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Preparation of Physical Catchment Descriptors (PCD)

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Sign Off

Organisation	Name	Position	Date
Compass Informatics	G O Riain	Director	20/05/2009

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1 Introduction

This Report describes work undertaken in the project “Preparation of Physical Catchment Descriptors” which constitutes Work Package 5.3 of the overall Flood Studies Update (FSU) Project coordinated by the Office of Public Works.

The project is a constituent of the FSU Work-Group 5 that addresses the development of information systems for the Flood Studies Update. *Inter alia* the project serves to provide data on catchment characteristics which are utilised by other FSU Work Packages as well as establishing an indicative flood attenuation indicator from elevation data.

The project is national in scope and is wholly established within a GIS framework. Source GIS data from other organisations (including Ordnance Survey of Ireland (OSi) and Environmental Protection Agency (EPA)) have been incorporated as foundation building blocks for the project.

In particular, national standard datasets on the river and lakes, maintained by the EPA and used throughout the group of organisations participating in the implementation of the Water Framework Directive (WFD) are used. National feature code identification schemes developed for the WFD are maintained by the project. This ensures compatibility between the information systems used for the WFD and Flood Studies and helps to facilitate interoperability between these strategic and related initiatives.

The terms of reference of the project require that geographical analyses are carried out to a considerable level of detail This has resulted in a database that contains some 134,000 separate locations of analysis (with individual site sub-catchment characterisation and local flood plain analysis). This level of detail is thought to compare very favourably with related international studies.

The detailed scale of analysis has required a thorough assessment of the source datasets and attention to detail in the derivation of the required characteristics and descriptors. During implementation of the project it has been necessary to liaise with OPW on several occasions to determine optimum methods for particular technical matters as these arose. Many issues stem from (localised) errors or limitations in source datasets.

The project is structured into 4 principal stages:

- The development and mapping of a flood attenuation indicator polygon along rivers, streams and around lakes. To facilitate the analysis sampling points (un-gauged nodes) are placed along the river network at an interval of 500 metres. Analysis is performed anywhere the catchment drainage area exceeds 1km^2. (Stage I).

- The development of sub-catchment boundaries for the un-gauged nodes and calculation of fundamental sub-catchment properties – area, centroid and mean elevation. (Stage III).

- The derivation of Hydrological Catchment Descriptors and Spatial Catchment Descriptors for the sub-catchments of a series of gauged locations (Stage II) and the un-gauged nodes (Stage IV). The Hydrological Catchment Descriptors are based on different analyses of the river network in the catchments of the respective catchments. The Spatial Catchment Descriptors utilise relevant datasets from other national organisations useful in describing hydrological properties of the catchments – returning mean value or percentage class area statistics in most cases.

It is pertinent to indicate key issues where improvements in source data would enable the calculation of more accurate descriptors:

- Scale and resolution of DEM elevation data (including LIDAR and other high resolution sources)

- Incorporation of Northern Ireland datasets to complete the catchment characterisation in cross border river systems.

A series of Appendices are provided:

Appendix 1 - Key Statistical summaries on a Hydrometric Area basis

-Length of river channel analysed in study
-Number of Un-gauged and intermediate nodes
-Number of Nodes with sub-catchments and Spatial Descriptors
-Number of Nodes with Hydrological Descriptors
-Number of river systems with FAI polygons
-Number of river segments with FAI component polygons
-Number of lakes with FAI component polygons
-Area (km^2) of FAI polygon along river segments
-Area (km^2) of FAI polygon at lakes (inc. lake area)
-Area (km^2) of FAI polygon in Upper Estuary

Appendix 2 - Data model diagram (to show linkage of component datasets)

Appendices 3-12 - Database fields in component datasets

2. Stage I Indicative Flood Attenuation Indicator (FAI)

2.1 Introduction

Objective
The objective of Stage I is to develop a map of an indicative flood attenuation descriptor for rivers and streams in Ireland. This map should reflect the extents of flood inundation for an assumed fixed depth of water above the level of the average or typical riverbank at all locations (nodes). The output should be a continuous vector polygon for each river course.

The following section outlines the development of the different GIS data components required for the development of the FAI polygons:

- Rivers, streams and lakes
- Nodes and Intermediate Nodes
- OSi DEM (node elevations)
- Cross-Section lines
- FAI polygons for each river segment and individual lake
- Integrated FAI polygons for river systems

The datasets of rivers/streams and lakes were obtained from the Environmental Protection Agency (EPA). These datasets are derived from original medium resolution 1:50,000 scale Ordnance Survey of Ireland map features but have been subject to significant improvement by EPA to provide a suitable water feature geo-database for implementation of the Water Framework Directive (WFD) in Ireland. The standard identification codes developed by EPA for each river segment and lake have been retained in the OPW FSU geo-database ensuring that correspondence can be maintained between the different WFD and OPW FSU applications.

The geometric model for the river system is based on a series of river segments. A river segment is defined as the line between two confluences. A river main stem or its branch network, as discernible on a map, is thus comprised of a chain of river segments. There is thus no a priori minimum or maximum river segment length. In particular it should be noted that a river can contain short river segment elements dependent on the geometry of a river and its tributaries.

See Appendix A3 and A4 for River and Lake Dataset Fields

2.2 Nodes

The specification for the project requires that node points (ungauged nodes) are placed at 500m intervals along each river/stream where the catchment area >= 1km^2. The nodes are effectively a series of systematic sampling points along the river network continuum and form a fundamental data component of the whole project. The nodes provide the points at which the shape of the FAI polygons is mapped and FAI width is determined. In addition the nodes provide the sampling points at which the Spatial and Hydrological Catchment Descriptors are measured.

To meet the node location objective an initial analysis was performed to determine the initiation points on each river system where the 1km^2 drainage area threshold was exceeded. Two datasets are required to perform this task – the EPA vector river network which defines the path of the rivers and a raster Digital Terrain Model (DTM) that records catchment area information. This analysis used the EPA 1:50,000 scale Hydrologically Corrected DTM (hDTM) as it is thought to provide the best available source of landscape drainage path information (Preston and Mills, 2002).

Whereas the mapped river network is recorded from analysis of aerial photography and stored in the vector river segment class, a secondary set of flow paths across the landscape is inherent within the hDTM. These flow paths represent a synthetic drainage network that can also be converted to vector format for comparative analysis against the true mapped river network.

The hDTM based synthetic drainage network has a calculated drainage area at every point whereas this is not known in the mapped river network. Thus it is necessary to analyse the hDTM data to determine the location of the 1 km^2 drainage area threshold along each river branch. Such synthetic flow paths were extracted only where the drainage area was >= 1 km^2.

Points that represent the threshold of 1 km^2 drainage area were located at the 1 km^2 threshold boundary on the synthetic drainage network. Subsequently flow lines were extracted from the DTM that run from these threshold points downstream to the river system outlets at the marine boundary.

The initial task in the node placement routine was to identify the locations on the vector river network that best correspond with the 1km^2 drainage area threshold points on the hDTM. In most locations a good correspondence exists between the vector river lines and the DTM flow lines permitting a straightforward placement of the initial nodes.

Where a good correspondence exists between the mapped river network segments and the synthetic flow path vectors (Figure 1) a correspondence code can be recorded between the two objects. *Inter alia* this assists the automated delineation of un-gauged node sub-catchments described in Stage III.

However, in certain locations typically occurring in flat terrain, the correspondence between the DTM flow lines and vector river lines is poor or variable (Figure 2). In these situations a point has to be identified on the vector river network that best corresponds to the initiation of the 1km^2 drainage area threshold in the DTM. This task required manual verification and in certain locations correction of points initially determined from automated analysis.

It is also important to note that in some localities the DTM analysis indicates that the upstream ends of the vector river network occur where the drainage area already exceeds 1km^2. In these locations the initial node is placed at the start of the relevant 1st order streams.

Once the suite of initial nodes has been placed in the upstream region of each river system, subsequent nodes are placed at 500m intervals along each river segment and at the end of each river segment. Nodes were not placed where these would occur within 100m of the downstream node at the segment end (either at a confluence or lake inflow). Thus a gap of up to 600m can occur between the penultimate node on a river segment and the segment end node.

