Groundwater Body Delineation in the Republic of Ireland

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INTRODUCTION

The groundwater body (GWB) is the management unit under the WFD that is necessary for the subdivision of large geographical areas of aquifer in order for them to be effectively managed. The concept of "groundwater bodies" embraces:

- groundwater that can provide for the abstraction of significant quantities of water (i.e. the groundwater which can and should be managed to ensure sustainable, balanced and equitable water use); and
- groundwater which is in continuity with ecosystems and can place them at risk, either through the transmission of pollution or by unsustainable abstraction that reduces baseflows (i.e. the groundwater which can and should be managed to prevent environmental impacts on surface ecosystems).

GROUNDWATER BODY DELINEATION METHODOLOGY

The methodology outlined on this poster is described in the document, "Approach to Delineation of Groundwater Bodies", Guidance Document GW2, Irish Working Group on Groundwater. It is based largely on the CIS guidance.

Initial GWB delineation in the Republic of Ireland was completed by the Geological Survey of Ireland (GSI) using the following steps:

Step 1: Aquifer Delineation and Description
Step 2: Preliminary Groundwater Body Delineation and Description

Further steps, undertaken by RBD consultants, are:
Step 3: Completion of Initial Characterisation
Step 4: Identification of new monitoring points, installing where necessary and commencing monitoring
Step 5: Continuing 'Further Characterisation'

Within each step, there are one or more tasks, and these are outlined in more detail in subsequent boxes.

Republic of Ireland (RoI) groundwater body delineation methodology and aquifer characterisation were undertaken in consultation with the Geological Survey of Northern Ireland (GSNI) and Northern Ireland's Environment and Heritage Service (EHS).

STEP 1: AQUIFER DELINEATION AND DESCRIPTION

Bedrock aquifers were delineated using mapped bedrock geology and hydrogeological information.

a. **Compilation and grouping of Rock Unit Groups:** Within the RoI, there are more than 1130 geological formations and members. They are delineated using various factors, many of which have no hydrogeological relevance (for example, type of fossil). The Groundwater Section of the GSI, grouped these formations and members into 27 'Rock Unit Groups' (RUGs, **Figure 1**). There are three additional RUGs in Northern Ireland.

Aquifer classification was undertaken on the basis of 'Rock Unit Groups' rather than the individual 'rock units' (Formations). Note that a particular Rock Unit Group can, and often does, have a different aquifer classification in different parts of the country (for example, the Dinantian Pure Unbedded Limestones aquifer classification ranges from LI to Rkc and Rkd, depending upon location).

b. **Compilation of hydrogeological data and aquifer classification:** Hydrogeological data for each individual rock unit were compiled into a holistic table. About 4,800 relevant well/spring data were available in the GSI database. The data were assessed for individual rock units and the Rock Unit Groups.

If significant variation of hydrogeological properties between individual rock units in a RUG was noted (e.g. between conglomerates and sandstones/siltstones in the ORS), the variation was explained and the relevant units separated out.

Significant regional variation of hydrogeological properties within each group of rock units was determined (e.g. the groundwater flow characteristics of Old Red Sandstone and Pure Unbedded Limestones in the south of the country are different to those in the midlands and north). Where possible, an explanation for the variation was given.

An aquifer classification was assigned to each group of rock units on a country-wide basis (**Figure 2**). A comparison of RoI and NI aquifer classifications was made (**Table 2**). Where regional variations were noted, a physical basis for bounding the different areas was sought. In some cases, areas were delineated on the basis of different structural provinces as defined in Dunphy (2004).

