Kinvara/GortGWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
29 Galway/Clare Co. Co.	**Rivers**: Owenshree, Cannahowna, Boleyneendorrish (Ballylee), Beagh (Owendalulleegh/Gort). **Lakes**: Aughrim, Ballynamantan, Caherglassaun, Castle, Coole, Doo, Fahy's, Gortboyheen, Hawkhill, Avatia, Awaddy, Briskeen, Bunny, Cool, Coy, Cutra, Duff, Fadda, Loum, Mannagh, Nacarriga, Nackervan, Namona, Oona, Skeardeen, Loughaunakeagh, Monreagh, Pollifern, Rockforest, Skaghard, Termon, Travaun.	Peterswell Turlough (000318), Lough Coy (002117), Caherglassaun Turlough (000238), Coole-Garyland Complex (000252), Kiltartan Cave (000286), Pollduagh Cave (000320), Lough Cutra (000299), Termon Lough (001321),	256

Topography		The GWB occupies the area between Kinvara-Gort lowlands. The land surface is low lying and relatively flat, with elevations ranging from sea level to 30 mAOD. The GWB is bounded by the coastline at Kinvara. The boundary to the east is with the poor aquifer lithologies of the Derrybrien GWB. To the north and south, surface water divides act as the boundaries, which includes the catchment divide between the Shannon and the Western RBD areas. Location and boundaries are shown in Figure 1.
Geology and Aquifers	**Aquifer categories**	**Rk^c:** Regionally important karstified aquifer.
	Main aquifer lithologies	The GWB is almost entirely dominated by Dinantian Pure Bedded Limestones. Table 1 presents the rock units.
	Key structures	The beds dip 0-10^o in a southerly direction. There is a N-S trending fault, named ‘MacDermot’s Fault’, in the southwestern part of the GWB.
	Key properties	**Karstification** is widespread, with 273 features recorded. This is only considered to represent only a fraction of existing features. **Transmissivity and Storativity:** Yields are variable, being distributed through all the well yield categories. 72% are either “excellent” (>400 m^3/d) or “good” (100-400 m^3/d), and 27% are either “poor” (<40 m^3/d) or “moderate” (40-100 m^3/d) [N=29]. The median yield is 131 m^3/d. Specific capacity values are available for 16 wells. The range is 0.93-5000 m^3/d/m, with a mean of 3 m^3/d/m, thus transmissivities range from 1 to greater than 5000 m^2/d. Productivity values are distributed throughout all the productivity categories, but are skewed to the lower end of the Productivity Index, with 75% either IV or V. Note: productivity is an index relating specific capacity to yield, and the higher the productivity the higher the transmissivity. The well yield data indicate the variability of the aquifer properties. Water table levels have high annual variations, which indicates that the storativity is low - approximately 0.01-0.02 (Daly, 1985). The springs reflect the low storativity as many of the spring flows rise and fall quickly in response to rainfall events. **Groundwater velocity:** are in the order of 60-1000 m/hr depending on location and groundwater levels. Examples from tracer tests include, Ballylee sink to Coole Lough (>50m/hr) and Coole Lough to Kinvara Springs (>150m/hr). Extensive conduit systems exist, including the cave systems at Pollduagh, Coole Cave and Pollbeahan-Pollaloughabo. Generally, conduit development is influenced by N-S and E-W joint sets (Drew and Daly, 1993). **Groundwater flow directions and gradients:** Overall, flow directions are to the northwest, with groundwater discharging to littoral or submarine springs on the coast. There is no surface water outlet to the sea. Groundwater can flow across surface water divides and beneath surface water channels. Some groundwater from the Burren Plateau is expected to flow to Kinvara Springs. Gradients are in the region of 0.0005 in the low-lying areas. Due to the large conduits and the low hydraulic gradient in the low lying areas, flow directions are reversed by the tide, as far inland as Poulaloughabo, some 2.5 km from Kinvara.
	Thickness	Most groundwater flows in an epikarstic layer (1-10 m depth) and in a zone of interconnected solutionally-enlarged fissures and conduits that extends approximately 30 m below this. The major conduits are up to 20 m in diameter (Polldeelin). Deeper inflows can occur in areas associated with faults or dolomitisation. Deep groundwater flow was encountered at 77 m below ground level (60 m below sea level) at Loughcurra South, 2 km southeast of Kinvara.
Overlying	**Lithologies**	The subsoils are predominantly till, occupying approximately 50% of the area, with rock outcrop accounting for a large proportion of the rest.

