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PHYSIOGRAPHIC UNITS MAP OF IRELAND
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1. Background

Physiographic maps are cartographic representations of the broad-scale physical landscape units of a region. These are generally based on a unified geological history and distinguishing terrain characteristics (*e.g.* altitude, slope), sediment and bedrock types, and bedrock structure (Salisbury, 1909; Raisz, 1931). Physiographic map datasets therefore delineate physical regions showing internal uniformity with respect to one or more environmental attributes that can be clearly differentiated from neighbouring regions (Schaetzl *et al*., 2013). The value of physiographic unit maps is becoming increasingly acknowledged, particularly in the fields of regional land-use planning, landscape evolution, and the influence of physical landscape on aspects of the ecological environment (Martin-Duque *et al*., 2003; Daly *et al*., 2008; Fearer *et al*., 2008; Johnson and Fecko, 2008; Gawde *et al*., 2009; Rinaldi *et al.*, 2013).

The European Landscape Convention (Council of Europe, 2000), which is a treaty that came into effect on 1st March 2004, obliges Member States to recognise and protect landscapes in law. The Convention dictates that the landscape and its territorial types must be characterised within a framework for identification, characterisation and mapping of landscapes. Whilst the definition of landscape in the Convention is composed of various elements that have to be taken together, it is recognised that the physical landscape underpins any system of landscape characterisation. Through its ground-breaking approach and its broader scope, it complements the Council of Europe’s and UNESCO’s heritage conventions.

The Irish physical landscape is a geological product of the interaction between ‘older’ bedrock and ‘younger’ Quaternary sediment cover and the processes of erosion, deposition and deformation that have been acting upon them throughout Earth’s history. The landscape gives rise to sets of physical features which are clustered and discrete across broad areas, and which have been captured and synthesised into ‘physiographic units’ in this work. The map product also supports the National Landscape Strategy for Ireland 2015 – 2025 (Department of Arts, Heritage and the Gaeltacht, 2015), particularly Action 2.

Several counties within Ireland have published a landscape assessment, including the delineation of the physical landscape (*e.g.* Leitrim County Council, 2002; Monaghan County Council, 2008; Hegarty, 2014; Longford County Council, 2014; Roscommon County Council, 2014; Meehan, 2015); however, a consistent, standardised, nationwide physiographic map of Ireland has not yet been delineated. Therefore, this work presents the first national physiographic units map and classification scheme for Ireland.

Object orientated (OO) mapping techniques applied to digital elevation models (DEMs) combined with thematic datasets, and analysed within a geographical information systems (GIS) digital platform, have been used to produce automated landforms and/or physiographic units non-subjective maps (e.g. Asselen and Seijmonsbergen, 2006; Saha et al., 2011; Jasiewicz et al., 2014). However, these often result as highly pixelated datasets overlooking important landscape features and boundaries (Stepinski and Bagaria, 2009). The recent, increasing volume and quality of these available spatial data in Ireland, such as high resolution DEM), and detailed GIS-based representations of Ireland's bedrock geology, Quaternary sediments and geomorphology allow the construction of a physiographic unit map of the country. Ireland has an intricate and complex bedrock history. The modification of this landscape by subsequent Quaternary glaciations yields a multifaceted physiography. Given the complexity of the Irish landscape, direct delineation using OO mapping was found to be inappropriate during a pilot physiographic unit mapping exercise. Instead, a consistent approach based the visual analysis of a range of digital topographic and geological datasets and expert judgement was therefore adopted to produce a standardised, national physiographic units map.

A hierarchical classification system was derived in order to provide representations of the landscape physiography at different levels of complexity. Level 1 differentiates between six broad physiographic units, which are further divided into 2 further levels of subclasses, providing additional detail in the landscape, based on geological influences.

Furthermore, a supplementary classification scheme was developed, in partnership with the Environmental Protection Agency (EPA), to underpin a hydromorphological assessment method and river hydromorphological classification scheme currently being developed by the EPA in support of the Irish obligations under the Water Framework

Directive (European Commission, 2000; McGinnitty *et al*., 2005; ISPRA, 2009; Fryirs, 2015; Quinlan, 2015).