FIGURE 1: Rock Unit Groups

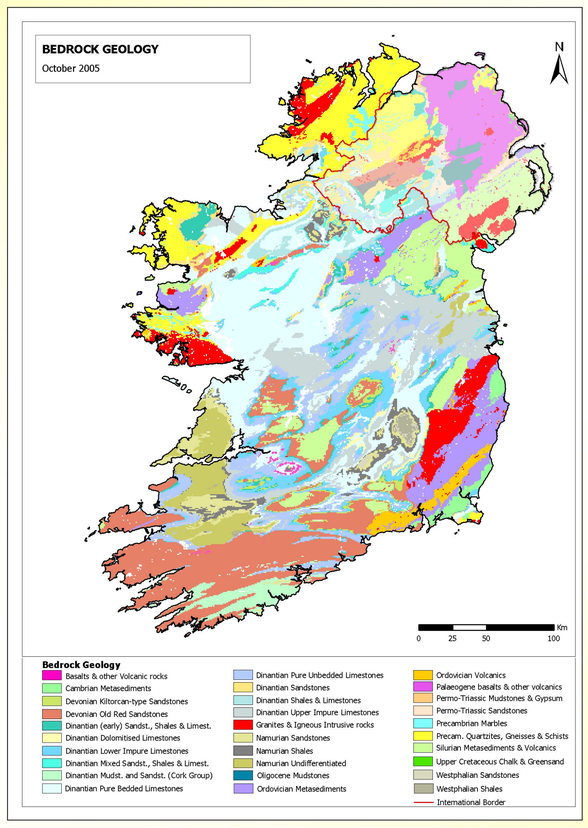
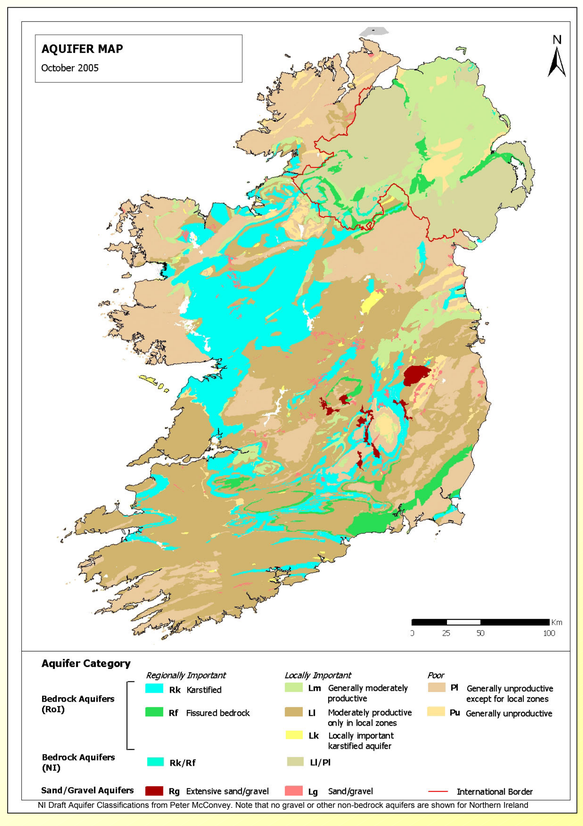


FIGURE 2: Aquifer Map



NI Draft Aquifer Classifications from Peter McConvey. Note that no gravel or other non-bedrock aquifers are shown for Northern Ireland

The RUGs were defined within a stratigraphic framework on the basis of important differences between rock units/ rock unit groups in terms of groundwater flow properties (e.g., limestone purity and susceptibility to karstification; bedding presence or absence and its influence on the prevalence of jointing, degree of deformation and its impact on flow properties (e.g., older rocks have been deformed many times since their formation, so lack pore spaces and connected fracture networks).

Factors used in aquifer classification in RoI:

Transmissivity; Productivity (related to specific yield); Borehole Yields; Springflow; Baseflow; Lithology; presence of Dolomite; Degree of Karstification; Structural Setting; Water level variation.

Type	Classification	Symbol	Description	Comparable Irish Classification
Bedrock	Good	Bg	Generally moderate to high yields in most locations. Includes karstic limestones.	Rf/Rk
	Moderate	Bm	Generally moderate yields in most locations, but can vary.	Lm
	Limited	Bl	Generally low but occasionally moderate yields. Can vary significantly locally.	Ll, Pl
	Poor	Bp	Only very low yields expected if water encountered. Not commonly exploited.	Pu
Super-ficial	Good-Moderate	Sgm	Generally moderate occasionally high yields.	Rg, Lg

TABLE 1: Cross-reference of NI and RoI Aquifer Classification Schemes

Source: McConvey, P. (2002)

STEP 2: PRELIMINARY GROUNDWATER BODY DELINEATION AND DESCRIPTION

a. Within the seven River Basin Districts (RBDs) in (or partially in) the RoI (**Figure 3**), hydrometric unit area boundaries were used as a starting point for GWB delineation. Where appropriate, other surface water body boundaries (i.e. catchments or sub-catchments) within the hydrometric areas were used. This assumes that the groundwater system is unconfined or partially confined only locally.

b. Aquifers were grouped into four Groundwater Flow Regime categories (**Figure 4**) to assist in delineating the boundaries:

i.) Karstic (Rk) aquifers;
ii.) Gravel (Rg and Lg) aquifers;
iii.) Productive fractured bedrock (Rf and Lm) aquifers;
iv.) Poorly productive bedrock (Ll, Pl and Pu) aquifers.