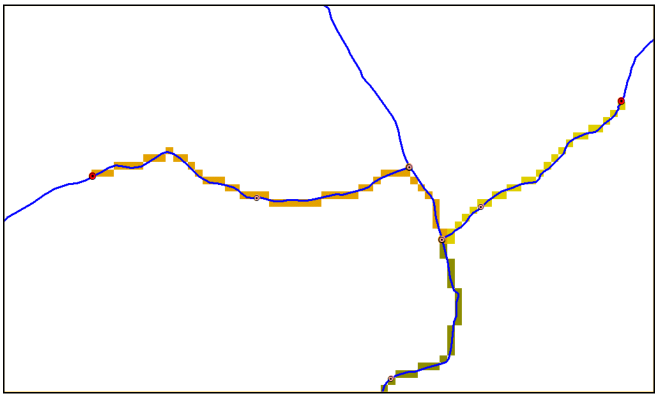


Figure 1 - Mapped river network (blue) and hDTM synthetic flow lines (good correspondence)

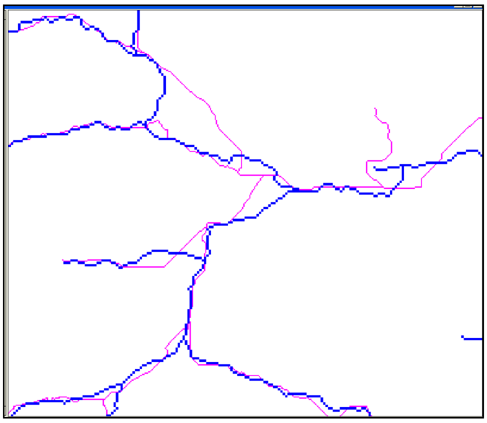


Figure 2 - Mapped river network (blue) and hDTM synthetic flow lines (variable correspondence)

Intermediate Nodes
To enhance the accuracy of the FAI polygons that would be determined subsequently, the Compass method also placed intermediate nodes at 100m intervals along the river network between the 500m spaced nodes that comprise the formal un-gauged node network (Figure 3).

Based on the 1km^2 drainage area threshold and 500m node interval rule a total of ~139,000 nodes were inserted into the un-gauged node network. In addition some 290,000 intermediate nodes were developed to assist the FAI polygon delineation process.

The node identification codes are set out in Table 1 below. The method applied uses a hierarchical convention that relates each node on a river segment to the parent river segment code and sequentially identifies each node using a numerical suffix that increases in the downstream direction. In a similar way, the intermediate nodes are identified by reference to their parent node and obtain a further numerical suffix that also increases in the downstream direction.

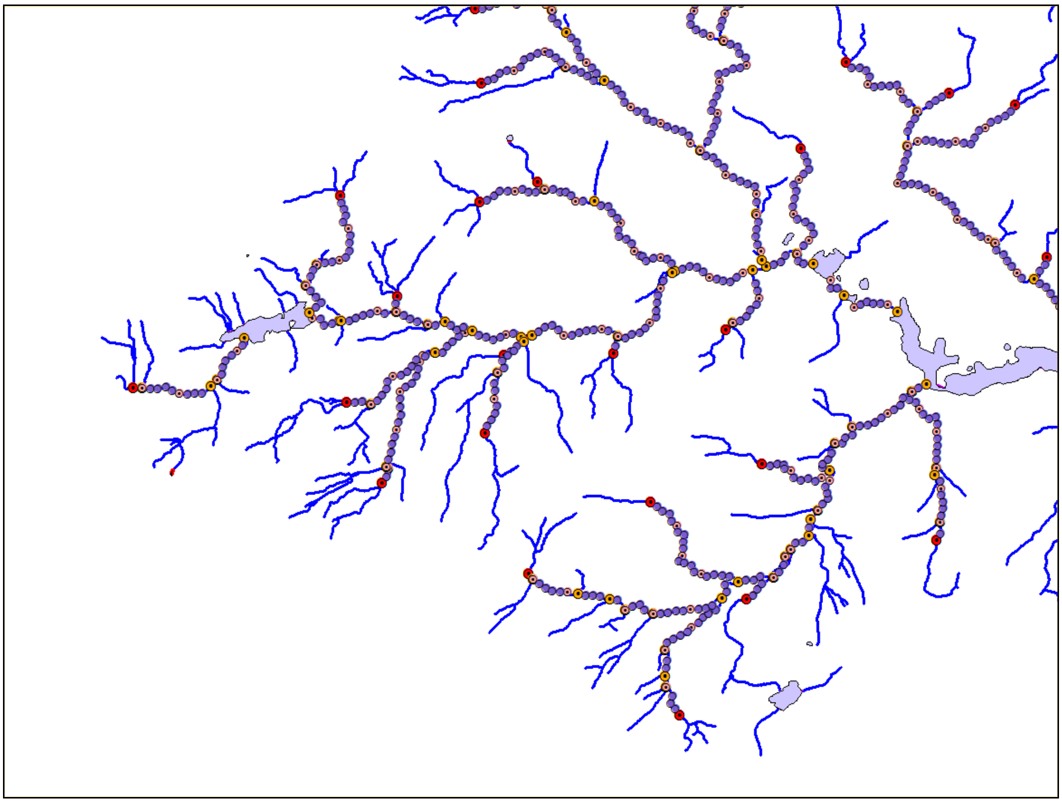


Figure 3 - Ungauged Nodes and Intermediate Nodes

Table 1 - Node Feature Class Table (identification fields)
(node_xx.shp and Node_int_xx.shp - where xx = Hydrometric Area Code)

Field	Example	Note
RWSEG_CD	08_206	River Segment Code
NODE_ID	08_206_1	Un-gauged Node ID (parent of Intermediate Node)
INTER_ID	08_206_1_1	Intermediate Node ID

See Appendix A5

2.3 OSI DEM

Flood plain and bank level elevations in the project are determined from the Ordnance Survey of Ireland (OSi) 10m spatial resolution DEM. These data were initially obtained from OSi as a series of ASCII format files each 20 x 20 km in extent and required data processing to derive suitable files for the elevation analysis task to map the FAI polygons.

In the initial stage the source data were converted to a series of GIS point files with a 10m spatial interval and extent of 20 x 20 km. In the second stage a DEM was developed for each of the 20 x 20 km tiles from the point data. Subsequently the series of DEM tiles required to cover the extent of each Hydrometric Area were identified and merged to provide integrated Hydrometric Area DEM datasets.

The OSI DEM is provided as a series of Hydrometric Area elevation grids.
(OSI_DEM_xx – where 'xx' = Hydrometric Area code)

2.4 Node Elevations

The elevation of each node (ungauged node and intermediate node) has been obtained through a three stage process. This is later taken as the nominal bank level in the derivation of the Floodplain Attenuation Indicator (see Section 2.6)

Node Site Elevation
In the first stage the elevation value of the OSi DEM grid cell on which the node occurs is obtained and recorded Node Table field ('osi_elev').

Node Patch Elevation
In discussion with OPW it was agreed that this value may not be a reliable measure of elevation due to potential misalignments between the 1:50,000 scale river network (along which nodes are placed) and the OSi DEM. Rather is was agreed that a median value, based on the elevations of a series of DEM grid cells adjacent to the node, would be recorded. However, in as far as is possible the grid cell series should avoid the floodplain. Thus the method applied uses an elevation sampling window whose size is dependent on the stream order value of the stream (Strahler, 1952):

Strahler Order 1-3	30 x 30 metres (3 x 3 grid cell array)
Strahler Order 4-5	50 x 50 metres (5 x 5 grid cell array)
Straher Order >5	70 x 70 metres (7 x 7 grid cell array)

The median value of the elevations within the sampling window is recorded in the Node Table field 'med_elev', and is taken as the nominal bank level in the derivation of the flood plain attenuation indicator. The square footprint polygons used to define the DEM sampling window for each node are recorded in the shapefiles 'osi_foot_xx.shp' (where 'xx' corresponds to the Hydrometric Area code).

The assumed flood level, as utilised to derive the Flood Attenuation Indicator (Section 2.6), is 1 metre above the median elevation.