2. Methods

Visual analysis of four main digital data sources aided to the construction of the national physiographic units map:

(1) Geological Survey bedrock geology maps at 1:100,000 and 1:500,000 scale;

(2) Geological Survey Quaternary sediments and geomorphology maps at 1: 50,000 scale;

(3) Hydrographically corrected DEM with 20 m pixel size (EPA) and 5 m pixel size DEM (Ordnance Survey Ireland, OSI);

(4) High resolution digitalglobe orthophotography dataset and national digital premium basemap map service cached from 1:4,000,000 to 1:1,000 scale (OSI).

Quaternary sediments and geomorphology datasets, allied with the bedrock geology maps and the DEMs, enabled the differentiation of regions dominated by distinctive geomorphological features (*e.g.* drumlins, eskers, peat bogs, *etc*.). The analysis of these datasets was combined with slope, altitude and hill-shade maps generated from the DEMs, which permitted differentiating broad altitude thresholds and convex, concave and straight segments in slope.

The defining elevation cut-offs between mountains, hills and lowlands are not universally standardised across the world, and this lack of a proper subdivision between these landscape sets also exists in Ireland. The threshold between mountain and hill adapted for this work follows work by the United Nations Environmental Programme (after Gardner, 1972), which defines a mountain as an "Elevation of at least 300 m, with a 300 m elevation range within 7 km" (Blyth et al, 2002). This threshold is unofficially reinforced in Ireland, by the digital 1:50,000 to 1:150,000 scale OSI topographic maps, which commonly indicate areas over 300 m as 'mountains'. Although a systematic threshold for mountain cannot be determined from these maps, as some named mountains are lower than 300 m and some higher regions are not marked as such, 300 m is in most cases the minimum altitude reached by 'mountains' in Ireland.

Landforms extending above the surrounding landscape often with a distinct summit ranging between 100 and 300 m altitude were classified as hills, to some extent in agreement with previous classification of soils in Ireland from a soil characterization perspective (Creamer et al., 2014).

Areas of lower elevation were generally characterized by the dominant sediment type within them, coupled with the dominant constituent landform (*e.g.* ribbed moraine, hummocky moraine, raised bog, *etc.*).

The visual analysis of the datasets listed above within a GIS environment coupled with expert judgement was used to delineate the outline of the discrete physiographic units. The mapping delineation consisted of three main steps:

(1) Production of physiographic unit maps for three pilot areas showing particularly differing landscapes (the Suir River catchment, the North Midlands drumlin belt and the western coastal stretch between Connemara and the mouth of the Shannon River) aiming to define a preliminary classification scheme (Fig. 1).
(2) Production of a nationwide map focussing on the delineation of physiographic units based on the DEM topography, Quaternary geomorphology, Quaternary sediments and bedrock datasets as listed above, followed by further development and definition of a more accurate classification scheme.
(3) Merging and reclassification of physiographic units and editing of their outlines based on major changes on slope and altitude thresholds, as identified from slope and altitude maps constructed from DEMs.

The data were digitized at scales ranging from 1:30,000 to 1:100,000 with the objective of generating a final dataset to be used at 1:250,000 scale. The use of a minimum physiographic unit size of 5 km^2 was considered appropriate, an area of 5 km^2 on the ground, cover approximately 0.8 cm^2 on a 1:250,000 scale map, Units less than 5 km^2 are cartographically were merged with the largest neighbouring unit. An exception was made for islands less than 5 km^2, as islands bigger than 0.1 km^2 are included in the map. As well as this, five small physiographic units located along coastal areas showing particularly differing landscape character from the neighbouring units were also allowed as exceptions.

It should be noted that the resulting physiographic units map is designed for general information and broad-scale planning usage. The boundaries are based on the interpretation of the datasets listed above, on many instances local details had to be generalised to fit the map scale. Characterization of the physical landscape at a larger scale will require further and more exhaustive assessment, and may frequently require of site investigation.

