Mitchelstown GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
18 Cork & Limerick Co. Cos	**Rivers:** Clydagh, Blackwater, Araglin, Awbeg, Funshion, Farahy, Douglas, Bregoge, Gradoge, Ogeen, Sheep, Behanagh, Castlepook, Attychrane, Geeragh. **Lakes:**Loughananna.	(000012) Ballinvoneer Pond; (000092) Kilcolman Bog; (001049) Eagle Lough; (000899) Ballindangan Marsh; (000074) Awbeg Valley (below Doneraile); (000075) Awbeg Valley (above Doneraile); (000085) Glanworth Ponds; (001029) Araglin Valley; (002036) Ballyhoura Mountains; (001829) Ballinaltig Beg Pond; (001561) Awbeg Valley Castletownroche; (000073) Blackwater River Callows; Blackwater Valley.	549

Topography

This GWB occupies a large low-lying area in North Cork that includes elongate east west trending valleys extending from Buttevant to Mitchelstown in the north, and Mallow to Fermoy in the south, and an intervening area. The body is generally flat to gently undulating (20-190 m OD). The highest ground occurs around the margins of the body.

Geology and Aquifers

Aquifer categories	**Rkd**: Regionally important karstified aquifer dominated by diffuse flow (73%) **Ll:** Locally important aquifer, moderately productive only in local zones (24%) **Pl:** Poor aquifer, generally unproductive except for local zones (3%) These areas may need to have classification changed *Lm: Locally important aquifer which is generally moderately productive (0.3%)* ***Rf:** Regionally important fissured aquifer (0.2%)*
Main aquifer lithologies	Dinantian Pure Unbedded Limestones (58%), Dinantian Pure Bedded Limestones (15%), Dinantian Lower Impure Limestones (12%), Dinantian Upper Impure Limestones (12%), Dinantian (early) Sandstones, Shales and Limestones (2%). *There area also some tiny areas of Namurian Shales (0.3%)Devonian Old Red Sandstones (0.3%) and Basalts & other Volcanic rocks (0.3%).*
Key structures	During the Variscan Orogeny rocks in the South Munster region were compressed from the south into a series of folds on east west axes. Subsequent erosion generally stripped the more soluble Carboniferous Limestones from the fold crests or ridges (anticlines) exposing the harder, more resistant sandstones underneath. The Carboniferous Limestones were preserved in the fold troughs (synclines) which today line elongate east-west trending valleys separated by the intervening sandstone ridges. The youngest rocks are at the centre of the syncline. Extensive fracturing and faulting accompanied the folding of the rocks which has significantly enhanced the permeability of the limestones in this region. This body covers an area that includes the Mitchelstown Syncline, the Buttevant Syncline and the Churchtown Anticline and the western end of the Fermoy-Lismore Syncline. Figure 1 shows a cross section through the Mitchelstown Syncline in the east of the body. These major synclines are large upward facing open structures. Second and third order folds are developed on the flanks of the major folds. The synclines are cut by a series of shear faults trending approximately north-south and a series of thrust faults with a general east-west trend. The occurrence of thrust faults and transverse faults may have an influence on groundwater flow. The transverse faults divide the area into compartments and can act as preferential flow zones. Some thrust faults may act as barriers causing springs to rise near the thrust fault plane. Thrust faults within formations may act as a focus for karstification because the limestone has been weakened (Ree & Rot, 1981). Frequent jointing is also recorded in the pure limestones in this region. From geological observations it is known that the direction of the joints is broadly north-south and east-west. From cave plans for Castlepook cave, east of Buttevant, it can be seen that karstification is best developed along north south joints (Ree & Rot, 1981). A similar influence of north south jointing on karstification is seen in the pure limestones of the Cloyne and Midleton GWBs in east Cork.