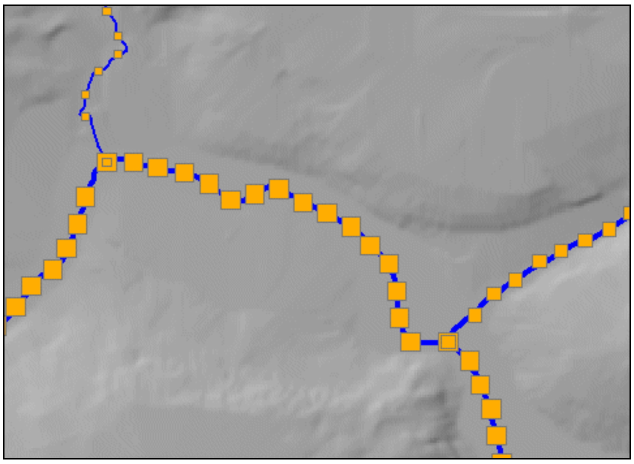


Figure 4 - OSI Footprint for nodes along rivers

Table 2 - OSI_Footprint Feature Class Table
(OSI_FOOT_xx.shp - where 'xx' = Hydrometric Area code)

Fields	sample	Issued Fields
NODE_ID	26_1_1	NODE_ID / INTERMEDIATE NODE ID
RWSEG_CD	26_1	parent RWSEG_CD Code
WIDTH	50	WIDTH of OSI DEM sampling Footprint (width is multiple of 10m cells)
HEIGHT	50	HEIGHT of OSI DEM sampling Footprint (height is multiple of 10m cells)

See Appendix A6

Backwater Elevation
Backwatering upstream of structures may occur along watercourses. In addition limitations in the OSI DEM can lead to apparent localised increases in the general topography in the downstream direction. In discussion with OPW it was agreed to derive a further estimate of elevation at each node on the basis of a potential backwatering or 'false' topographic effect. It is applied through analysis of the river network from the river system outlet (marine boundary) back up through each tributary system to the most upstream node on each branch (at the 1km^2 catchment threshold).

The backwatered node elevation values are recorded in the Node table field 'back_elev'. At the marine boundary the median elevation value of the downstream node sets the initial value for the backwatered elevation. In succession, the median elevation value of the next node (or nodes if a tributary branching is encountered) is compared to the backwatered elevation of the downstream node to implement the following rules:

- where the median elevation of the relevant node(s) is greater than the downstream node backwatered elevation then the backwatered value for the relevant nodes is set equal to the median elevation.

- where the downstream backwatered elevation is greater than the node(s) median elevation then the backwatered elevation value for the node(s) is set to equal the downstream node backwatered elevation, except

- where the downstream backwatered node elevation exceeds the node median elevation by > 1 metre then the backwatered elevation for the node is capped at the node median elevation + 1 metre.

The backwatering analysis therefore allows a backwatering effect to be added to the median elevation for the node to a maximum of 1 metre and ensures that no elevation decrease is recorded in an upstream direction (except in those extreme cases where the downstream median elevation is more than 1m above the upstream median elevation). The method thus helps to remove the effect of inaccuracies associated with all elevation values recorded in the OSI DEM.

It is important to note that the detection of a potential backwater effect is based solely on analysis of the OSi DEM using a median estimate of elevation adjacent to each node. It is possible therefore that artefacts or errors in the DEM could indicate a false backwatering. Such artefacts or falsely increased estimates of river channel elevation can occur in particular in the vicinity of engineered structures (e.g. bridges) or where natural rock structures occur adjacent to the channel.

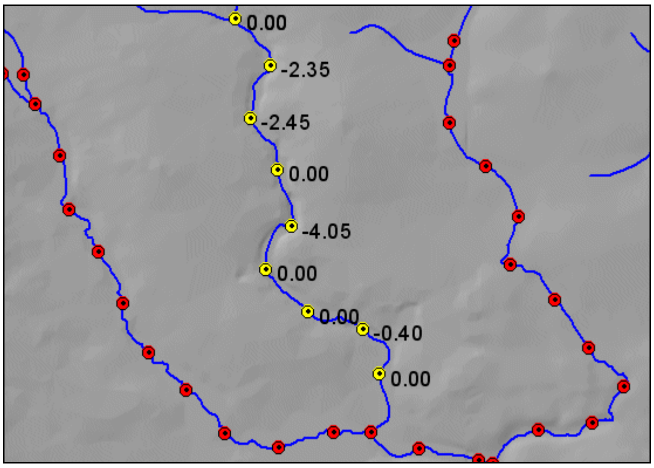


Figure 5 - Backwatering Requirement

Table 3 - Node Feature Class Table (elevation fields)

Field	Example	Note
OSI_ELEV	12.649	OSI DEM elevation at node
MED_ELEV	12.745	Median OSI DEM elevation adjacent to node
BACK_ELEV	13.523	Backwatering adjusted DEM elevation assigned to node

2.5 Cross sections

Cross section lines are located at each un-gauged node and intermediate node. These extend onto the floodplain and comprise a separate left-hand and right-hand element. The maximum length of each element in the pair is 5km giving a maximum cross section width of 10km.

The orientation of the cross section for each node is set by a two stage process. In the first stage a primary orientation vector is developed as a straight line that connects the start point and end point of the river segment vector. The river segments are GIS river lines drawn between river confluences and are of variable length. However, to accommodate meanders or other local deviations in direction along the river segment a second stage ‘flexing’ modification is introduced that is specific to each node (which are spaced at 500m intervals along the river segment). This is based on the orientation of a shorter straight line drawn between points along the river channel adjacent to the node as described below.

The length of these local secondary lines is adapted to the size of the stream which is determined by stream order value and is shorter on small streams. Thus deviations from the primary orientation vector can be greater along small streams. Cross section lines are placed orthogonal to the direction of the secondary lines. The overall objective is to place cross sections on the floodplain in a direction that is orthogonal to the direction of the stream and to anticipate that flood plains associated with small streams are likely to be narrow. The rule base for the orientation of the secondary vectors is:

Stream Order value	1-2	secondary line length 100 metres
Stream Order value	3-4	secondary line length 300 metres
Stream Order value	5-6	secondary line length 600 metres
Stream Order value	>6	secondary line length 800 metres

In should be noted that the length of an individual river segment may be less than the stream order based secondary line length. In these cases the primary orientation vector is used to determine the cross section orientation.

At a river confluence the data model contains three nodes – the end points of the two upstream branches and the start node of the downstream element. Each of these nodes has an associated cross section. The orientation of each of these cross section lines can be different dependent on the direction of the primary or secondary orientation vectors.

Analysis of elevation along the cross section lines is subsequently used to determine the shape and width of the Flood Attenuation Indicator (FAI) polygon. Therefore the database Table of the Cross-Section class includes the elevation values associated with the parent nodes (median elevation values of the nodes, as described in Section 2.4) to facilitate the analysis.

The FAI polygon also incorporates a zone around lakes. Radial lines rather than cross section lines are placed around the shore of the lake to facilitate the development of the FAI. Radial lines are placed at an interval of 100metres along the shoreline. A minimum of 4 radial lines are placed around each lake – thus where a lake shoreline length is less than 400 metres the interval between the radial lines is less than 100m.