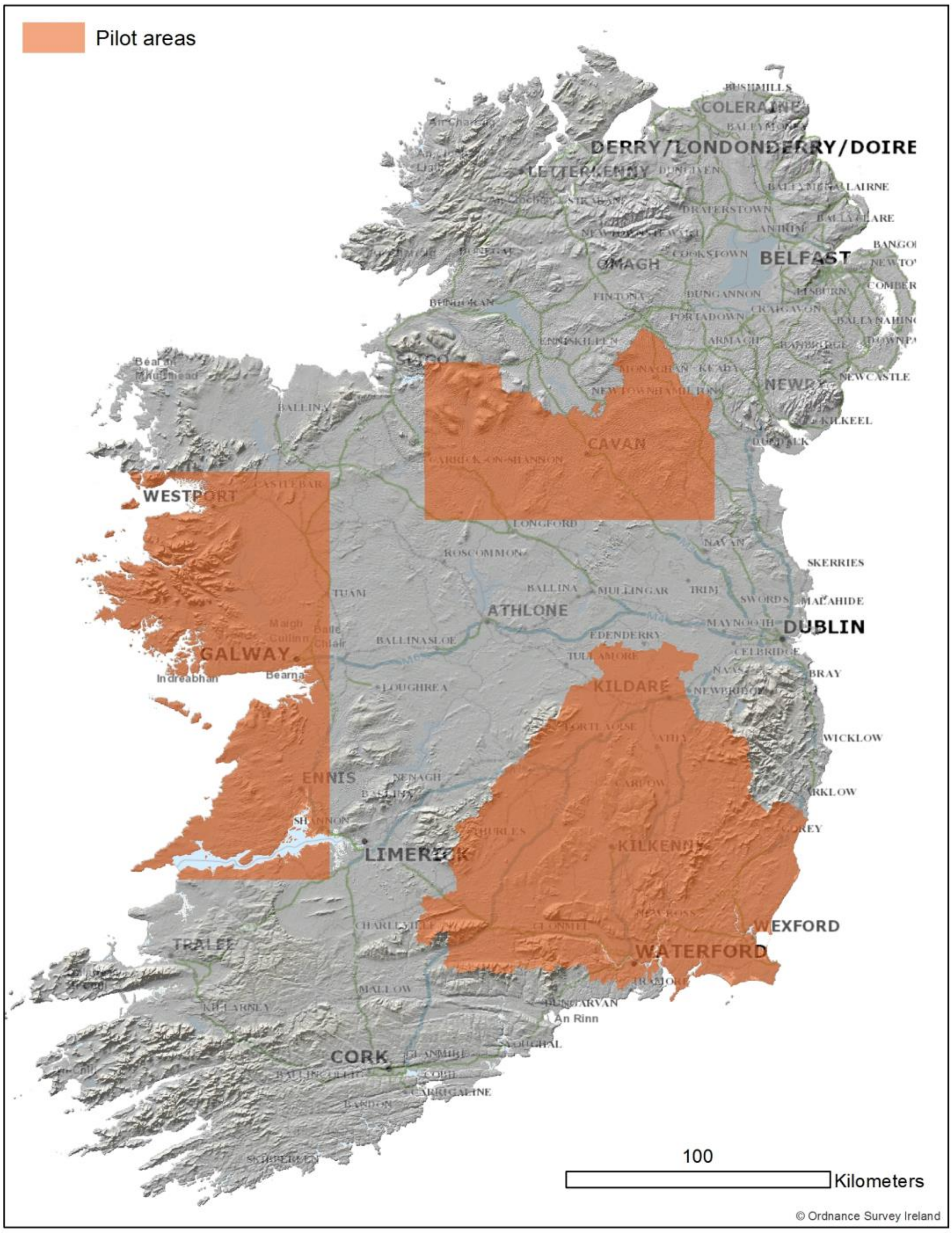

Figure 1 – Location of pilot areas

3. Classification scheme

The three tier classification scheme presented in Table 1a shows a number of hierarchical landscape divisions, different levels of which will be used by different end users depending on the level of detail required. The map was initially produced by characterizing the physical landscape at the highest level of complexity (*i.e.* Level 3 in Tables 1a,b), which comprises 29 physiographic unit types differentiating the landscape morphology, and assessing the main geological processes producing the landforms within these. This dataset was then conflated into a Level 2 grouping including 16 classes. This grouping amalgamates classes with landforms yielding analogous landscape character (Level 2, Tables 1a,b). The Level 2 classes were further generalized into seven broad categories illustrating only the major differences in topographic setting and the macro- geomorphology (Level 1, Tables 1a,b). This scheme comprising seven physiographic units categorized mostly by relief, elevation, topography and position (*e.g.* upland versus lowland settings) follows Brierley and Fryirs (2005) and, in Ireland, broadly equates to the subdivisions of the physiographic units map of Gardiner and Radford (1980), and was especially useful in supporting the hydromorphological assessment of rivers carried out in collaboration with the EPA, Table 1a,b.

A total of 1,175 physiographic units were mapped at LEVEL 3, of these 230 are small islands, not reaching the minimum size of 5 km^2. From this, 944 physiographic units are considered as the total number of units mapped across Ireland at this level of detail, classified within 29 physiographic unit types. LEVEL 2 includes a total of 848 physiographic unit polygons, classified within 16 physiographic units. LEVEL 1 comprises 674 polygons classified in seven macro-scale physiographic units. A description of these physiographic unit types is presented in Tables 2a,b. Maps representing the physiographic units spatial distribution for the three levels of detail are presented in Appendix I.

LEVEL 1	LEVEL 2	LEVEL 3	EPA
Mountain to hill	Mountain rounded	Mountain rounded	Mountain to hill
		Mountain streamlined rounded	Mountain to hill