	Key properties	The pure unbedded limestones of the South Munster region are highly productive. Faults and joints were enlarged by karstification as groundwater moved through the limestones. There are numerous surface karst features in these limestones (e.g. caves, enclosed depressions, swallow holes) Transmissivity in the pure unbedded limestones can range from a few m^2/d to a few thousand m^2/d. A pumping test at a public supply borehole at Kildorrery gave a specific capacity of 860 $m^3/d/m$ and estimated transmissivity of 1700-2000 m^2/d. This borehole is believed to tap a fault zone. Other boreholes near the Kildorrery supply borehole had estimated transmissivities of 1-10 m^2/d, much lower than for the pumping well. One borehole drilled to over 90 m met no water. It would appear that these boreholes never intersected the major fault zone, or any smaller fault zone. (Kelly 2000). Pumping test data from a public supply borehole at Olivers Cross indicate a transmissivity of 280 m^2/d (using the observation well data). The porosity is 0.025, and permeability is estimated at about 10 m/d. Flow velocity was calculated to be about 4 m/d. Test pumping at Downing Bridge public supply borehole and at Teagasc's Moorepark research farm suggests transmissivities ranging 15-3400 m^2/d, and permeabilities ranging 10-200 m/d. (Motherway, 1999). The porosity is considered to be about 0.025. Groundwater velocity at Downing Bridge was estimated to be about 30 m/d in the vicinity of the borehole. In general, velocities range 4-2500 m/d within the Waulsortian Limestone. In 1979 a tracing test was carried out by the G.S.I. at a sinkhole/swallow hole in Aghern, Fermoy. A spring 1.1 km to the southeast of the swallow hole showed a positive trace within 11 hours, indicating a velocity of about 100 m/hr. (Kelly & Motherway, 2000) The pure bedded limestones which include the Liscarroll and Caherduggan Limestone Formations are also highly productive but show less evidence of karstification. In the impure limestones, transmissivities are lower; they will generally be in the range 5-20 m^2/d but may be higher where karstification has occurred. Groundwater gradients will also be steeper than in the pure limestones. The Copstone Limestone Formation occurs between the pure limestones of the GWB and is much less permeable as it contains chert and shale bands. The Ballysteen & Ballymartin Limestones occur at the margins of the GWB and dip beneath the pure limestones (Figure 1). Storativity is low in all aquifers, but may be enhanced by overlying sand and gravel deposits where they are in continuity with the underlying limestone and provide them with additional storage.
	Thickness	The Dinantian Pure Unbedded Limestones (Waulsortian Limestone) are estimated as being about 750 m thick in the Fermoy Syncline and somewhat less in the Mitchelstown Syncline (Sleeman & McConnell, 1995). Most groundwater flow may occur in an epikarstic layer a couple of metres thick and in a zone of interconnected solutionally-enlarged fissures and conduits that extends approximately 30 m below this. However deeper flows can occur. In the Impure Limestones that occur at the margins of this GWB, most groundwater flow occurs in an upper weathered layer of a few metres and a zone of interconnected fissures often not extending more than 15 m from the top of the rock, although occasional deep inflows associated with major faults can be encountered. Impure limestones are also much less susceptible to karstification.
Overlying Strata	**Lithologies**	This GWB is primarily covered by glacial till. Till derived from Namurian Shales and Sandstones dominates in the west and southwest of the body, while till derived from Devonian Sandstones occurs in the east and north, and a smaller area of limestone-derived till occurs in the southwest. No Groundwater Protection Scheme has yet been prepared for North Cork and subsoil permeability has not been mapped in detail. Frequent areas of rock outcrop and shallow rock occur within the body. Alluvium also occurs, in particular in the extreme northwest and southeast of the GWB and along the major river channels. Some sand and gravel deposits are mapped in the northeast of the body. *Subsoil Types identified in Mitchelstown GWB by Teagasc Parent Material Mapping (Draft): Alluvium (A); Limestone sands and gravels (Carboniferous) (GLs); Lake sediments undifferentiated (L); Made Ground (Made); Rock outcrop and rock close to surface (Rck); Raised Peat (RsPt); Till –Devonian Sandstone Till (TDSs); Limestone Till (TLs); Namurian Sandstone and Shale Till (TNSSs).*
	Thickness	There are many areas throughout this GWB with subsoils of <3m where rock outcrop is common. Currently available depth to bedrock data from borehole logs within this GWB ranges 1-20 m. Most subsoil depths are <10 m although isolated points of deep subsoil do occur. The underlying pure unbedded limestone in this GWB is highly karstified and likely to have a very irregular bedrock surface. Subsoil depths in these areas can therefore be highly variable within short distances.
	% area aquifer near surface	
	Vulnerability	A Groundwater Protection Scheme for North Cork has not yet been prepared and no Groundwater Vulnerability map is available. It is likely that frequent areas of Extreme Vulnerability occur within this GWB close to rock outcrop, shallow rock and karst features such as swallow holes, collapse features and sinking streams. Areas of High to Low Vulnerability cannot be delineated at this time.