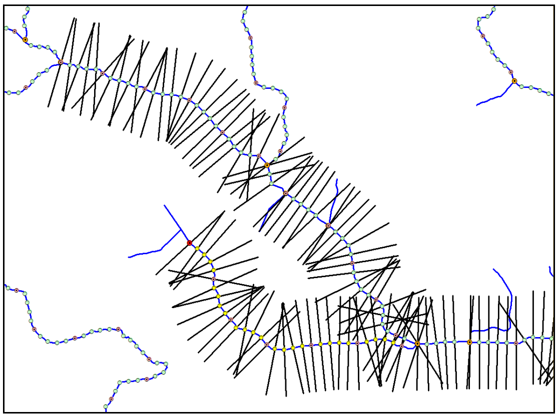


Figure 6 - Node Cross Section Lines

Table 4 - Cross Section Feature Class Table
(XSECTt_xx.shp – where 'xx' = Hydrometric Area code)

Fields	sample	Note
NODE_ID	09_1_1	NODE_ID / INTERMEDIATE NODE ID
NODE_TYPE	river	River or Lake
SIDE	right	Left or Right side from Node (d/s direction)
COUNTER	1	Counter (1..n along river segment or around lake)
RWSEG_CD	09_1	parent river RWSEG_CD Code (river cross sections only)
MED_ELEV		Median OSI DEM elevation adjacent to node
BACK_ELEV		Backwatering adjusted DEM elevation assigned to node
LWSEG_CD		parent lake LWSEG_CD Code (lake shore radial 'sections lines' only)

See Appendix A6

2.6 FAI polygons (river segment and individual lakes)

The indicative flood attenuation descriptor (FAI) is developed from topographic analysis of the floodplain adjacent to each river segment. Specifically the topographic analysis is carried out at each node and intermediate node placed along the river segment. Flood plain elevation is recorded from the OSi 10 metre DEM (as described in Section 2.4).

As outlined in previous sections each un-gauged node and intermediate node is assigned median elevation and backwatered elevation values. In addition each node is associated with a pair of cross-section limbs placed on the adjacent floodplain whose orientation is adapted to the orientation of a local sub-reach of the river channel.

The FAI polygon developed is based on an assumed depth of 1 metre above the nominal bank level (which in turn has been derived from the median elevation analysis at the nodes – section 2.4). An option to derive other scenarios, as alternative fixed values of depth or alternative function values that yield a notional depth, was provided to OPW as part of the project scope.

A multiple stage process was employed to develop the FAI polygon for each river segment or lake. In synoptic form this involved 3 tasks – cross section DEM analysis for the 1 metre limit; creation of FAI polygons based on limits along each associated cross section line and post- processing of individual FAI polygons to address certain artefacts as agreed with OPW. In more detail the process involved:

Cross Section DEM Analysis

- Points placed at 10 metre intervals along each cross-section line associated with each un-gauged and intermediate node.
- Based on backwatered elevation values recorded for each node, DEM analysis was performed for each 10m spaced point along each cross section line to identify the 1 metre elevation gain limit on both the left and right banks.
- In instances where the 1 metre elevation gain was not obtained along each 5km long cross section limb, a notional FAI polygon limit point was assumed at the end (5m extent) of the cross section line.
- In the uncommon instance where a drop-out or 'null value' patch was encountered in the OSi DEM along a cross section line and where the 1 metre elevation gain had not been obtained, a notional FAI polygon limit point was placed at the point prior to the 'null value' patch.
- The FAI cross section line 1 metre elevation gain limit points for each bank were recorded to a point feature class (xsect_ends_*xx*.shp – where 'xx' = Hydrometric Area code).
- Lakes obtain their backwatered elevation value from the river node at the start of the outlet river or stream.

  The rule base used for floodplain elevation analysis around a lake is the same as for a river, except the method employs the radial lines rather than river cross sections. The lake nominal bank level is assumed to be the level recorded at the lake outflow node.

FAI Polygon Creation

- An initial FAI polygon was developed, for each river segment and lake, by threading together a line that connected the 1 metre elevation gain limit points identified along each associated cross section line. This outline was converted to polygon format.
- The width of the FAI polygon at each node (sum of left and right limb cross section limits distances) is recorded to the Node Feature Class Table.

Post Processing of FAI polygon

- In planform the shape of the FAI polygon, based on the DEM analysis of the individual cross section lines, often exhibits spikes. These arise where the length along a cross section line to obtain a 1 metre elevation gain is significantly greater than the length to obtain same along the neighbouring upstream and downstream cross sections. Whereas this effect can arise from real differences in flood plain topography it can also be an effect from errors in or as a consequence of the inaccuracy factor associated with the OSi DEM (considered to be in the region of +/- 3 metres. In discussion with OPW it was agreed that a degree of 'spike' shortening would be performed to reduce the degree of irregularity in the shape of the FAI polygon. The rule base for spike reduction was :-

  - a spike is defined where the distance along a cross section line to the 1 metre elevation gain limit exceeds 150% of the mean of the neighbouring cross section 1 metre gain lengths. In these instances the spike is reduced to 150% of the mean of the neighbouring cross section 1 metre gain lengths, except

  - where the spike is within 100 metres of the river segment no modification is made.

  - where two or more adjacent cross section lines all exhibit an extended 1 metre elevation gain distance this is not considered to be a 'spike'. Rather this is referred to as a 'spike wedge' and it is not modified as it is more likely to represent the true nature of the floodplain topography.

- The raw FAI polygons for a particular river segment can, on occasion, extend onto and beyond a neighbouring river branch. This infers that the 'interfluve' between the adjacent rivers does not exceed 1 metre in elevation, as recorded on the OSi DEM. In discussion with OPW it was agreed that the extent of a FAI polygon for a particular river segment should be limited to the edge of a neighbouring river segment. This rule, however, can only be readily implemented where overlay of the raw FAI polygon by the neighbouring river segment completely divides or cuts the FAI polygon.

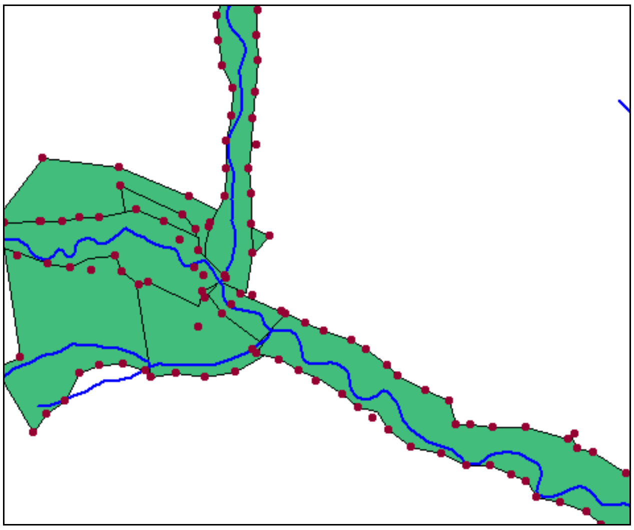


Figure 7 - FAI Polygon

Table 5 - Node Feature Class Table (FAI width fields)

Fields	sample	Note
NODE_ID	08_206_1	Un-gauged Node ID
WIDTH	200	FAI analysis width along Cross-Section line associated with Node
L_WIDTH	110	Left Hand Side - FAI analysis partial width along Cross-Section line associated with Node
R_WIDTH	90	Right Hand Side - FAI analysis partial width along Cross-Section line associated with Node

Table 6 - Component FAI Polygon Feature Class Table
(XSECTPOLY_xx.shp – where 'xx' = Hydrometric Area code)

Fields	sample	Note
SEG_CD	09_1	parent river RWSEG_CD code
FLOOD_Z	1	Flood Level above Bank. (Derived as 1m above the Node Backwatered Median OSI DEM Elevation
AREA_KM	0.016	Area of River Segment piece FAI polygon (have overlap with another segment FAI polygon piece)
NODE_TYPE	river	River or Lake
SYSTEM_CD	09_631	Code of river system outlet river segment. Used to integrate all u/s river segment FAI pieces to single river system FAI polygon

See Appendix A7

2.7 FAI polygons (river systems)

Each river segment or lake assessed in the development of the individual FAI polygons is associated with a particular river system. A river system is defined as a series of river segments and associated lakes that has a discrete outlet at the marine boundary. In the project scope river systems with a minimum catchment area of 1km^2 contain nodes and FAI polygons. Many of the river systems are large and are named on Ordnance Survey maps, however, many others are small and not named on maps.

Irrespective of whether the river system is large or small, all river segments and lakes within the system are encoded with a unique catchment code. This code is identical to the river segment code of the most downstream river segment at the marine boundary.

At the individual river segment or lake level, the FAI polygon associated with each feature can have a partial overlap with neighbouring FAI polygons. This overlap is removed once an integrated (river system) FAI polygon is created.