	Mountain plateau	Mountain plateau	Mountain to hill
		Mountain streamlined plateau	Mountain to hill
	Mountain ridge	Mountain ridge	Mountain to hill
		Mountain streamlined ridge	Mountain to hill
	Mountain ice-sculpted	Mountain ice-sculpted ridge	Mountain to hill
		Mountain ice-sculpted U-shaped valley	Mountain to hill or Rolling lowland
Hill to rolling lowland bedrock	Hill to rolling lowland rounded bedrock	Hill to rolling lowland rounded bedrock	Hill to rolling lowland or Rolling lowland
		Hill to rolling lowland rounded streamlined bedrock	Hill to rolling lowland or Rolling lowland
	Hill to rolling lowland bedrock ridge	Hill to rolling lowland bedrock ridge	Hill to rolling lowland or Rolling lowland
		Hill to rolling lowland bedrock streamlined ridge	Hill to rolling lowland or Rolling lowland
Bedrock plain	Bedrock plain	Bedrock plain	Flat to undulating
		Bedrock streamlined plain	Flat to undulating

Table 1a – Physiographic units classification scheme for physiographic units associated with bedrock outcrop dominating.

The EPA classification scheme includes a total of 646 polygons classified in seven physiographic unit types, the difference in numbers with LEVEL 1 classification is due to amalgamation process used where neighbouring polygons with same label are merged into a single feature. The EPA classification comprise six landscape classes as follows:

(1) **Mountain to hill** (Mountain to hill in Table 2a);

(2) **Hill to rolling lowland** defined as sets of landforms extending above the surrounding landscape, often with distinct summits ranging between 100 and 300 m altitude;

(3) **Drumlins and ribbed moraines,** which includes drumlin and ribbed moraine ridge topography (Drumlin and ribbed moraine topography in Table 2b)

(4) **Rolling terrain,** which is defined as rolling landscapes within large mountain systems or low-lying regions with gentle to moderately steep slopes. In low-lying areas this unit can be defined as a transitional unit between ***hill to rolling lowland*** and ***flat to undulating*** landscapes.

(5) **Hummocky** topography (Hummocky sediments in Table 2b).

(6) **Flat to undulating** landscapes include flat to undulating sediments (Level 1 in Table 2b) and bedrock plains (Level 1 Table 2a).

(7) **Water** bodies covering an area over 5 km^2.