Recharge	**Main recharge mechanisms**	The Devonian ORS ridges to the north, east and south of this GWB (Ballyhoura, Knockmealdown & Glenville GWBs), as well as areas underlain by Namurian rocks to the west (Rathmore & Rathanacally GWBs) provide abundant runoff which supplies recharge to the limestone aquifer in the valleys. The low permeability rocks around the margins of the body however (Lower Limestone Shales, Ballymartin and Ballysteen Limestones) generally prevent throughflow from the underlying productive Kiltorcan-type sandstones which occur at the edges of the Ballyhoura and Knockmealdown uplands in the north and east, acting as a confining layer. In the GWB itself both point and diffuse recharge will occur. Swallow holes and collapse features provide the means for point recharge to the karstified aquifer. Diffuse recharge will occur over the entire GWB via rainfall percolating through the subsoil. The lack of surface drainage in several parts of this GWB indicates that potential recharge readily percolates into the groundwater system. In this highly productive aquifer there are some low-lying areas with a high water table, where a proportion of the effective rainfall is rejected due to lack of storage space in the aquifer.
	Est. recharge rates	
Discharge	**Large springs and high yielding wells (m^3/d)**	*Note: The following data need to be checked and updated by RBD Project Consultants.* Data from GSI Well Database: Patrician Academy Mallow (2180 m^3/d); Mart Well, Mallow; Assolas, Kanturk (545 m^3/d); Mitchelstown (654 m^3/d); Ballyenahan North (916 m^3/d); Spaglan, Mallow (475 m^3/d) Public Supplies for which Source Protection Reports have been prepared by GSI: Castletownroche – Redstone Spring (8861m^3/d) & Ballinvoher Spring (5888 m^3/d); Kilworth – Downing Bridge Bore (1500 m^3/d); Glanworth - Ballykenly Spring (4000 m^3/d); Kildorrory – Glenavuddig Bridge Bore (720 m^3/d maximum pump capacity); Olivers Cross, Parkadallane, Bore (1282 m^3/d). Additional data from EPA Groundwater Sources List: Donneraile, Shanballymore (Spring - CON034) (3200 m^3/d); Ballyclough Co-Op, Buttevant (Bore – CON 094) (545 m^3/d); Ballyclough Co-Op, Doneraile (Bore – CON 095) (545 m^3/d); Mitchelstown Co-Op, Clonmel Rd (Bores – CON109) (7273 m^3/d) Downing Bridge (CON158) (2500 m^3/d) *Note: Charleville RWS (CON026) draws water from the confined portion of the Ballyhoura Kiltorcan GWB).*
	Main discharge mechanisms	Groundwater discharges to large springs within the GWB and to the rivers and streams crossing the GWB. Some spring lines occur where bedding planes intersect the sides of valleys (eg Redstone and Ballinvoher Springs of Castletownroche WS). Others may be fault controlled.
	Hydrochemical Signature	The groundwater in this body is dominated by calcium and bicarbonate ions. Hardness can range from moderately hard to very hard (200 mg/l to >400 mg/l (as $CaCO_3$). Spring waters tend to be softer as throughput is quicker and there is less time for the dissolution of minerals into the groundwater. Groundwater alkalinity is high, up to 400 mg/l (as $CaCO_3$). These hydrochemical signatures are characteristic of clean limestone. Like hardness and alkalinity, electrical conductivities can vary greatly. Typical limestone water conductivities (EC) are of the order of 500-700 µS/cm Lower values suggest that the residence times of some of the sources are very short. Due to the high level of interaction between groundwater and surface water in karstic aquifers, microbial pollution can travel very quickly from the surface into the groundwater system. The normal filtering and protective action of the subsoil is often bypassed in karstic aquifers due to the number of swallow holes, dolines and large areas of shallow rock. The hydrochemical signature of groundwater from public supply wells in the Mitchelstown GWB is demonstrated in an expanded Durov plot in Figure 3 below.