The integrated FAI polygon Table contains the following attribute fields:

CATCH_CD	unique identification for river system
COUNT	number of individual river and lake FAI elements
AREA_KM	Area (km^2) of integrated FAI polygon

Table 7 - Integrated (river system) FAI Polygon Feature Class Table
(FAI_*xx*.shp – where 'xx' = Hydrometric Area code)

Fields	sample	median elevation sampling
CATCH_CD	32_1052	Code of river system outlet river segment. Used to integrate all u/s river segment FAI pieces to single river system FAI polygon
COUNT	11	number of river segment FAI polygon elements comprising integrated river system FAI polygon
AREA_KM	0.551	area km^2 of integrated FAI polygon

See Appendix A7

Appendix 1 provides summary statistics on the FAI polygons on a Hydrometric Area basis

3. Stage III Sub-Catchment Delineation

3.1 Introduction

Objective
The objective of Stage III of the Contract (Provisional) is to develop a tool to delineate sub-catchments (i.e. create polygons, areas, centroid locations and mean altitudes) for ungauged sub-catchments to points (or nodes) at equal intervals of 500m starting at the upstream end, along every river and stream, and at all confluences in the Republic of Ireland. The tool shall be based on a hydrologically corrected digital terrain model of the Republic of Ireland (e.g. A Hydrologically Corrected Digital Terrain Model for Ireland – Preston, Mills, 2002).

The delineation of the sub-catchments (polygons) is based on the distribution of un-gauged nodes described in Stage I of the Report. These are located along the river network where the catchment area >= $1km^2$.

In principal a sub-catchment is delineated for each ungauged node – i.e. including 3 separate polygons at each confluence point and a polygon at lake inflow *and outflow* locations. However, in certain locations typified by flat terrain, analysis of the Hydrologically Corrected Digital Terrain Model (hDTM) does not provide an adequate representation of the catchment area at the un-gauged node and a sub-catchment is not recorded. This failure is restricted to approx 4% of the 139,000 un-gauged nodes.

Sub-catchments are not recorded for the intermediate nodes, spaced at 100 metre intervals between the un-gauged nodes, which serve solely to aid development of the FAI polygons (Stage I).

3.2 Automated Process

Derivation of sub-catchments using the hDTM requires the availability of two subsidiary grids derived from the DTM known as the Flow Direction and Flow Accumulation Grids. The Flow Direction grid records the direction of flow out of each cell into one of its eight neighbours. The Flow Accumulation grid records the accumulated flow to each cell, by summing the number of upstream cells that flow into each downslope 'target' cell. Both of these grids were provided by EPA to the FSU project in conjunction with the source hDTM grids.

As described in Stage I (Nodes), the position of the river segments (along which the un-gauged nodes are located) does not always coincide with the flow lines contained in the hDTM (and visualised by the Flow Accumulation grid). In extreme cases this prevents creation of the un-gauged node sub-catchments. Examples of these situations are described.

In principal the development of sub-catchments for the un-gauged nodes can be achieved through an automated process. Each node has an exact position, represented in Irish National Grid coordinates and recorded in the Node attribute table fields 'node_east' and 'node_north'. Analysis of the hDTM synthetic flow path element and Flow Accumulation Grid in the vicinity of the node point indicates equivalent points on the hDTM at which a catchment can be defined using the standard GIS 'Watershed' function. These locations are technically known as 'pour points' and their location is recorded in the Node attribute table fields 'pour_east' and 'pour_north'.

3.3 Adaptive Process

Where an adequate correspondence does not exist between the river segment and synthetic flow path vectors, the nodes are flagged for the 'adaptive' sub-catchment delineation process. This process zooms to each such river segment and presents the river segment, nodes and synthetic hDTM flow path to the operator. The operator can select each component node in turn and point to a representative location on the hDTM – the position of which is recorded as the node's pour point in the attribute Table fields 'pour_east' and 'pour_north'.

Where it is not possible to identify adequate pour points for any node associated with the river segment the operator can elect to flag the whole segment as failing to record any sub-catchments. This occurs on ~ 1265 segments or 3% of the total number of river segments with nodes (i.e. catchment area >= $1km^2$). This property of the river segment is recorded in the River Attribute Table field 'pour_stat'. Values in this field are:

- 'Pourpt' -where some or all of the segment's nodes obtain pour points and thus sub-catchments
- 'FAIL' -where no sub-catchments are made for any node along the segment
- 'No Node' - where the segment does not contain nodes – i.e. area threshold < $1km^2$.

During the adaptive process some of the nodes may obtain pour points and others not if adequate sub-catchment representation is not possible adjacent to the un-gauged node location.

3.4 Catchment Delineation

The actual derivation of the sub-catchments from the hDTM is a time consuming automated process that can take several days to complete for the set of un-gauged nodes in a large Hydrometric Area.

The watershed function returns an individual grid file that represents the sub-catchment for each of the un-gauged nodes. These grid files are not retained, rather a vector polygon version is derived (Figure 8) and saved as a separate shapefile and the area of the shapefile polygon is recorded as an attribute of the Node Table (field 'poly_area' as km^2).

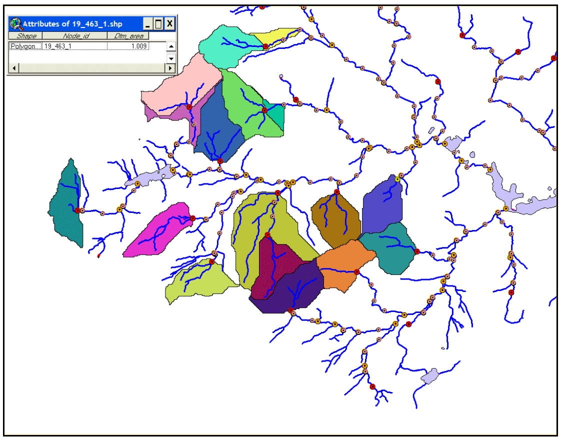


Figure 8 - Sub-Catchment examples

3.5 Verification

Given that the majority of the un-gauged node catchments are derived from an automated process it is important that Quality Control processes are applied to verify that a correct representation of the catchment has been obtained for all nodes, irrespective of whether the hDTM pour point for the node has been derived by the automated process or the operator assisted adaptive process.

A rule base was applied to enable an automated verification process:-

- The area of the 1st node on the downstream segment at a confluence must exceed the sum of the sub-catchment areas of the end nodes of the branches that flow into the confluence.

- The area of the 1st node on the outflow segment at a lake must exceed the sum of the sub-catchment areas of the end nodes of the lake inflow streams

- Along a river segment the sub-catchment area of each consecutive node must exceed the catchment area of the upstream node.

- The catchment area of the last node on a river segment should not exceed the area of the penultimate node on the same river segment by more than 100%. This is to ensure that the catchment area of the segment end node does not extend beyond the true segment end (i.e. does not extend into a confluence that may occur near the marine boundary etc).

Where these verification rules are not violated, the set of sub-catchments associated with the un-gauged nodes along a river segment can be considered to be correct.

Where the rules are violated the operator can inspect the nodes and perform the following steps:

- re position the node's pour point on the hDTM

- flag that a sub-catchment can not be derived for an individual node

- flag that no sub-catchment can be derived for the suite of nodes along the segment

If a re-positioning of node pour points on the hDTM is carried out then the automated catchment delineation process is re-run for those nodes and subsequently the verification rules are re-applies. This remains an iterative process until an adequate sub-catchment has been obtained for the nodes or they are flagged as failing to obtain a sub-catchment.

At the node level, the status of sub-catchment delineation for each node is recorded in the Node Attribute Table field 'node_catch'. Values in this field are:

- 'Poly' -where an adequate sub-catchment was obtained from the original automated process and the verification checks were passed.

- 'Mod Poly' –where an inadequate sub-catchment was obtained initially, but the operator assisted ' adaptive' process subsequently obtained an adequate sub-catchment polygon

- 'FF' -where an adequate sub-catchment polygon is not available for the node, despite attempts made through the 'adaptive' process.

Summary statistics indicate that ~ 3% of the nodes failed to obtain a polygon (attribute = "FF") and ~17% acquired a catchment polygon via the adaptive process (attribute = "Mod_Poly").