LEVEL 1	LEVEL 2	LEVEL 3	EPA
Rolling ice-moulded sediments	Drumlin and ribbed moraine topography	Ribbed moraine	Drumlins and ribbed moraine
		Drumlinised ribbed moraine	Drumlins and ribbed moraine
		Drumlins	Drumlins and ribbed moraine
	Rolling ice-moulded topography	Megascale lineations	Rolling lowland
		Rolling to gently undulating glacial sediments	Rolling lowland
Flat to undulating sediments	Flat to gently undulating ice-moulded topography	Flat to gently undulating glacial sediments	Flat to undulating
	Coastal plain	Coastal plain	Flat to undulating
	Bog plain	Bog - raised	Flat to undulating
		Bog - atlantic blanket	Flat to undulating
	Flat fluvial - lacustrine plain	Flat alluvial - glaciofluvial plain	Flat to undulating
		Flat alluvial - lacustrine plain	Flat to undulating
Hummocky sediments	Hummocky glaciofluvial sediment topography	Hummocky eskers and associated sands and gravels	Hummocky
		Hummocky ice-marginal sediments	Hummocky
	Hummocky to undulating aeolian sand topography	Hummocky to undulating aeolian sands	Hummocky

Table 1b – Physiographic units classification scheme physiographic units associated with glacial and post-glacial sediments dominating.

Mountain to hill landscapes: Natural elevation of the earth surface rising more or less abruptly from the surrounding ground attaining a minimum altitude of 300 m and significantly higher than the surrounding landscape. The unit outline often depicts a concave change in slope along mountain foothills. Such landscapes are associated with high energy, steep hydrological networks.	**Mountain rounded landscapes**: Steep to gradual, bedrock-cored, high elevation region generally cored by Igneous (*e.g.* granite) and sedimentary (*e.g.* sandstone, limestone) bedrock.	**Mountain streamlined rounded** landscapes show an abundance of glacial abrasion landforms such as glacial striae or streamlined bedrock.
		Mountain rounded landscapes may comprise weathered regolith and shows no evidence of glacial abrasion landforms.
	Mountain plateau landscapes: Highland area with relatively flat terrain rising significantly above the surrounding landscape generally bounded by steep slopes. The geology often comprises flat to gently dipping, relatively hard bedrock (*e.g*. sandstone) overlying relatively softer bedrock (*e.g.* shale).	**Mountain streamlined plateau** landscapes show glacial abrasion landforms such as glacial striae or streamlined bedrock.
		Mountain plateau landscapes are flat to gently dipping, relatively hard bedrock related to differential erosion with no evidence of glacial abrasion landforms.
	Mountain ridge landscapes: Steep, bedrock-cored, high elevation region generally cored by metamorphic (*e.g.* quartzites, schists) bedrock and/or strongly dipping sedimentary bedrock (*e.g.* sandstone and shale) showing significant 'hardness' contrast with surrounding landscape.	**Mountain streamlined ridge** landscapes show glacial abrasion landforms such as glacial striae or streamlined bedrock on ice moulded ridge forms
		Mountain ridge landscapes often presenting a significant 'hardness' contrast with the surrounding landscape and showing no evidence of glacial abrasion landforms.
	Mountain ice-sculpted landscapes: Steep to smooth, bedrock-cored, high elevation ridge-like region showing the typical landforms associated with mountain glaciation including corries, arêtes, cols, truncated spurs and U-shaped valleys.	**Mountain ice-sculpted ridge** landscapes are generally steep mountains with typical mountain glaciation landforms such as arêtes, cols, corries and truncated spurs.
		Mountain ice-sculpted U-shaped valley landscapes are formed by the process of erosion of mountain glaciation ice sheets along valleys generating valley forms consisting of steep, straight sides/walls and a wide, relatively flat floor.