	Thickness	The thickness is generally less than 3 m (N=41). However, there are areas of greater depths, for example, to the east of Ardrahan, in the northeasternmost corner of the GWB, the thickness varies from 0-6 m, with 2 instances of greater than 10 m.
	% area aquifer near surface	*[Information to be added at a later date]*
	Vulnerability	*[Information to be added at a later date]*
Recharge	**Main recharge mechanisms**	Both point and diffuse recharge occur. Diffuse recharge occurs via rainfall percolating through the permeable subsoil and rock outcrops. Point recharge occurs by means of swallow holes, collapse features/dolines, and where flow is concentrated in the epikarst. Streams flowing off the non-limestone rocks sink on meeting the limestone, thus the majority of the swallow holes are located near the inland boundaries of the GWB. Recharge also occurs along 'losing' sections of streams, for example along a well defined 2 km stretch of the Owenshree River (Daly, 1985; Drew and Daly, 1993).
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	**Large springs and high yielding wells (m^3/d)**	Excellent wells : Loughcurra South – 1,400 m^3/d (2). Springs: Kinvara 40,000 m^3/d.
	Main discharge mechanisms	Kinvara Springs are the main outlet for the entire Kinvara-Gort Lowlands and the western uplands of Slieve Aughty. Three main rivers drain the Slieve Aughty uplands (Owenshree, Boleyneendorrish and Beagh). On reaching the limestone they tend to flow to the southwest for a short distance before sinking. Most of the groundwater that sinks focuses on the Coole Lough area, and from there water flows entirely underground in a northwesterly direction, via a single major conduit system, up to 25 m in diameter, discharging to a group of large springs located in the intertidal zone at Kinvara, some 10-15 km distant (Drew, 2001; Drew and Daly, 1993). Flooding is a serious issue in the area. There is no surface outlet to Galway Bay and the dimensions of the major conduits are fixed therefore there is a limit to what the underground system can take. Thus, during periods of heavy rainfall, the water backs up and floods the area upstream of the swallow holes (Drew and Daly, 1993). There is some degree of flooding each year.
	Hydrochemical Signature	The groundwater has a calcium bicarbonate signature which is illustrated using an expanded Durov plot, presented in Figure 2. The springs at Kinvara have a daily variability in chemistry, as saline conditions survive for up to 4 hours after high tide, for example, Naughton (1975) describes how chloride levels decrease from approximately 3,500 mg/l to 50 mg/l as the tide drops. Brackish water occurs up to 5 kilometers inland due to the large conduits and the low hydraulic gradient. The range and median values for selected parameters for Kinvara and Roo (Gort) are given below.

	Kinvara (N=14)	Roo (Gort) (N=6)
Alkalinity (mg/lCaCO3)	140-228, 186	264-324, 314
Hardness (mg/lCaCO3)	168-372, 226	332-348, 344
Conductivity (microsiemens/cm)	262-574, 460	676-691, 687

Groundwater Flow Paths	These rocks are generally devoid of intergranular permeability. Groundwater flows through conduits, fissures, faults, joints and bedding planes. In pure bedded limestones these openings are enlarged by karstification which significantly enhances the permeability of the rock. Karstification can be accentuated along structural features such as fold axes and faults. Groundwater flow through karst areas is extremely complex and difficult to predict. As flow pathways are often determined by discrete conduits, actual flow directions will not necessarily be perpendicular to the assumed water table contours, as shown by several tracing studies (Drew and Daly, 1993). The tracer tests show that groundwater can flow across surface water catchment divides and beneath surface water channels. A proportion of the groundwater from the eastern side of the Ballyvaughan area is considered to flow to Kinvara. Flow velocities can be rapid and variable, both spatially and temporally. Rapid groundwater flow velocities indicate that a large proportion of groundwater flow occurs in enlarged conduit systems. Groundwater flow in highly permeable karstified limestones is of a regional scale. Flow path lengths are up to ten kilometres. Overall, groundwater flow will be towards sea, but the highly karstified nature of the bedrock means that locally groundwater flow directions can be highly variable. Groundwater flow is trimodal: (1) flow via the epikarst (1-10m depth). (2) flow via solutionally enlarged conduits and cave systems, up to 40 m below ground. (3) flow via smaller fractures and joints linked to the main conduit systems. From Caherglassaun Lough to the sea a single large conduit up to 25 m diameter carries all of the underground drainage to Kinvara, though at high stage conditions water discharges to Corranroo, an ancient outlet for discharge from this major conduit. (Drew, 2001). Figure 3 shows the groundwater flow directions in the Kinvara-Gort lowlands. There is evidence for a deeper groundwater flow system. A borehole 2 km southeast of Kinvara encountered water at 60 m below sea level, the chemistry of which is distinct and is possible that it is derived from the eastern area of the Burren uplands (Drew and Daly, 1993).