The deliverables from STAGE III comprise:

- Sub-catchment polygons for the un-gauged nodes.
  (These are amalgamated into a single shapefile per Hydrometric Area, with a sub-catchment polygon for each mapped un-gauged node) *(Ungauged_xx.shp – where 'xx' = Hydrometric Area code).*

- Sub-catchment Area
- Sub-catchment Centroid coordinates
- Sub-catchment Mean Altitude
  (These three descriptors are discussed in Report Section IV)

Table 8 - Node Feature Class Table (sub-catchment related fields)

Field	Example	Note
RWSEG_CD	08_206	River Segment Code
NODE_ID	08_206_1	Un-gauged Node ID
NODE_EAST	314057	Node Easting
NODE_NORTH	274126	Node Northing
POUR_EAST	314063	EPA hDTM pour point for Node (easting)
POUR_NORTH	274123	EPA hDTM pour point for Node (northing)
NODE_CATCH	poly	Valid values: 'Poly' ,'Mod Poly', 'FF'
POLY_AREA	1.008	Node catchment area km^2

Table 9 - Ungauged Catchment Feature Class Table
(Ungauged_xx.shp – where 'xx' = Hydrometric Area code)

Field	Example	Note
NODE_ID	03_410_1	Node Identification code - see Stage I
DTM_AREA	1.097	Catchment Area (km^2)
CENTE	264940	*Catchment Centroid - ING Easting*
CENTN	349260	Catchment Centroid - ING Northing
ALTBAR	71.9	Catchment Mean Altitude m^{-1}

See Appendix A9

4. Stage II / IV Hydrological & Spatial Catchment Descriptors

4.1 Introduction

Objective
Creation of Spatial Catchment Descriptors
To clip and quantify, the proportion of Spatial parameters or attributes (Spatial Catchment Descriptors, supplied as GIS layers) within each catchment, as well as computing the mean altitude and centroid for .. gauged and un-gauged locations (nodes).

Creation of Hydrological Catchment Descriptors
To clip the vector river and stream network of Ireland (Ordnance Survey of Ireland / Environmental Protection Agency) and undertake vector analysis to determine physical properties of the river and stream network (Hydrological Catchment Descriptors), supplied as GIS layers, including mainstream length, stream network length, mainstream slope, stream frequency, and an index of arterial drainage extent, within each sub-catchment for .. gauged and un-gauged locations (nodes).

Stages II and IV involve the derivation of Hydrological Catchment and Spatial Catchment descriptors for the gauged and un-gauged nodes. Stage II refers to the Gauged nodes and Stage IV the un-gauged nodes.

Given that the same Descriptors, source datasets and basic methods are involved for both gauged and un-gauged nodes a single combined section is provided to describe the works.

Points that should be noted include:

- Gauged Locations

  - the sub-catchment polygons for these sites were delineated previously and provided to the WP 5-3 project by OPW. The sites are the locations of selected river gauges operated by OPW, EPA (in conjunction with Local authorities) and the ESB.

  - the sub-catchment polygons for the individual gauged sites are derived from either hDTM analysis or digitisation of boundaries drawn on 1:126,720 "1/2 inch" scale maps by OPW staff. Boundaries drawn on the ½ scale maps include areas of Northern Ireland where appropriate. Boundaries derived from hDTM analysis are restricted to the RoI area.

- Ungauged Nodes

  -the sub-catchment polygons for the un-gauged nodes have been derived during Stage III of this project based on hDTM analysis (as reported in Section 3). The sub-catchment polygons are restricted to the RoI area even where the natural catchment includes areas in Northern Ireland.

- The Spatial Catchment descriptor layers, with the exception of SAAR, SAAPE and FLATWET, and the Hydrological vector river network are restricted to the RoI area.

  - gauged sub-catchments that are cross-border will thus have a sub-catchment polygon that is larger in extent than the coverage area of the descriptor layers (known sites are 06011, 06012, 06070, 06031, 35071, and 36015). In these instances descriptors that describe mean statistics are based on an area that is less than the recorded catchment, descriptors that describe the percentage area of different classes will sum to less than 100%.

  - un-gauged catchments will coincide with the area of Spatial Catchment layers on cross border rivers but these are not complete catchment areas. In these instances the mean statistics are for partial areas, descriptors that describe the percentage area of different classes can sum to 100% but are only partial in extent.

  - A small proportion of un-gauged nodes (~3%) do not have mapped sub-catchment polygons (see Report Stage III). In these instances Spatial Catchment descriptors are not .

- The Hydrological Catchment descriptors are based on analysis of a river network that does not include Northern Ireland. Thus in cross-border catchments, for either gauged or un-gauged nodes, the descriptors are based on an incomplete river network.

- Some un-gauged nodes occur at the top of the river network (where the 1km2 catchment area threshold is already exceeded). In these instances Hydrological Catchment Descriptors, that describe the upstream network, are not available.

4.2 Hydrological Descriptors

The hydrological network dataset comprises the stream network mapped by Ordnance Survey Ireland at scale 1:50,000 into which connector lines through lakes have been added to connect the points at which inflowing streams enter the lake and the lake outlet. Where multiple inflow streams occur the connecting lines comprise a dentritic network through the lake that results in a single lake connector line joining the lake outflow river. As such the dataset is suitable for hydrological network analysis to determine collections of streams that lie upstream or downstream of given points such as gauge locations.

4.2.1 Network length (NETLEN)

The descriptor NETLEN records the length in kilometres of the hydrological network above the gauge. Where lakes occur along the hydrological network the length of connector lines through the lake is included in the NETLEN calculation.

4.2.2 Stream Frequency (STMFRQ)

The descriptor STMFRQ records the number of discrete channel elements in the hydrological network above the gauge. The EPA data model that defines the river network contains a discrete single drainage line element 1) between each confluence, 2) from a headwater initiation point to the 1st confluence and 3) from a confluence to a lake. In addition the number of lake connector lines through lakes along the network is included.

4.2.3 Drainage Density (DRAIND)

The descriptor DRAIND is a simple index that relates the length of the upstream hydrological network (km^{-1}) and the area of the gauge catchment (km^2). In the dataset for the gauged locations the descriptor DRAIND has a range from 3.479 to 0.019.

4.2.4 Mainstream Length (MSL)

The mainstream length descriptor for each gauged location is determined by a step-wise process in an automated GIS routine:

- determination of all upstream hydrological network elements
- analysis of the 'downstream distance' attribute recorded for each stream element to determine the stream element that is at the furthest network distance from the river catchment outlet – i.e. the assumed headwater*
- recording of the headwater stream element code to the geodatabase

- creation of a collection of stream (and lake connector line) elements that traverse the hydrological network between the headwater and the stream element of the gauge
- summation of the length between the top of the headwater element to the gauge location on the downstream
- (the MSL route to each gauge is also recorded in the geo-database as a single composite GIS polyline that includes any relevant lake connector lines)

MSL is recorded as a distance in kilometres

* an alternative means to determine the mainstream headwater would be, in an upstream direction, to follow the stream path that utilises the largest catchment area of each stream confluence element. This approach is not adopted in the current project.

4.2.5 Mainstream slope (S1085)

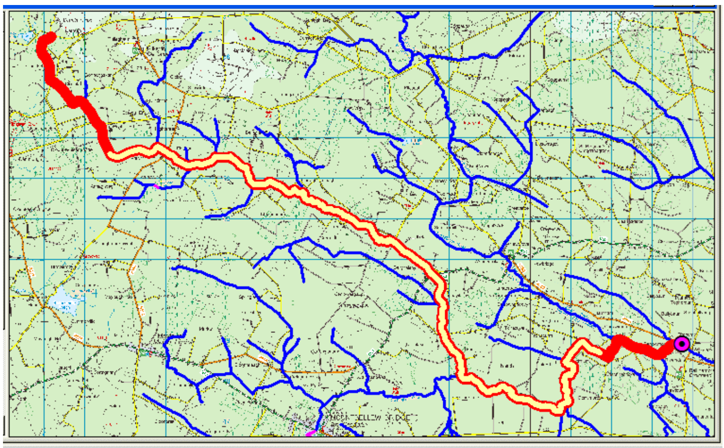
As per the Flood Studies Report (NERC, 1975) the mainstream slope was determined between the 10 and 85 percentiles of the mainstream length (upstream from the gauge station) in a method previously utilised by the United States Geological Survey. Exclusion of the terminal portions is thought likely to exclude the highest and lowest gradients in most instances.