Hill to rolling lowland bedrock landscapes: Landforms extend above the surrounding landscape, often with a distinct summit ranging between 100 m and 300 m in elevation. The landscape may occur on areas below 100 m altitude, as bedrock dominated rolling landscape. Such landscapes are associated with high to medium energy hydrological networks.	**Hill to rolling lowland rounded bedrock landscapes:** Steep to gradually sloping, bedrock-cored, ground of moderate elevation (less than 300 m) generally cored by Igneous *(e.g.* granite) and sedimentary (*e.g.* sandstone, limestone) bedrock.	**Hill to rolling lowland rounded streamlined bedrock** landscapes show an abundance of glacial abrasion landforms such as glacial striae or streamlined bedrock.
		Hill to rolling lowland rounded bedrock landscapes show little evidence of glacial abrasion, dominated by rounded forms
	Hill to rolling lowland bedrock ridge landscapes: Steep, bedrock-cored, ground of moderate elevation (less than 300 m) generally cored by metamorphic rocks (*e.g.* quartzites, schists) and/or strongly dipping sedimentary bedrock (*e.g.* sandstone and shales) often showing a significant 'hardness' contrast with the surrounding landscape.	**Hill to rolling lowland bedrock streamlined ridge** landscapes show glacial abrasion landforms such as glacial striae or streamlined bedrock, yet no rounding of form.
		Hill to rolling lowland bedrock ridge landscapes show no evidence of glacial abrasion landforms dominated by ridged forms

Bedrock plain landscapes: Flat to gently dipping, low–lying, bedrock dominated landscape associated with large areas of highly weathered karstified limestone bedrock and/or low-lying bedrock along coastal areas. Such landscapes are associated with low energy and low density hydrological networks.	**Bedrock streamlined plain** landscapes involves the occurrence of landforms indicative of glacial abrasion such as streamlined bedrock or crag-and-tail.
	Non-streamlined bedrock plain landscapes do not show clear evidence indicative of glacial abrasion, and with planar morphology

Table 2a – Description of hierarchy of physiographic unit landscape types across Ireland, which have bedrock outcrop dominating.

Rolling ice-moulded sediment landscapes: include drumlins, ribbed moraines and mega-scale glacial lineations covering large portions of the lowland areas of the north midlands, and rolling landscapes generally associated with bedrock draped by relatively thin glacial sediments.	**Drumlin and ribbed moraine topography landscapes** consist of rolling landscape composed of high-frequency, low altitude, elongated hills and flat-topped ridges, yielding very dense hydrological networks with low flow velocities.	**Ribbed moraine landscapes** are a subglacial landform assemblage associated with the central portions under former ice sheets, consisting of wavy ridges made of glacial till orientated transverse to ice flow, often closely and regularly spaced, forming fields of ribbed moraines.
		Drumlinised ribbed moraine landscapes form by the superimposition of drumlins on ribbed moraine features, within a landscape giving a disjointed appearance to usually continuous and consistent ribbed moraines.
		Drumlin landscapes comprise smooth, oval-shaped hills with a long axis aligned with ice flow direction and composed of glacial sediments. Generally associated with the former 'warm- based', fast-flowing ice sheets.
	Rolling ice-moulded topography landscapes comprise rounded or elongated, low altitude and low frequency hills, with gentle slopes interspersed with undulating, low-lying ground.	**Mega-scale glacial lineation landscapes** consist of smooth hills comprised of glacial till with particularly elongate long-axes (3 km to12 km long) oriented parallel to the direction of a former ice sheet's flow.
		Rolling to gently undulating glacial sediment landscapes consist of generally rounded, bedrock–cored, low altitude and low frequency hills, with gentle slopes interspersed on an undulating to gently undulating landscape comprised of glacial sediments.