Groundwater Flow Paths	The rocks of this GWB are devoid of intergranular permeability. Groundwater flow occurs in the many faults and joints, in the pure limestones these openings have been enlarged by karstification. Because of the high frequency of fissures in this region, overall groundwater flow is thought to be of a diffuse nature, although solutionally enlarged conduits and cave systems do occur. Groundwater flow in the pure limestones occurs in an upper shallow highly karstified weathered zone in which groundwater moves quickly in rapid response to recharge. Below this is a deeper zone where there are two components to groundwater flow. Groundwater flows through interconnected, solutionally enlarged conduits and cave systems that are controlled by structural deformation. In addition there is a more dispersed slow groundwater flow component in smaller fractures and joints outside the larger conduits. Groundwater level data range from 1-21 m below ground level. Typical annual fluctuation of the water table ranges up to 6 or 7 m. Hydrographs for a number of wells within this GWB are shown in Figure 3 below. Groundwater in this GWB is generally unconfined. The highly permeable aquifer supports a regional scale flow system. At a local scale groundwater flow direction may not follow local topography due to flow in karstified conduit systems. Groundwater flow paths can be up to several kilometres long, but may be significantly shorter in areas where the water table is very close to the surface. Regional groundwater flow will be away from the surrounding uplands towards the main rivers draining the valleys. The impure limestones that outcrop around the margins of the body and underlie the pure limestones are much less productive, although zones of enhanced permeability may occur in the vicinity of fault zones and areas of intensive fracturing. Limited karstification can also occur. These impure limestones act as a confining layer overlying the productive Kiltorcan-type Sandstones which surround the uplands to the north and east. Groundwater levels are generally shallow in the impure limestones (<10 m below ground surface), and commonly less than 3 mbgl. Local groundwater flows are determined by the local topography.
Groundwater & Surface water interactions	The karstic system allows rapid interchanges of water between surface and underground. Swallowholes and caves receive surface water, and groundwater is discharged to surface as springs or as baseflow to rivers crossing the groundwater body. There are numerous NHAs within this GWB with varying degrees of dependence on groundwater. Kilcoleman Bog/Marsh (000092) is fed by calcareous groundwater (NHA Site Synopsis). Ree & van Rot (1981) discuss the influence of the groundwater system on Kilcoleman Marsh. Eagle Lake (1049) displays many of the characteristics of a turlough, and is believed to be the only turlough-type lake in Cork (NHA Site Synopsis).