The S1085 descriptor for each gauged location is determined by a step-wise process in an automated GIS routine:

- removal of the downstream end 10% and upstream end 15% from the original MSL polyline to create a specific S1085 GIS polyline
- query of the OSI DEM to determine the elevation at the upstream and downstream ends of the S1085 line
- calculation of the elevation difference between the S1085 upstream and downstream limits
- determination of the S1085 slope as 'elevation *difference' / S1085 length*.
- (the S1085 route to each gauge is also recorded in the geo-database as a single composite GIS polyline that includes any relevant lake connector lines)

<u>*Adaptive process*</u>
In a small number of locations the upper or lower ends of the S1085 line may occur on 'drop out' or null value patches on the OSI DEM. In these instances the S1085 is followed downstream from the start or upstream from the end, as appropriate, until a valid elevation value is recorded. Where this occurs the S1085 slope is recorded as the slope over this shorter distance.

In any instance where the calculated value of the S1085 slope is less than 1:10000 the value is recorded as 1:10000.



gauged_hydrol_issue_2910.dbf

Station_nu	Waterbody	Location	Area	Msl	Netlen	Strmfrq	Draind	S1085
26001	SHIVEN	BALLINAMORE	240.28	25.568	201.224	146	0.837	0.001250

Figure 9 - Hydrological Descriptors – MSL and S1085

4.2.6 Taylor Schwarz slope (TAYSLO)

An alternative form of mainstream slope has also been recorded for each gauged and un-gauged location as described by Taylor and Schwarz (1952). The method used divides the MSL mainstream route into a series of discrete elements of 500m length for each of which the gradient is determined by reference to the OSI DEM. A residual section at the downstream end that is shorter than 500m normally occurs and is included in the set of slope calculations.

The TAYSLO descriptor is determined from the series of elements as:

- derivation of each element gradient [S] as {rise / run}
- derivation of square root of each element slope SQRT[S]
- derivation of the inverse of the square root of each slope {1/ SQRT[S]}
- summation of each inverse square root term
- division of the number of 500m elements [N] by the slope summation term
- derivation of the square of this term

The set of TAYSLO 500m elements to each gauged or un-gauged node is also recorded in the geo-database as a set of individual GIS polylines.

Adaptive processes

OSi DEM 'drop out'
In a small number of locations the upper or lower ends of the component TAYSLO 500 metre lines may occur on 'drop out' or null value patches on the OSI DEM. In these instances the following rule base has been implemented:

- From the downstream end in the marine zone, where OSI DEM elevation values are not available, 500 metre elements are assigned a slope of 1:10000 until valid values are found. This is based on the assumption that slopes are likely to be low.

- From the upstream end, where OSI DEM elevation values are not available, the 500 metre elements are removed from the TAYSLO calculation until valid values are found.

- Where gaps occur in the OSI DEM data along the sequence of 500 metre elements an interpolation is applied that assigns a slope value based on the last known downstream and upstream values.

Minimum Slope and Compensation
In a secondary stage, irrespective of whether the 500 metre element slopes are directly derived from the OSI DEM or from interpolation, a minimum slope algorithm is applied and a compensation effect applied in the upstream direction:

- Where the downstream slope of a 500m element is less than 1:10000 or negative (i.e. rising in the downstream direction) the elevation at the upper end of the element is elevated to provide a slope of 1:10000.

- Subsequently this 'lifting' amount is added to the OSI DEM elevation at the bottom of the next upstream section and a modified slope for the element is calculated.

- If the element slope, from direct OSI elevations or as a consequence of compensation 'lifting' is less than 1:10000 then the 'lifting' mechanism is applied in turn.

- This process of minimum slope assignment and upstream compensation is performed in a step-wise manner to the upper end of the TAYSLO 500m sequence.

- The modified slope values, for the sequence of 500 metre elements is used to determine the TAYSLO descriptor for the node.

4.2.7 Index of Arterial Drainage

Two forms or indices of arterial drainage are recorded for each gauge location:

- percentage of upstream river network length included in Drainage Schemes
- percentage of catchment area with Benefiting Lands from Drainage Schemes

Network Length (ARTDRAIN2)
The source dataset is a GIS polyline dataset 'channels_scheme_v1' originated by the OPW that maps channels included in Drainage Scheme works completed. This dataset is derived from larger scale mapping than the 1:50,000 scale national river network utilised by the PCD project – it exhibits more detail in the planform of the river elements and includes channels not present in the national river dataset.

To develop an index of the proportion of the river network of a gauged catchment that is included in Drainage Schemes a method to relate the two datasets is required. Within the ESRI ArcGIS system the Drainage Scheme network has been mapped against the river network, based on a proximity tolerance of 25m, to create a 'linear event table' that maps the occurrence and length of Scheme elements that correspond to the river network.

The ARTDRAIN2 descriptor is determined as the percentage of the catchment river network that is included in the Drainage Schemes. The actual length of such channel is recorded separately in the geo-database field ARTDR_LEN.

Benefiting Land area
The source dataset is a GIS polygon dataset 'benefit_scheme_v1' provided by the OPW. This dataset records areas considered as Benefiting Lands within Drainage Schemes completed. The original dataset categorises lands into a series of types some of which have been excluded from the analysis after consultation with OPW.

The ARTDRAIN descriptor is determined as the percentage of the catchment area that is categorised as Benefiting Lands. The actual area of such land is recorded separately in the geo-database field ARTDR_AR.

See Appendix A10 for description of Gauged and un-Gauged Hydrological Catchment Descriptor files.

4.3 Spatial Catchment Descriptors

The spatial descriptors used in the PCD project utilise relevant national datasets deemed pertinent to the estimation of flood effects from the catchment wide distribution of selected parameters or attributes. These also include analysis of the gauge catchment areas to determine attributes of AREA, centroid location (CENTE, CENTN) and mean elevation (ALTBAR).

4.3.1 Catchment Area (AREA)

The catchment area of each river gauge is directly obtained from the gauge catchment polygons for the gauge location provided to the PCD project by OPW. The catchment area of the ungauged nodes is sourced from the ungauged nodes catchment polygons developed during the project.

4.3.2 Centroid (CENTE, CENTN)

The centroid coordinates CENTE and CENTN (recorded as Easting and Northing values in the Irish National Grid system) of the gauged and ungauged node catchments are obtained by a GIS function that returns the centroid of the catchment polygon.

4.3.3 Mean Elevation (ALTBAR)

The mean elevation of the gauged and ungauged node catchment areas has been calculated by reference to the national EPA DTM grid (Preston and Mills, 2002) by utilisation of a Zonal Statistics function in the GIS. In addition to the mean elevation

(ALTBAR), the minimum, maximum and range of elevation values are provided in geo-database fields ALT_MIN, ALT_MAX and ALT_RANGE respectively.

4.3.4 Standard Period Average Annual Rainfall (SAAR)

The SAAR descriptor is derived from a dataset provided by MetEireann of the long term average annual rainfall for the return period from 1961-1990. The format of the data is a GIS raster grid dataset. The SAAR value for the gauge catchment area is determined by utilisation of a Zonal Statistics function in the GIS.

4.3.5 Flood Attenuation by Reservoirs and Lakes (FARL)

The FARL descriptor provides an index value of the attenuation effect of reservoirs and lakes as set out in the Flood Estimation Handbook, vol 5 (Scarrott, R.M.J., Reed, D. W. and A. C. Bayliss (1999), Institute of Hydrology, Wallingford).

The method utilises 3 elements of information that are contained in the GIS – lake area, lake catchment area and the catchment area at the node-point (gauged or ungauged node) along the river at which the index is calculated. Only lakes and reservoirs in the relevant catchment that are connected to the river network by mapped flow lines are included in the index – isolated lakes without mapped inflows and outflows are ignored.