c. A map was generated of each hydrometric area showing these aquifer groups, together with other relevant information such as sub-catchments, location of gauging stations, groundwater monitoring points, groundwater-dependent terrestrial ecosystems (GWDTEs), etc.

d. GWB boundaries were delineated (**Figure 3, Table 2**) using the following hierarchy (taken largely from the CIS guidance, with the exception of *iii),* which is considered to be appropriate to the situation in Ireland):

i.) No flow, or relatively low flow, geological boundaries (this requirement is to facilitate water balance calculations and also because these boundaries separate more or less distinct hydrogeological flow systems).
ii.) Boundaries based on groundwater highs (these will generally be groundwater highs that coincide with surface water catchment boundaries.)
iii) Boundaries based on differing flow systems (e.g. karst vs. intergranular) *(Note: This appears to contradict i.). However it is a justifiable approach in situations (most of Ireland) where the quantitative status is good. It does not prevent water balance calculations being made at the initial stage, prior to making a further sub-division based on the flow regime. It is felt that, for instance, the flow regime in many karst areas will have specific implications for the management measures needed for those areas.)*
iv.) Boundaries based on flow lines. (Comment: These boundaries are only used to separate out groundwater bodies which have a different status.)

e. Initial Characterisation Tables were completed. **Tables 3 and 4** (see separate sheets) give examples of GWB descriptions. A small number of conceptual models were developed which fit the limited range of situations encountered in Ireland; each GWB was informally allocated to one of these.

f. For the purpose of description, some GWBs were grouped. This has been done for some Gravel GWBs and Island GWBs, and, for example, some long and thin non-contiguous aquifers in the Western RBD.

SPECIFIC ISSUES ENCOUNTERED AND SOLUTIONS:

Whilst the CIS guidance was followed and used to develop a methodology for use in Ireland, there were, of course, issues raised during the application of the methodology that is outlined above. Some of these were:

National Aquifer Map

Aquifer classification had previously been done on a geological formation basis (for county-based studies). Dealing with more than 1130 formations, many of which had no hydrogeological data, was too complex, so to make the classification tractable, the formations were grouped into RUGs. In some cases, allocating bedrock formations to RUGs was not straightforward, either because the rock unit was distinct and unique, or because in trying to minimise the number of RUGs, the scheme was not sufficiently flexible for all rock units. All formations were assigned to one of 27 eventual RUGs (in the RoI) by a process of iteration. For some RUGs in some parts of the country, there were too few hydrogeological data for interpretation of aquifer potential. To derive aquifer classifications for these areas, other indicators (see box below Figure 2) were used, and interpretations from well-characterised areas were extrapolated to data-poor zones.

GWB delineation

Due to the complex pattern of bedrock geology in Ireland and its interaction with the surface water catchment boundaries, it was possible to generate very small GWBs by following the delineation rules outlined in Step 2. Therefore, there was the issue of setting a lower limit on the size of a GWB. Overall, we erred on the side of smaller GWBs where necessary, with the idea that they could later be grouped if such fine-scale delineation proved unnecessary (i.e. if the GWBs are in a low pressure area). The lower limit to subdivision into smaller GWBs was subjective and case-specific, and dependent on criteria such as: prior knowledge of poor status, presence of GWDTEs, groundwater flow regime (karstic or productive fissured aquifers were potentially subdivided more, since flow paths can be several kilometres long and therefore a small GWB could potentially be one flow system, whereas in poorly productive aquifers, groundwater flow paths are generally less than 300m, therefore a GWB any larger than about 0.1 km^2 could have one or more groundwater divides within it, so defining small GWBs for specific purposes is irrelevant). Intially-delineated GWB areas range from 6.5 km^2 to 1867 km^2 (average size 65 km^2). GWBs subsequently delineated around known contaminated areas (e.g. landfills, Step 3) may be smaller.

GWBs were not subdivided on the basis of whether the bedrock aquifer was calcareous or non-calcareous (i.e., siliceous). In retrospect, such subdivision might have been desirable in order to define background concentrations for various parameters for GWBs or groups of GWBs for the monitoring phase.

Many gravel GWBs were grouped, since they tend to occur in clusters of smaller bodies. One issue was deciding on which gravel aquifers were also gravel GWBs. A lower limit of 5km^2 was used as a guideline, but where the gravel aquifers were the source of a significant and locally important supply, this criterion may have been relaxed.