Conceptual model	• This GWB occupies a large low-lying area in North Cork that includes the elongate east west trending valleys (limestone synclines) extending from Buttevant to Mitchelstown in the north, and Mallow to Fermoy in the south, and the low-lying area underlain by limestone that connects them. The body is generally flat to gently undulating (20-190 m OD). • The GWB is bounded by the contact with the underlying Kiltorcan-type Sandstones to the east (Ballyhoura Kiltorcan and Cappoquin Kiltorcan GWBs), the contact with the Dinantian (early) Sandstones, Shales and Limestones (Glenville GWB) to the south and the contact with the overlying Namurian rocks to the west (Rathmore GWB) and the contact with impure limestones to the northeast (Newtown Ballyhay GWB). The Southwestern RBD boundary forms part of the GWB boundary in the east and north west. • The GWB is composed mainly of diffusely karstified, highly permeable pure limestones with a narrow underlying layer of less permeable impure limestone around the margins of the body. To the north and east of the body are narrow productive Kiltorcan-type sandstones which are partially confined by the impure limestones at the north and eastern margin of this GWB. To the north east and south are ridges of low permeability sandstones. Low permeability Namurian rocks overly the limestones to the west. • The regional structural deformation that created the characteristic South Munster sandstone ridge (anticline)-limestone valley (syncline) topography was accompanied by intense fracturing and high frequency jointing (N-S jointing dominates) within the limestone synclines. Subsequent karstification of these openings has significantly enhanced the permeability of the pure limestones. Karst features such as cave systems, sinking streams, springs, swallow holes and other collapse features are common in this GWB. • Groundwater flows through the many faults and joints formed by deformation that were subsequently enlarged by karstification. Most groundwater flow occurs in an upper shallow highly karstified weathered zone of a few metres thick in which groundwater moves quickly in rapid response to recharge. Below this is a deeper zone where there are two components to groundwater flow. Groundwater flows through interconnected, solutionally enlarged conduits and cave systems that are controlled by structural deformation (influence of N-S jointing). In addition there is a more dispersed slow groundwater flow component in smaller fractures and joints outside the larger conduits. Generally this connected fractured zone extends to about 30 mbgl in pure limestones, although deeper flows do occur. • Groundwater in this body is unconfined. Groundwater gradients are very flat in the permeable limestones (0.001-0.002). The highly permeable aquifer can support regional scale flow systems. Groundwater flow paths can be up to several kilometres long, but may be significantly shorter in areas where the water table is very close to the surface. Overall groundwater flow is away from the surrounding uplands to the main rivers draining the valleys. • Recharge to this GWB is both point and diffuse. The uplands surrounding this GWB provide runoff which supplies recharge to the limestone aquifer in the valley. Swallow holes, collapse features and sinking streams provide the means for point recharge to the karstified aquifer. Diffuse recharge will occur over the entire GWB via rainfall percolating through the subsoil. The lack of surface drainage in much of this GWB indicates that potential recharge readily percolates into the groundwater system. • There are likely to be many areas of Extreme Vulnerability within this GWB near of rock outcrop and shallow rock and in the vicinity of karst features such as swallow holes and enclosed depressions. In a highly karstified aquifer such as this GWB the underlying limestone will have a very irregular surface. Subsoil depths in this GWB can therefore be highly variable within short distances. • There is a high degree of interaction between surface water and groundwater in this GWB. Swallow holes and caves receive surface water, and groundwater is discharged to surface as springs or as baseflow to rivers crossing the groundwater body.
Attachments	
Instrumentation	**Stream gauges:** 18003*, 18004*, 18005*, 18006*, 18007, 18008*, 18013, 18022, 18023, 18024, 18027*, 18030, 18032, 18035, 18036*, 18055, 18057, 18058, 18102. * Specific Dry Water Flow Data available. **EPA Water Level Monitoring boreholes:** (CON055) Bowens Court; (CON144) Ballyclough Co-op (Buttevant); (CON148) Box Cross East – 138; (CON149) Box Cross Middle – 139; (CON150) Box Cross West – 140; (CON151) Cahermee Cross; (CON155) Summer Park. (Note (CON026) Charleville RWS draws water from the confined portion of the Ballyhoura Kiltorcan GWB). **EPA Representative Monitoring points:** (CON034) Doneraile /Shanballymore WS; (LIM007) Ballyagran-Castletown. (Note (CON026) Charleville RWS draws water from the confined portion of the Ballyhoura Kiltorcan GWB).