Groundwater & Surface water interactions	There is a high degree of interconnection between groundwater and surface water, particularly in the area between Caherglassaun Lough and the sinking rivers, where the drainage alternates from being on the surface to being underground. For example the Owendullagh/Beagh/Gort river sinks and re-appears six times over a distance of less than 10 kilometres. Coole Lough is a permanent water body but also functions as a swallow hole. Between Caherglassaun Lough and the sea there is virtually no surface drainage. There are enclosed depressions into the underground environment which extend along a NW/W trending line from Caherglassaun Lough to Kinvara. This is illustrated in Figure 4. Collapse features in these areas provide a direct connection between the surface and the groundwater systems. The close interaction between surface water and groundwater in karstified aquifers is reflected in their closely linked water quality. Any contamination of surface water is rapidly transported into the groundwater system, and vice versa. Furthermore, there are a number of terrestrial ecosystems within this GWB with varying dependence on groundwater. The drainage system has not undergone the same level of change from major arterial drainage works as found in the other major karst GWB's, such as the Clare-Corrib and the Cong-Robe GWB's. Thus the hydrological system in place in the Kinvara-Gort area may be representative of conditions that were more widespread throughout the karst systems of Clare-Corrib and the Cong-Robe GWB's (Drew and Daly, 1993).
Conceptual model	• The GWB occupies the area between Gort, Kinvara, and Ardrahan. It is bounded by the coastline along Kinvara. The eastern boundary is with the poor aquifer lithologies of the Derrybrien GWB. The northern and southern boundaries are surface water divides. • A large number of karst features occur, including turloughs, caves, dolines, swallow holes and springs. • The GWB is composed primarily of high transmissivity karstified limestone (**Rk**^{c}). Transmissivity and well yields are variable. Storativity is low. Gradients are typically 0.0005 in the low lying areas. • Groundwater flow is trimodal: (1) flow via the epikarst (1-10m depth). (2) flow via solutionally enlarged conduits and cave systems, up to 40 m below ground. (3) flow via smaller fractures and joints linked to the main conduit systems. • Rapid groundwater flow velocities have been recorded through groundwater tracing. • Recharge occurs via losing streams, point and diffuse mechanisms. • In general, the degree of interconnection in karstic systems is high and they support regional scale flow systems. Flow paths are up to 10 kilometres in length. • Surface water catchments are often bypassed by groundwater flowing beneath surface water channels and across surface water catchment divides. A proportion of groundwater from the Burren Uplands is considered to discharge to Kinvara. • Some areas are of extreme vulnerability due to the thin nature of the subsoil, as well as the frequency of karst features, allowing point recharge. Storativity is low and the potential for contaminant attenuation in such aquifers is limited. • Kinvara Springs are the main outlet for the entire Kinvara-Gort Lowlands and the western uplands of Slieve Aughty. Rivers draining the Slieve Aughty uplands sink on reaching the limestone. Most of the groundwater that sinks focuses on the Coole Lough area, and from there water flows entirely underground in a northwesterly direction via a major cave system, discharging to a group of large springs located in the intertidal zone at Kinvara. • There is a high degree of interaction between surface water and groundwater. In the eastern area water frequently sinks and rises before being transmitted underground mostly to Kinvara. • The groundwater has a calcium bicarbonate signature. The water is saline up to several kilometers inland.
Attachments	Table 1 and Figure 1, 2, 3, 4.
Instrumentation	**Stream gauges:** **EPA Water Level Monitoring boreholes:** (GAL 283) **EPA Representative Monitoring points:** (GAL 062), (GAL 293).
Information Sources	Daly, D. (1995) *A report on the Flooding in the Glenamaddy area.* Groundwater Section Report File 2.2.7. 34pp. Daly, D. (1985) *Groundwater in County Galway with particular reference to its Protection from Pollution.* Geological Survey of Ireland report for Galway County Council. 98pp. Deakin, J., Daly D. (2000) *County Clare Groundwater Protection Scheme*. Main Report. Clare County Council & Geological Survey of Ireland. Drew, D. (2001) The Burren and the Gort-Kinvara Lowland, Groundwater Flow Systems in Karstified Limestones. Irish Group. Karst Field Trip October 2001. Unpublished IAH Report. Drew D.P. and Daly D. (1993) *Groundwater and Karstification in Mid-Galway, South Mayo and North Clare.* A Joint Report: Department of Geography, Trinity College Dublin and Groundwater Section, Geological Survey of Ireland. Geological Survey of Ireland Report Series 93/3 (Groundwater), 86 pp Hickey, C., Lee, M., Drew, D., Meehan, R. and Daly D. (2002) *Lowland Karst of North Roscommon and Westmeath*. International Association of Hydrogeologists Irish Group. Karst Field Trip October 2002. Unpublished IAH Report. Naughton, M. (1975) *Groundwater and related features in a temperate limestone area.* B.A. (Mod) Dissertation, (unpublished). Geography Department, Trinity College Dublin.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae.