Flat to undulating sediment landscapes: are recorded as (1) glacial till and bog plains covering a large portion of the Irish Midlands; (2) alluvium and glaciofluvial plains developing along wide river channels; (3) coastal plains present along coastal strips and; (4) Atlantic bog 'plains', typical of the low–lying, high rainfall areas along the west coast.	**Flat to gently undulating ice-moulded topography landscapes** dominate the low-lying areas of the Irish Midlands. Often characterized by low energy and low frequency drainage networks, anastomosing in places.	**Flat to gently undulating glacial sediment landscapes** consist of smooth topography often composed of tightly-packed, unsorted and unbedded sediments of glacial origin.
	Coastal plain landscapes are relatively flat regions along the coastline, ranging from sea level to 10 m above it.	**Coastal plain landscapes** are generally comprised of estuarine silts and clays or marine (beach) sands and gravels.
	Bog plain landscapes are flat, low-lying areas covered by peat. Peat may deposit as Atlantic blanket bog in elevated or low-lying areas with excessive rainfall along the west coast, or as raised bogs or fens infilling former lake depressions across the Irish Midlands.	**Bog - raised bog landscapes** develop in former basins filled by decomposed organic matter as fen peat, ultimately developing into raised bogs which often expand outwards from the original basin.
		Bog - Atlantic blanket bog landscapes associated with very high rainfall, cover low-lying areas along the west coast characterized by smooth topography with surface pools.
	Flat alluvial-glaciofluvial plain landscapes generally occur in areas where wide river valleys widen and provide the conditions susceptible to the development of seasonal flooding events. These landscapes are also represented by relatively high river terraces (often associated with glaciofluvial deposits) laid down in braided rivers at the front of former ice margins.	**Flat alluvial - glaciofluvial plain landscapes** consist of sorted and bedded, sand and gravel dominated river terraces, often laid down in braided rivers at the front of a former ice margin, as well as along the major current river valleys
		Flat alluvial-lacustrine plain landscapes illustrate areas prone to flooding, and are comprised of a mixture of bedded gravels, sands, silts or clays, often with a significant percentage of organic carbon, and blanketed by boggy peat deposits in places.

Hummocky sediment landscapes: intensely undulating ground composed mostly of sands and/or gravels, and associated with former ice-marginal or modern day Aeolian, coastal environments.	**Hummocky glaciofluvial sediment topography landscapes** are characterized by intensely undulating topography with up to 40 m relief and generally steep slopes, with deep, enclosed depressions and incised channels.	**Hummocky eskers and associated gravel landscapes** comprise long, sinuous ridges (up to 10 km long) formed by the infilling of former ice-walled channels and associated with glaciolacustrine and glaciofluvial outwash fans and deltas, comprised of sand and gravel.
		Hummocky ice-marginal sediment landscapes are intensely undulating surfaces of ice-marginal sediments, with up to 10 m relief with steep slopes generally composed of matrix–rich, sands and gravels.
	Hummocky to undulating aeolian sand topography landscapes consist of sand dunes and sand sheets in coastal areas, with up to 20m relief and with a virtually non-existent drainage network.	**Hummocky to undulating aeolian sand landscapes** form as sand dunes or sand sheets in coastal areas, often alongside sandy beaches and by onshore winds with sufficient supply of sand-sized sediments.

Table 2b – Description hierarchy of physiographic unit landscape types across Ireland, which have glacial and post-glacial sediments dominating within.

References

Asselen, S.V. and Seijmonsbergen, A.C. (2006). Expert-driven semi-automated geomorphological mapping for a mountainous area using a laser DTM. Geomorphology, 78, 309–320.

Blyth, S., Groombridge, B., Lysenko, I., Miles, L., and Newton, A., (2002). Mountain watch. UNEP World Conservation Monitoring Centre, Cambridge, UK.

Brierley, G.J. and Fryirs, K.A. (2005). Geomorphology and River Management: Applications of the River Style Framework. Blackwell, Oxford, UK . 398 pp.

Council of of Europe (2000). European landscape convention. European Treaty Series, (176).

Creamer, R., Simo, I., Reidy, B., Carvalho, J., Fealy, R., Hallett, S., Jones, R., Holden, A., Holden, N., Hannam, J., Massey, P., Mayr, T., McDonald, E., O'Rourke, S., Sills, P., Truckell, I., Zawadzka, J., Schulte, R. (2014). Irish Soil Information System, Synthesis Report. Report No. 130; Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Daly, C., Halbleib, M., Smith, J.I., Gibson, W.P., Doggett, M.K., Taylor, G.H., Curtis, J. and Pasteris, P.P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. International Journal of Climatology, 28, 2031–2064.

Department of Arts, Heritage and the Gaeltacht (2015). National Landscape Strategy for Ireland 2015 – 2025. Dublin. http://www.ahrrga.gov.ie/heritage/built-heritage/national-landscape-strategy/

European Commission (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal L 327, 22.12.2000, 73 pp.