Information Sources	Ancker H van der (1978) A Reconnaissance Survey of the Groundwater around Mallow, Co Cork (Ireland) and some remarks on the Mallow warm springs. Unpublished thesis, Free University Amsterdam, in co-operation with the Geological Survey of Ireland. Campbell KJM (1988) The geology of the area around Mallow, County Cork. Unpublished MSc thesis, University of Dublin. Cooper C *et al* (1983) The warm springs of Munster, Ireland: Final Report. Unpublished report from Department of Geology, University College Cork. Occasional Report Series. Deakin J, Daly D, Coxon C (1998) *County Limerick Groundwater Protection Scheme*. Geological Survey of Ireland, 61 pp. De Witt GJ (1979) Water in the Mallow Area, Co. Cork, Ireland. Unpublished thesis from the Free University, Amsterdam, in co-operation with the Geological Survey of Ireland. Kelly C (2000) *Oliver's Cross Water Supply Scheme - Groundwater Source Protection Zones.* Geological Survey of Ireland, 13pp. Kelly C (2000) *Castletownroche Water Supply Scheme – Groundwater Source Protection Zones.* Geological Survey of Ireland, 16pp. Kelly C (2000) *Kildorrery Water Supply Scheme Glenavuddig Bridge Groundwater Source Protection Zones.* Geological Survey of Ireland, 12pp Kelly C, Motherway K (2000) *Kilworth Water Supply Scheme–Downing Bridge - Groundwater Source Protection Zones.* Geological Survey of Ireland, 11pp. Kelly D, Leader U, Wright G (2002) *South Cork Groundwater Protection Scheme*. Main Report. Final Report to South Cork County Council. Geological Survey of Ireland. Minerex Ltd (1983) Irish Geothermal Project Phase 1. Report to Geological Survey of Ireland by Minerex Limited. Volumes I & II). Motherway K (1999) *A study of nitrate and vulnerability in the Waulsortian Limestone Aquifer of North Cork, Ireland.* Unpublished MSc thesis. University College London. Shearley EP (1988) *The Carboniferous Geology of the Fermoy and Mitchelstown synclines, Southern Ireland.* Unpublished PhD thesis. University of Dublin. Pracht M (1997) Geology of Kerry-Cork: a geological description, to accompany bedrock geology 1:100,000 scale map, Sheet 21, Kerry - Cork. Geological Survey of Ireland. 70pp Ree van C & Rot G (1981) The Lower Carboniferous Limestone Aquifer near Buttevant (Co. Cork). Unpublished thesis from the Fee University, Amsterdam in co-operation with the Geological Survey of Ireland. 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. Wright G (2000) Fermoy Water Supply Scheme – Coolroe Infiltration Gallery and Borehole – Groundwater Source Protection Zones, 14pp Wright G (1979) Groundwater in the South Munster Synclines. In: Hydrogeology in Ireland, Proceedings of a Hydrogeological Meeting and associated Field Trips held in the Republic of Ireland from 22 to 27 May, 1979. Published by the Irish National Committee of the International Hydrological Programme.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

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.)

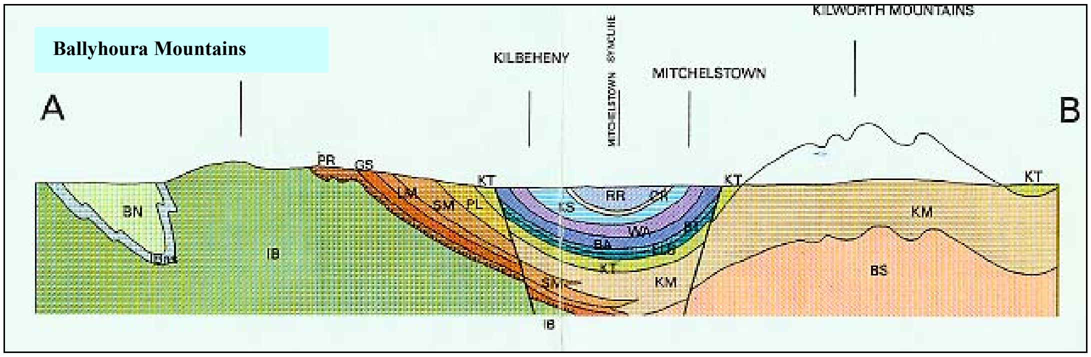


Figure 2: Hydrochemical signature

(EPA Representative Monitoring)

