, on: The future of Groundwater Development in Ireland. Published by: IAH (Irish Group).
Instrumentation	**Stream gauges:** none **EPA Water Level Monitoring boreholes:** (CON026) Charleville RWS The borehole is drilled through the Ballysteen Limestones of the Mitchelstown GWB but draws water from the confined portion of the Ballyhoura Kiltorcan GWB **EPA Representative Monitoring points:** (Note (CON026) Charleville RWS The borehole is drilled through the Ballysteen Limestones of the Mitchelstown GWB but draws water from the confined portion of the Ballyhoura Kiltorcan GWB.
Information Sources	Daly EP (1985). *Groundwater Resources of the Nore River Basin: Hydrogeology of the Kiltorcan Aquifer System*. Unpublished internal GSI report Daly EP (1988) *The Kiltorcan Sandstone Aquifer*. Paper presented at the 8th Annual Groundwater Seminar held in Portlaoise, on: The future of Groundwater Development in Ireland. Published by: IAH (Irish Group). Daly EP (1994) "*Groundwater Resources of the Nore River Basin*" Internal Report Series, Geological Survey of Ireland. Duffy S (1994) "*The Protection of Groundwater Resources in County Waterford*" unpublished MSc Thesis for University College Galway. Hudson M (1996) Cappoquin Public Supply, Groundwater Source Protection Zones. Final report to Waterford County Council. Geological Survey of Ireland. Hudson M, Daly D, Johnston P, Duffy S (1998) *County Waterford Groundwater Protection Scheme*. Main Report. Final report to Waterford County Council. Geological Survey of Ireland, 87pp. O'Sullivan MC (1980) Report on the Investigation of Underground Sources for Rathluirc (Charleville) Water Supply Scheme for Cork County Council. Sleeman AG, McConnell B (1995). Geology of East Cork - Waterford. A geological description of East Cork, Waterford and adjoining parts of Tipperary and Limerick, to accompany the Bedrock Geology 1:100,000 scale map series, Sheet 22, East Cork - Waterford. Geological Survey of Ireland.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

Ballyhoura Kiltorcan GWB (For Reference)



List of Rock units in Ballyhoura Kiltorcan GWB

Rock unit name and code	Description	Rock unit group
Kiltorcan Formation (KT)	Yellow & red sandstone & green mudstone	Devonian Kiltorcan-type Sandstones

Figure 1: Schematic Cross Section through the Mitchelstown Syncline

(From Geology of East Cork – Waterford Sheet 22. 1:100,000 Bedrock Map Series, Geological Survey of Ireland.)

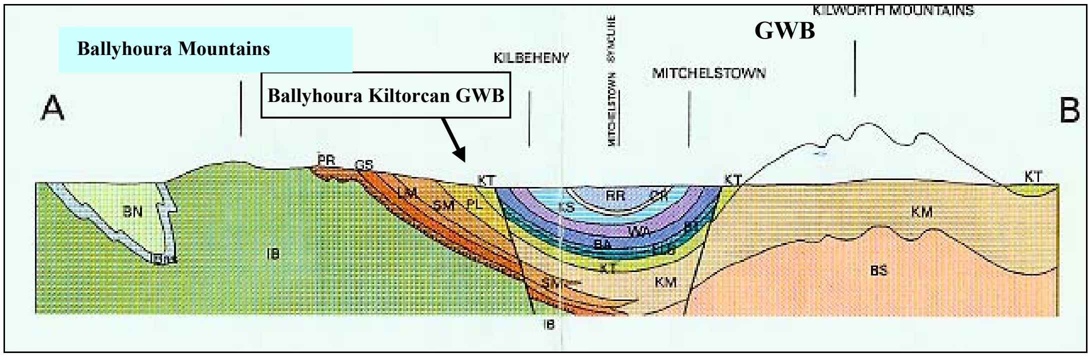


Figure 2: Conceptual Model of Groundwater Flow in the Slieve Bloom area

(From E.P Daly, 1988)