Fearer, T.M., Norman, G.W., Pack, J.C., Bittner, S. and Healy, W.M. (2008). Influence of physiographic and climatic factors on spatial patterns of acorn production in Maryland and Virginia, USA. Journal of Biogeography, 35, 2012–2025.

Fryirs, K.A. (2015). *Developing and using geomorphic condition assessments for river rehabilitation planning, implementation and monitoring*. WIRES Water. doi: 10.1002/wat2.1100.

Gardner, R.N. (1972). The role of the UN in environmental problems. In: Kay, D.A. and Skolnikoff, E.B. (Eds.) World Eco-Crisis: International Organizations in Response, University of Wisconsin Press.

Gawde, A.J., Zheljazkov, V.D., Maddox, V. and Cantrell, C.L. (2009). Bioprospection of Eastern red cedar from nine physiographic regions in Mississippi. Industrial Crops and Products, 30, 59–64.

Hegarty, S. (2014). County Cavan's physical geography - the canvas for our cultural imprint. In: Cherry, J. and Scott, B. (Eeds) Cavan History and Society, Geography Publications, Dublin., pp. 11 - 34.

ISPRA (2009). Implementazione della Direttiva 200/60/CE – Analisi e valutazione degli aspetti idromorfologici.

Jasiewicz, J., Netzel, P. and Stepinski, T. F. (2014). Landscape similarity, retrieval, and machine mapping of physiographic units. Geomorphology, 221, 104-112.

Johnson, P.A. and Fecko, B.J. (2008). Regional channel geometry equations: A statistical comparison for physiographic provinces in the eastern US. River Research and Applications, 24, 823–834..

Leitrim County Council (2002). Landscape Assessment of County Leitrim. Technical Report on behalf of Comhairle Chontae Liatroma. 108 pp.

Longford County Council (2014) Annex 4: Landscape Character Assessment County Longford in Longford County Development Plan 2015-2021, pp. 371-412. Longford County Council, Longford.

Martin-Duque, J.F., Pedraza, J., Sanz, M.A., Bodoque, J.M., Godfrey, A.E., Diez, A. and Carrasco, R.M. (2003). Landform classification for land use planning in developed areas: An example in Segovia Province (Central Spain). Environmental Management, 32, 488–498.

McGinnity, P.M., Mills, P., Roche, W. and Müller, M. (2005). *A desk study to determine a methodology for the monitoring of the 'morphological conditions' of Irish Rivers*. Final report. Environmental RTDI Programme 2000–2006.

Meehan, R.T. (2015). The Physical Endowment of County Meath. In: Ludlow, F. and Crampsie, A. (Eds.) Meath, History and Society, Geography publications, Dublin pp. 23-56.

Quinlan, E. (2015). Review of Current Hydromorphological Assessment Method in Ireland and Feasibility of a Morphological Based Approach. Unpublished Report for Catchment Science Unit, EPA, 18 pp.

Raisz, E. (1931). The physiographic method of representing scenery on maps. Geographical Review, 21, 297–304.

Rinaldi, M., Surian, N., Comiti, F. and Bussettini, M. (2013). A method for the assessment and analysis of the hydromorphological condition of Italian streams: the Morphological Quality Index (MQI). Geomorphology, 180, 96-108.

Roscommon County Council (2014). Landscape Character Assessment of County Roscommon. Technical Report. 159 pp.

Saha, K., Wells, N.A. and Munro-Stasiuk, M. (2011). An object-oriented approach to automated landform mapping: A case study of drumlins. Computers and Geosciences, 37, 1324–1336.

Salisbury, R.D. (1909). Physiography. Holt and Co., New York..

Schaetzl, R. J., Enander, H., Luehmann, M. D., Lusch, D. P., Fish, C., Bigsby, M.and Pollyea, A. (2013). Mapping the physiography of Michigan with GIS. *Physical Geography*, *34*(1), 2-39.

Stepinski, T.F. and Bagaria, C. (2009). Segmentation-based unsupervised terrain classification for generation of physiographic maps. IEEE Geoscience and Remote Sensing Letters, 6, 733–737.