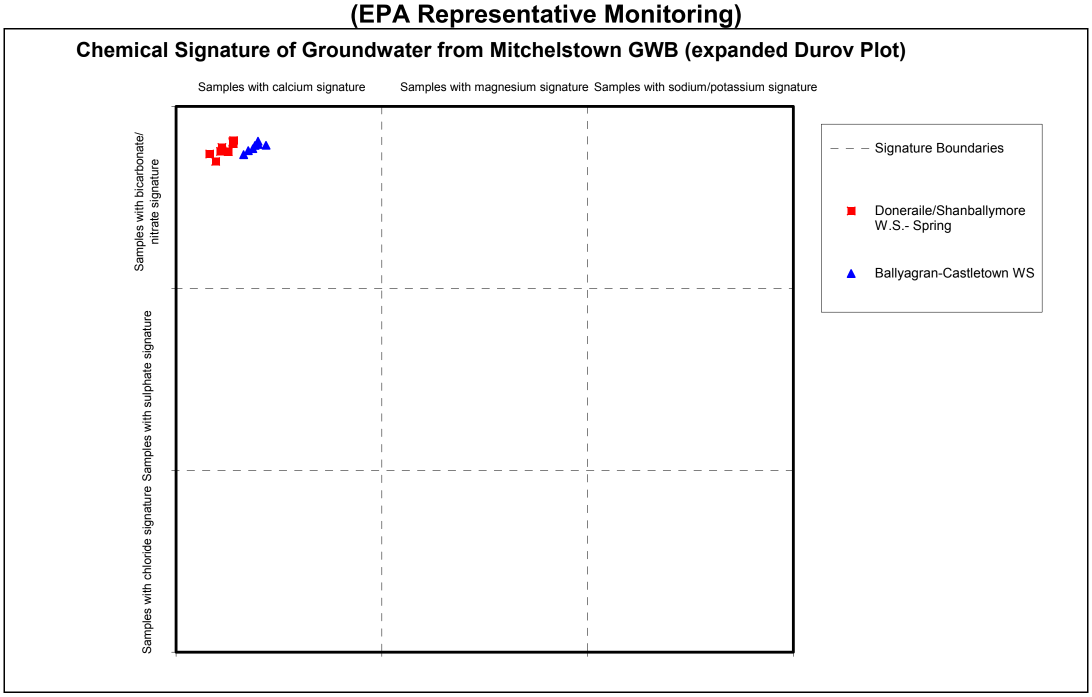
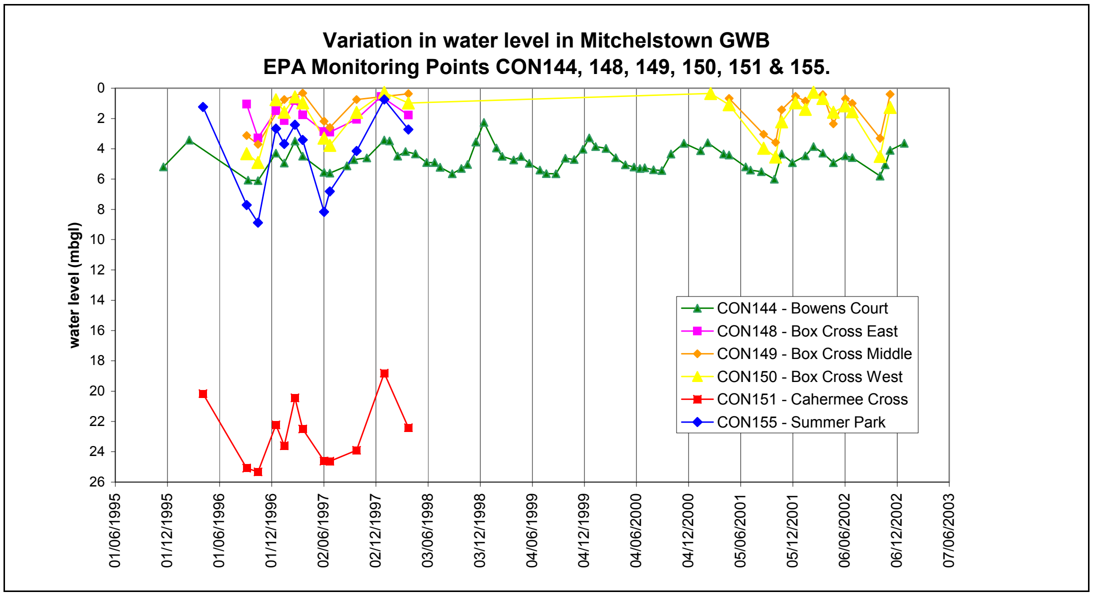
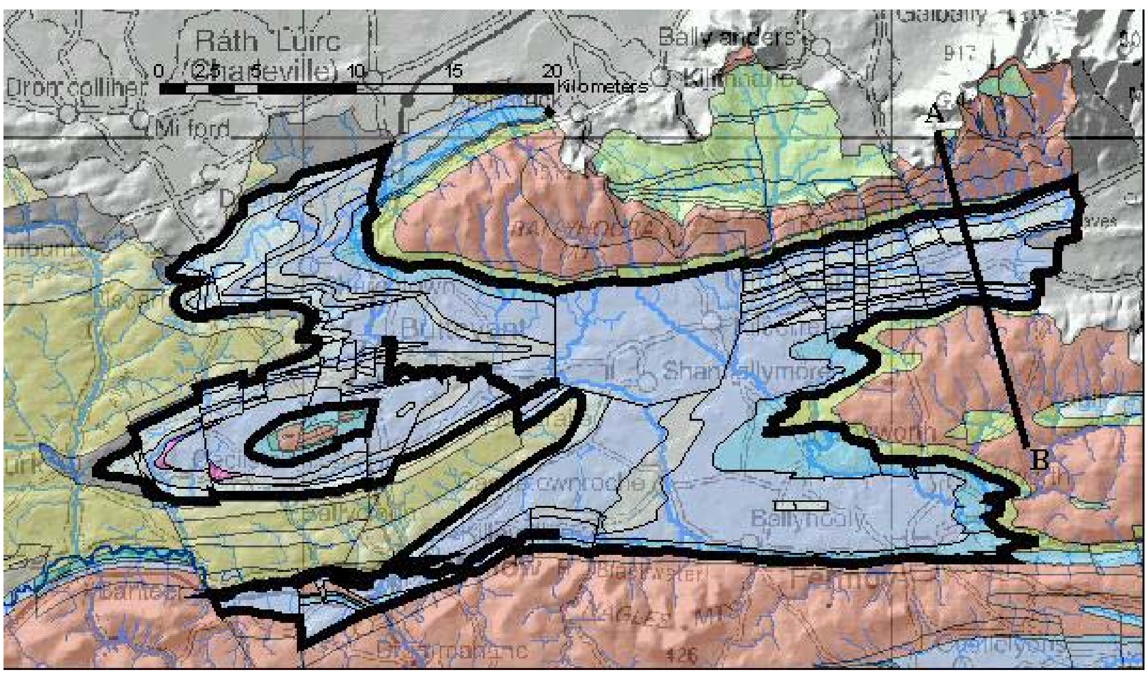