Cross-border GWBs were delineated in conjunction with GSNI/EHS. The initial characterisation (Step 1) was done by whichever geological survey "owned" the largest proportion of the GWB. Where possible, but only if hydrogeologically acceptable, to make reporting and management as easy as possible, the political boundary was taken as the GWB boundary. (This was quite easy in many cases, since geographical and geomorphological boundaries often define the political boundary – e.g., hills, rivers, etc.)

FIGURE 3: River Basin Districts on the island of Ireland

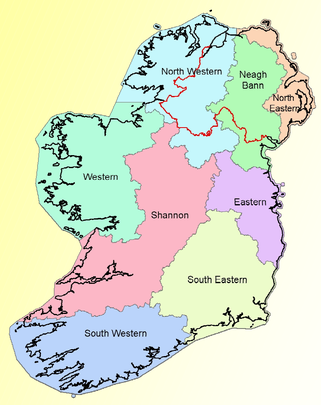


FIGURE 4: Groundwater flow regimes and initial delineated GWBs

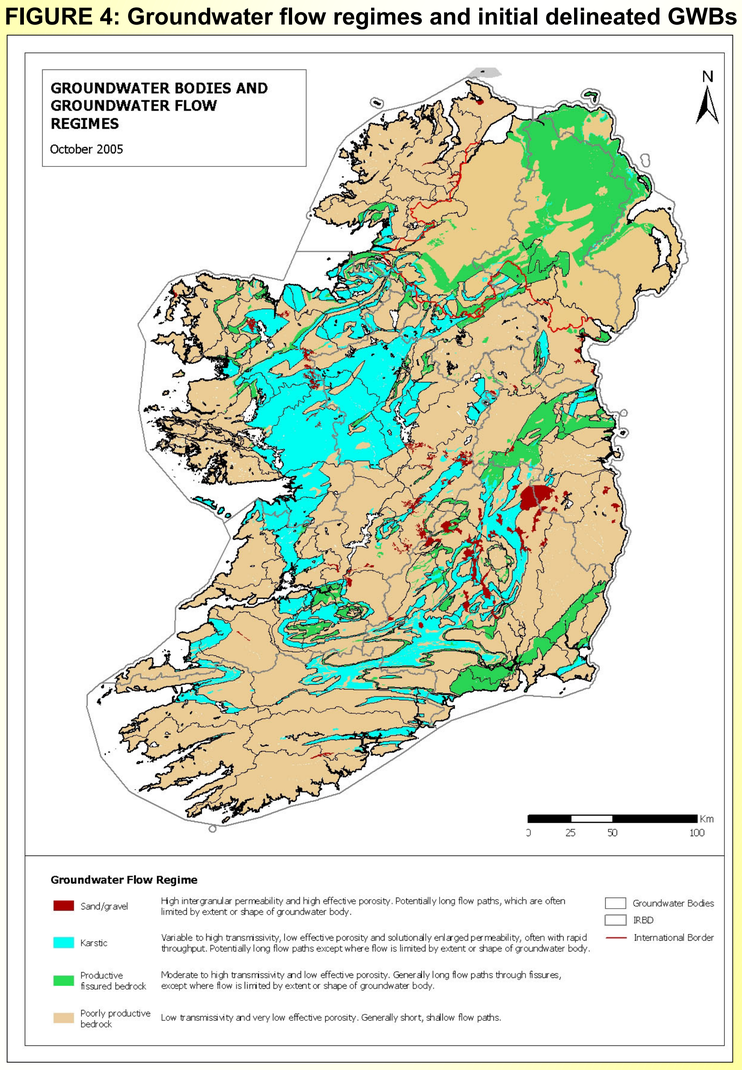
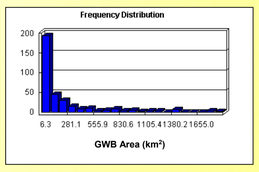


TABLE 2: GWB Summary Statistics

Groundwater bodies delineated by Groundwater Section, GSI (prior to risk assessment)		
River Basin District	**Bedrock GWBs**	**Gravel GWBs**
South Eastern	56	23
Eastern	24	11
Shannon	97	7 (described in Groups)
South Western	30	1
Western	62	3
IRBDs	93 (of which 46 reported on by GSI)	15 (in RoI, described in Groups)



SUMMARY

In the Republic of Ireland, there are:

- Seven RBDs, of which three are Transnational
- 335 bedrock GWBs, of which 34 are Transnational
- 44 Gravel GWBs or GWB groups

GWB delination on the basis of physical hydrogeological characterisistics (Step 2) gave around 380 GWBs (in RoI). There were 374 further GWBs delineated on the basis of risk assessment (Step 4).