Table 1. List of Rock units

Rock unit name and code	Description	Rock unit group	Aquifer Classification
Aillwee member (lower) (BUal)	bedded & massive fossiliferous limestone	Dinantian Pure Bedded Limestones	Rkc
Balliny Member (SLbi)	cyclical crinoidal limestone	Dinantian Pure Bedded Limestones	Rkc
Ballyelly Member (SLbe)	nodular & crinoidal limestone with chert	Dinantian Pure Bedded Limestones	Rkc
Black Head Member (BUbh)	limestone & dolomite with corals	Dinantian Pure Bedded Limestones	Rkc
Castlequarter Member (TUcq)	monotonous limestone and dolomite	Dinantian Pure Bedded Limestones	Rkc
Coranellistrum Formation (CT)	Medium to thick-bedded pure limestone	Dinantian Pure Bedded Limestones	Rkc
Fahee North Member (SLfh)	fossiliferous limestone with chert	Dinantian Pure Bedded Limestones	Rkc
Fanore Member (BUfn)	dolomitised limestone with shale	Dinantian Pure Bedded Limestones	Rkc
Finavarra Member (TUfv)	bioturbated limestone with dolomite	Dinantian Pure Bedded Limestones	Rkc
Hawkhill Member (BUhh)	peloidal limestone with chert	Dinantian Pure Bedded Limestones	Rkc
Maumcaha Member (BUmc)	massive limestone sparsely fossiliferous	Dinantian Pure Bedded Limestones	Rkc
Newtown Member (TUnt)	cherty limestone	Dinantian Pure Bedded Limestones	Rkc
Tubber Formation (TU)	Crinoidal & cherty limestone & dolomite	Dinantian Pure Bedded Limestones	Rkc