Figure 3: Groundwater hydrographs
(EPA Hydrographs)



Mitchelstown GWB (For Reference)



List of Rock units in Mitchelstown GWB

Rock unit name and code	Description	Rock unit group	Aquifer Classification
Giants Grave Formation (GG)	Dark-grey siltstone & mudstone	Namurian Shales	Pl
Dinantian Limestones (undifferentiated) (DIN)	Undifferentiated Limestone	Dinantian Pure Unbedded	Rk^d
Liscarroll Limestone Formation (LL)	Grey, cherty bioclastic limestone	Dinantian Pure Bedded Limestones	Rk^d
Caherduggan Limestone Formation (CD)	Crinoidal limestone & some modular chert	Dinantian Pure Bedded Limestones	Rk^d
Hazelwood Limestone Formation (HZ)	Pale-grey massive mud-grade limestone	Dinantian Pure Unbedded Limestones	Rk^d
Copstown Limestone Formation (CT)	Dark-grey well-bedded muddy limestone	Dinantian Upper Impure Limestone	Ll
OMahonys Rock Formation (OM)	Wavy-bedded algal laminite limestone	Dinantian Pure Bedded Limestones	Rk^d
Rathronan Formation (RR)	Pale-grey massive mud-grade limestone	Dinantian Pure Unbedded Limestones	Rk^d
Croane Formation (CR)	Dark shaly cherty fine-grained limestone	Dinantian Upper Impure Limestones	Ll
Kilsheelan Formation (KS)	Limestone, occasionally cherty	Dinantian Pure Bedded Limestones	Rk^d
Johnstown Red Marble (JM)	Red, pink & cream limestone	Dinantian Pure Bedded Limestones	Rf
Waulsortian Limestones (WA)	Massive unbedded fine-grained limestone	Dinantian Pure Unbedded Limestones	Rk^d
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones	Ll
Ballymartin Formation (BT)	Limestone & dark grey calcareous shale	Dinantian Lower Impure Limestones	Ll
Lower Limestone Shale (LLS)	Sandstone, mudstone & thin limestone	Dinantian (early) Sandstones, Shales and Limestones	Pl
Ringmoylan Formation (RM)	Calcareous shale & crinoidal limestone	Dinantian (early) Sandstones, Shales and Limestones	Pl
Gyleen Formation (GY)	Sandstone with mudstone & siltstone	Devonian Old Red Sandstones	Ll
Subulter Volcanic Formation (SV)	Pyroclastic flow & fall deposits	Basalts & other Volcanic rocks	Ll