The monitoring network has yet to be finalised. Currently, existing monitoring points are being assessed for representativity, and monitoring requirements GWB grouping protocols are being established.

STEP 3: COMPLETION OF INITIAL CHARACTERISATION

Initial characterisation was completed by the RBD Consultants, in consultation with the Environmental Protection Agency (EPA), GSI, National Parks and Wildlife Service (NPWS) and GW WG, as follows:

a. **Assessment of Monitoring Data**.

b. **Mapping and Assessment of Pressures**.

c. **'Extremely' Vulnerable Area Delineation** was achieved by using depth to rock data (some supplied by GSI), the subsoil map produced by Teagasc, and some geophysics. These areas are integrated with existing county vulnerability maps. The final national map is due for completion at the end of 2005.

d. Groundwater bodies were examined in terms of **ecosystems, pressures, trends and pollution risk**.

e. **Risk to Quantitative Status** was assessed by reference to water balances in GWBs, to delineate GWBs 'at risk' or 'probably at risk'.

f. **Risk to Chemical Status** was assessed and GWBs 'at risk' or 'probably at risk' delineated.

The risks to Chemical and Quantitative Status of the GWBs were, in the main, established through Predictive Risk Assessments undertaken in a GIS environment. Where monitoring data indicated a higher risk status than the predicted one, the risk category was modified. Four risk categories were established – at risk (1a), probably at risk (1b), probably not at risk (2a) and not at risk (2b). One of the purposes of Further Characterisation (Step 5) is to remove the uncertain categories (1b and 2a).

Where appropriate, 'at risk' areas within GWBs were delineated and separated from the original GWB.

STEP 4: MONITORING NETWORK DESIGN

This step is in progress. It involves assessment of the currently available monitoring points (MPs), their "integrity" (ie. Are they polluted by local stuff or not), and an assessment of their representativity in relation to a GWB or group of GWBs. The subtasks are:

a. Intial screening to ensure monitoring points are representative of a large enough area of aquifer within a GWB and are not contaminated by local sources.

b. Representativity assessment of MPs within a risk framework, i.e., as a function of aquifer type, vulnerability and other pathway factors, and pressure. These factors are combined in a matrix to derive impact potential, and it is this basis on which the MPs are assessed for representativity of the GWB or GWB group as a whole.

STEP 5: CONTINUE 'FURTHER CHARACTERISATION'

Initial characterisation must be refined in time for the of the draft first River Basin Management Plans in 2008. The next phase of the planning cycle (2005 - 2008) will involve further characterisation of 'at risk' water bodies, the implementation of WFD compliant monitoring programmes and the development of programmes of measures in response to the water management issues identified.

REFERENCES

Dunphy, R. (2004) *The role of fracture systems in controlling groundwater yields in the post-Silurian rocks of Ireland*. Final report to the GSI, 141 pp. Based on M. Res. Thesis, TCD.

EPA (2005) Article 5: The Characterisation and Analysis of Ireland's River Basin Districts - Summary Report on the Characterisation and Analysis of Ireland's River Basins.

Groundwater Working Group (2003) Guidance Document GW3. *Water Framework Directive (WFD) River Basin District Management Systems: Approach to delination of Groundwater Bodies*. Paper by Working Group on Groundwater, 16 pp.

McConvey, P. (2002) *Consideration of Aquifer Classification Schemes in Northern Ireland and the Republic of Ireland*. Internal report, GSNI/EHS.

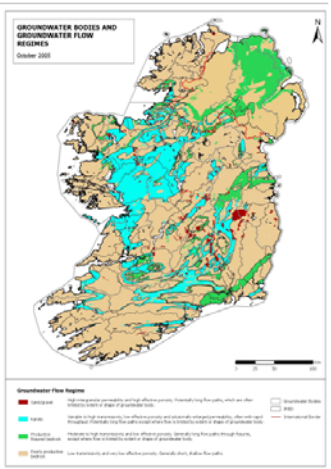
Meehan, R.T., Subsoils maps for counties. Maps produced as part of EPA Soil and Subsoil Mapping Project (formerly FIPS- IFS). Teagasc, Kinsealy.

See also other Irish Working Group on Groundwater Guidance Documents. These can be downloaded from http://www.wfdireland.ie by following the 'Article 5 characterisation report' link and scrolling down to the links in the 'Background Information' section.