Figure 1 Location and Boundaries of GWB

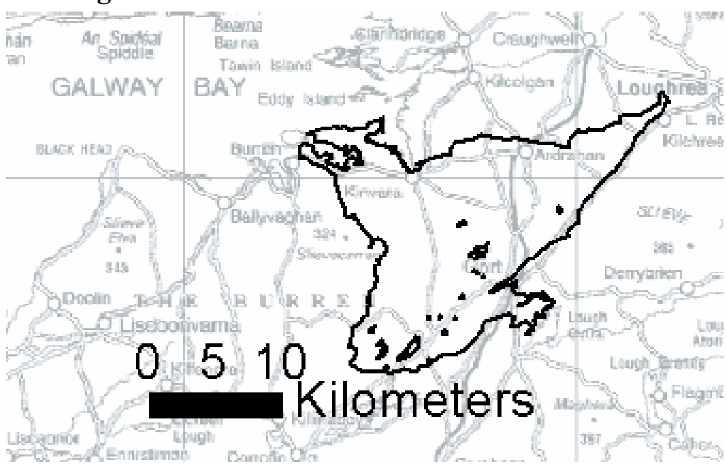

Figure 2

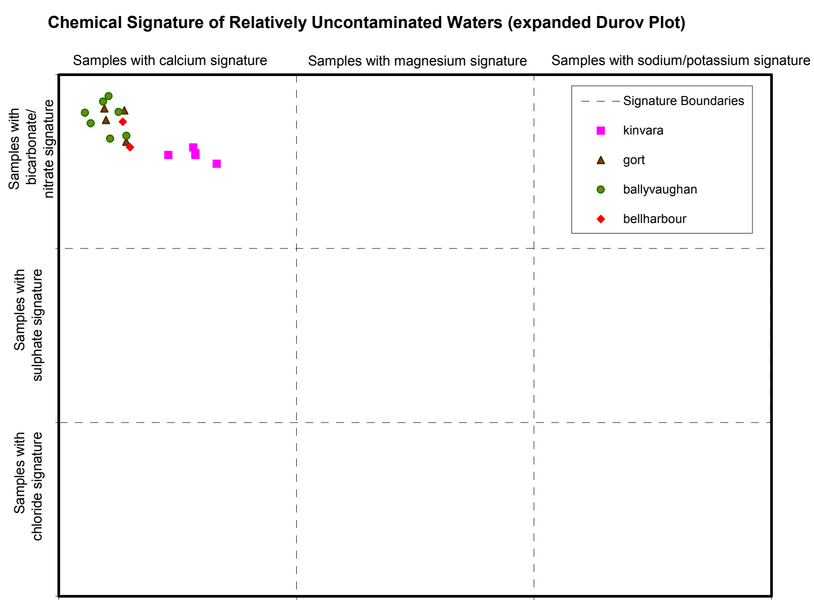

Figure 3 Groundwater flow systems in Gort-Kinvara Lowlands (after Drew, 2001)

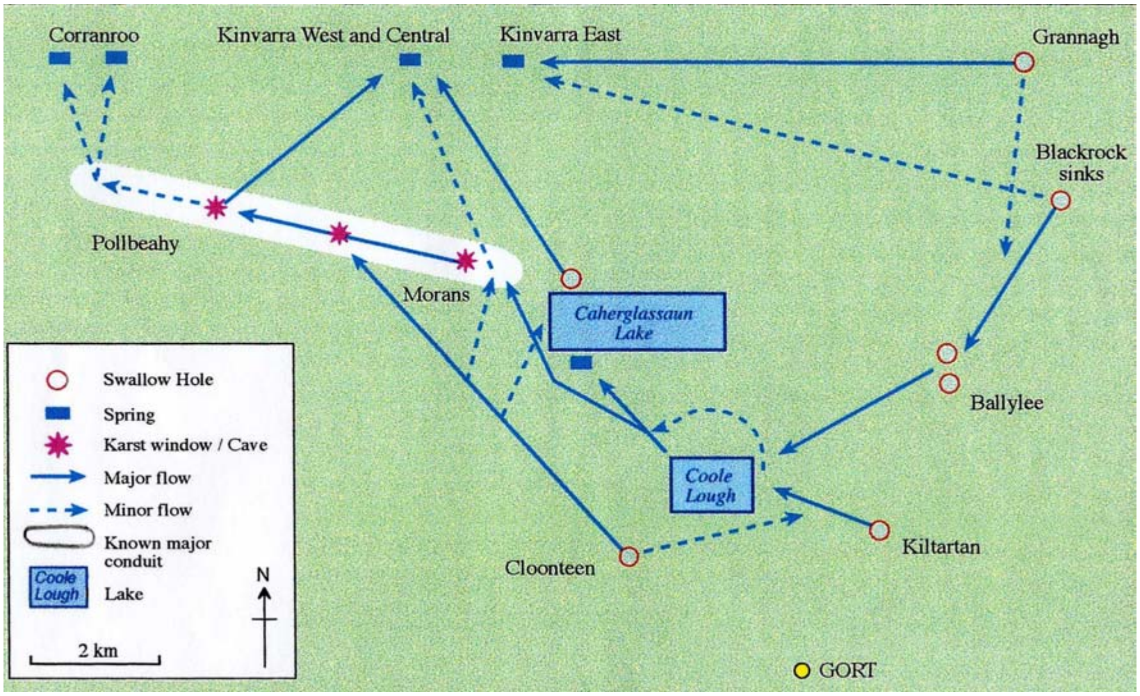

Figure 4 Hydrology of the Gort-Kinvara area (after Drew, 2001)