MEMBERS OF THE IRISH WORKING GROUP ON GROUNDWATER.

Organisation	Representative(s)	
Geological Survey of Ireland (GSI)	Donal Daly (Convenor) Geoff Wright Vincent Fitzsimons (now at SEPA)	Coran Kelly Taly Hunter Williams Monica Lee
Camp Dresser McKee (CDM)	Henning Moe	
Compass Informatics Ltd	Paul Mills	
Department of the Environment, Heritage and Local Government (DEHLG)	Pat Duggan Jim Ryan (NPWS)	Aine O'Connor (NPWS)
Environment and Heritage Service/ Geological Survey of Northern Ireland (EHS/GSNI)	Peter McConvey	
Environmental Protection Agency (EPA)	Margaret Keegan	Micheal McCarthaigh
RPS-Kirk McClure Morton (RPS-KMM)	Grace Glasgow	Kieran Fay
O'Callaghan Moran (OCM)	Sean Moran	Gerry Baker
O'Neill Groundwater Engineering (OGE)	Shane O'Neill	
Shannon Pilot River Basin – EPA/TCD Research Fellow	Garrett Kilroy	
Southeastern River Basin District (SERBD)	Colin Byrne	
Teagasc	Karl Richards	
Trinity College, Dublin (TCD)	Paul Johnston	Catherine Coxon

1st RBD Cycle GWBs (v. 2005)



Total number of GWBs = 757

Groundwater bodies delineated by Groundwater Section, GSI (prior to risk assessment)		
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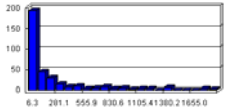
Western	62	3
IRBDs	93 (of which 46 reported on by GSI)	15 (in RoI, described in Groups)

Includes 341 primary bedrock/gravel GWBs (hydrogeological regime) and secondary GWBs (GWDTEs and point sources)

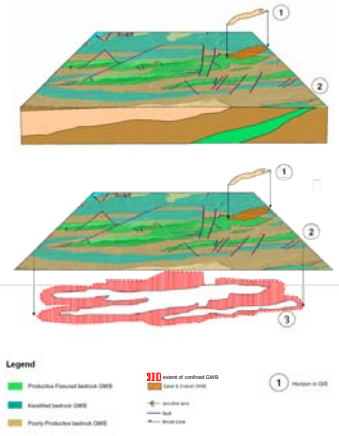
GWB sizes range from 0.333 – 1867 km²



GWB size (km²)

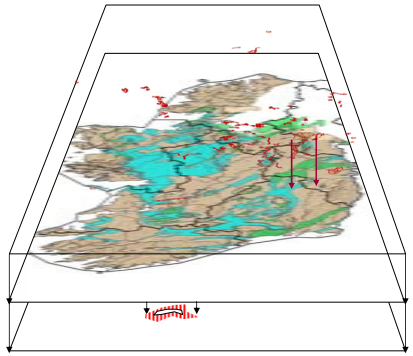
Representation 2D (no vertical variation)

2nd RBD Cycle GWBs (v. 2012)

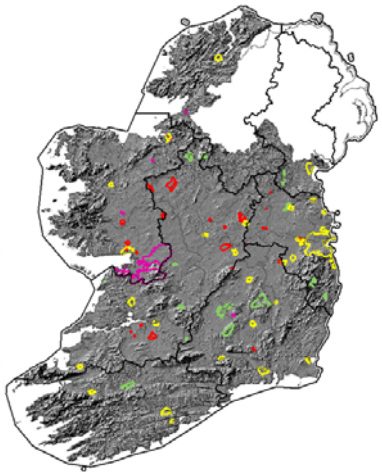


Primary

- Bedrock GWBs – descriptions, flow typologies, linework
- Gravel GWBs – update with new data

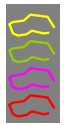


2nd RBD Cycle GWBs (v. 2012)



Point source

- Urban Area GWBs – update with revised urban areas
- Mines GWBs – update Historic Mines and Active Mines with new studies/data
- GWDTE GWBs – review and update turloughs and other GWDTEs with new studies/data



Urban areas
Mines (active/disused)
GWDTEs – turloughs
GWDTEs – other

Summary

- GWBs based on hydrogeological principals
- Further GWBs generated for point sources
- Original GWBs improved
  - new datasets
  - multilayer
- Strong interaction with Irish Environmental Protection Agency in GWB delineation decisions