The method considers 2 forms of attenuation effect in the derivation of a FARL value for each gauge location:

- a lake/reservoir specific effect based on *lake surface area / lake catchment area* of each lake
- a weighing of the relative importance of each lake in terms of flood attenuation at the (gauge) catchment scale as lake *subcatchment area / catchment area*.

The catchment descriptor FARL is the product of the individual local (i.e. per lake) index values of the lakes in the catchment.

Derivation of the FARL index values in the project is dependent on outputs from project Stage III that derives catchment boundaries for river nodes, including top nodes on lake outflow streams that describe inclusive lake catchment areas (i.e. contributing catchment to the outlet of the lake).

For each Hydrometric Gauge and un-gauged node in the Stage II/IV analysis a FARL index value has been calculated. The FARL value for a Gauge or un-gauged node is the product of the FARL index values of the individual lakes in the catchment (connected to the river network). To enable assessment of the lakes included in the FARL index for each Gauge a database table “farl_lake_list.dbf” is included (Appendix A.4 for description) which identifies each lake using the EPA national lake identification code.

It is to be noted that the specific lake catchment area of lakes with a catchment < 1km^2 has not been calculated – rather in these instances a catchment area of 1km^2 has been assumed. This arises from the overall project scope that does not require catchment area calculation where the area is < 1km^2

4.3.6 Index of urban extent (URBEXT)

The index of urban extent has been determined from the Corine Landcover 2000 dataset developed by the EPA. This is a polygon dataset derived from the analysis and classification of satellite imagery supported by ancillary information (see http://www.epa.ie/whatwedo/assessment/land/corine/). The descriptor URBEXT is based on the distribution of a subset of Corine Landcover codes and is defined as the area of urban fabric/the total contributing catchment area:

Corine 2000 code	**Description**
111	Continuous Urban Fabric
112	Discontinuous Urban Fabric
121	Industrial and Commercial Units
122	Road and Rail Networks
123	Sea Ports
124	Airports

4.3.7 Proportion of Forest Cover (FOREST)

The proportion of forest cover has been determined by analysis of three separate datasets:

- Coillte Teoranta forestry database
- Corine Landcover (EPA, 2000)
- FIPS – Forest Inventory and Planning System (Forest Service, 1998)

Spatial overlap occurs between these data sources. A single composite dataset has been developed from their combination for the determination of the descriptor FOREST.

The distribution of the following Corine Landcover 2000 classes are included in FOREST:

Corine 2000 code	**Description**
311	Broad-Leaved Forests
312	Coniferous Forests
313	Mixed Forests

The Forest Service FIPS database was published in 1998. Ongoing work is scheduled to provide an updated database in 2008. The index is defined as the area of forest area/the total contributing catchment area.

4.3.8 Proportion of Peat Cover (PEAT)

The proportion of peat cover has been determined from the Corine Landcover 2000 dataset developed by the EPA. The descriptor PEAT is based on the distribution of a single Corine Landcover code 412 – Peat Bogs. Within this class, sub-classes distinguish between Raised and Blanket, and Exploited and Intact bogs. The index is defined as the area of Peat areas/the total contributing catchment area.

4.3.9 Proportion of Grassland/Pasture/Agriculture (PASTURE)

The PASTURE descriptor is derived from the distribution of a subset of Corine Landcover 2000 classes:

Corine 2000 code	**Description**
211	Non-irrigated arable land
231	Pastures
242	Complex Cultivation Patterns
243	Land principally occupied by agriculture with significant areas of natural vegetation

The index is defined as the area of Pasture/the total contributing catchment area.

4.3.10 Proportion of extent of floodplain alluvial deposit (ALLUV)

The proportion of floodplain alluvial extent has been determined by reference to a national dataset of soil Parent Materials developed by Teagasc / EPA as a component dataset of the national Indicative Forestry Strategy project.

The descriptor ALLUV is based on the distribution of a single Parent Material class 'Alluvium'. The index is defined as the area of alluvial deposit/the total contributing catchment area.

4.3.11 Index of Wetness (FLATWET)

FLATWET is a dimensionless index of catchment wetness for Ireland developed under FSU Work-Package 5.4 (D. Reed, Report to OPW, 2007).

The variable *FLATWET* is the proportion of the time for which soils can be expected to be typically quite wet. It has been evaluated from Met Éireann estimates of soil moisture deficit (SMD) at 14 premier climatological stations. The index has been evaluated from 26 years of data (1981 to 2006). A spatial interpolation method has been devised to map the index across Ireland, so that a value of *FLATWET* can be inferred at any site or (with appropriate overlay) averaged across any catchment.

The FLATWET dataset ranges in value across the country from ~0.53 to ~0.74.

4.3.12 Standard Average Annual Potential Evapotranspiration (SAAPE)

The SAAPE descriptor is derived from a dataset provided by MetEireann of the long term average annual potential evapotranspiration for the return period from 1961-1990. The format of the data is a GIS raster grid dataset. The SAAPE value for the sub-catchment areas is determined by utilisation of a Zonal Statistics function in the GIS.

4.3.13 FAI Index

An FAI Index value is provided for the gauged and ungauged nodes. This is calculated as the proportion of the catchment area that is occupied by the FAI polygon. For a small number of ungauged nodes (<1%) no FAI index value is available. This occurs principally at headwater nodes upstream of which FAI flood analysis has not been undertaken.

4.3.14 Aquifer Class statistics

The groundwater aquifer map of Ireland is published by the Geological Survey of Ireland (GSI). It has been used in particular during the development of Groundwater Protection Schemes and groundwater characterisation, monitoring and protection measures under the Water Framework Directive.

The aquifer map is based on the hydro-geological characteristics of the principal rock formations in Ireland published as a separate Rock Unit dataset by GSI. In addition the principal overlying Sand and Gravel aquifers in the country are included in the aquifer dataset.

The aquifer data comprises some 11 primary classes. These have been grouped into 6 groups by GSI and EPA for catchment hydrological analysis – 5 bedrock aquifer groups and 1 group for sand and gravels aquifer types.

The area of each aquifer group type in each sub-catchment and the proportion of the aquifer data represented by the aquifer group are recorded as aquifer class statistics. (Appendix 12)

Aquifer Type	Code	Group
Regionally important karstified aquifer dominated by conduit flow	Rkc	Rkc / Rk

Regionally important karstified aquifer	Rk	Rkc / Rk
Regionally important karstified aquifer dominated by diffuse flow	Rkd	Rkd / Lk
Locally Important Aquifer - Karstified	Lk	Rkd / Lk
Regionally important fissured bedrock aquifer	Rf	Lm / Rf
Locally important aquifer which is generally moderately productive	Lm	Lm / Rf
Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones	Ll	Ll
Poor Aquifer - Bedrock which is Generally Unproductive	Pu	Pu / Pl
Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones'	Pl	Pu / Pl
Regionally important sand/gravel aquifer	Rg	Rg / Lg
Locally important sand/gravel aquifer	Lg	Rg / Lg

4.3.15 Soil Class statistics

A national soils dataset of Ireland has been developed by Teagasc as a component dataset of the national Indicative Forestry Strategy project. This dataset is currently released by the EPA. The dataset identifies some 27 soil types which for catchment hydrological analysis purposes have been grouped by EPA / ESBI into 6 groups. The area of each soil group type in each sub-catchment and the proportion of the soil map data represented by the soil group type are recorded as soil class statistics. (Appendix 12).

The Soil groups are:

- Poorly Drained 13 soil classes
- Well Drained 7 soil classes
- Peat 4 soil classes
- Alluvium 1 soil class
- Made ground 1 soil class
- Water 1 soil class

4.3.16 Subsoil Permeability Class statistics

A national subsoil permeability dataset has been developed by GSI. The dataset identifies 5 subsoil permeability classes. The area of each subsoil group type in each sub-catchment and the proportion of the subsoil map data represented by the subsoil group type are recorded as soil class statistics. (Appendix 12).

The subsoil permeability groups are:

- High Permeability
- Moderate Permeability
- Low Permeability
- Moderate / Low Permeability
- Unclassified (frequently areas of bare rock)

See Appendix A10 for description of Gauged and Ungauged Hydrological Catchment Descriptor files.

Appendices

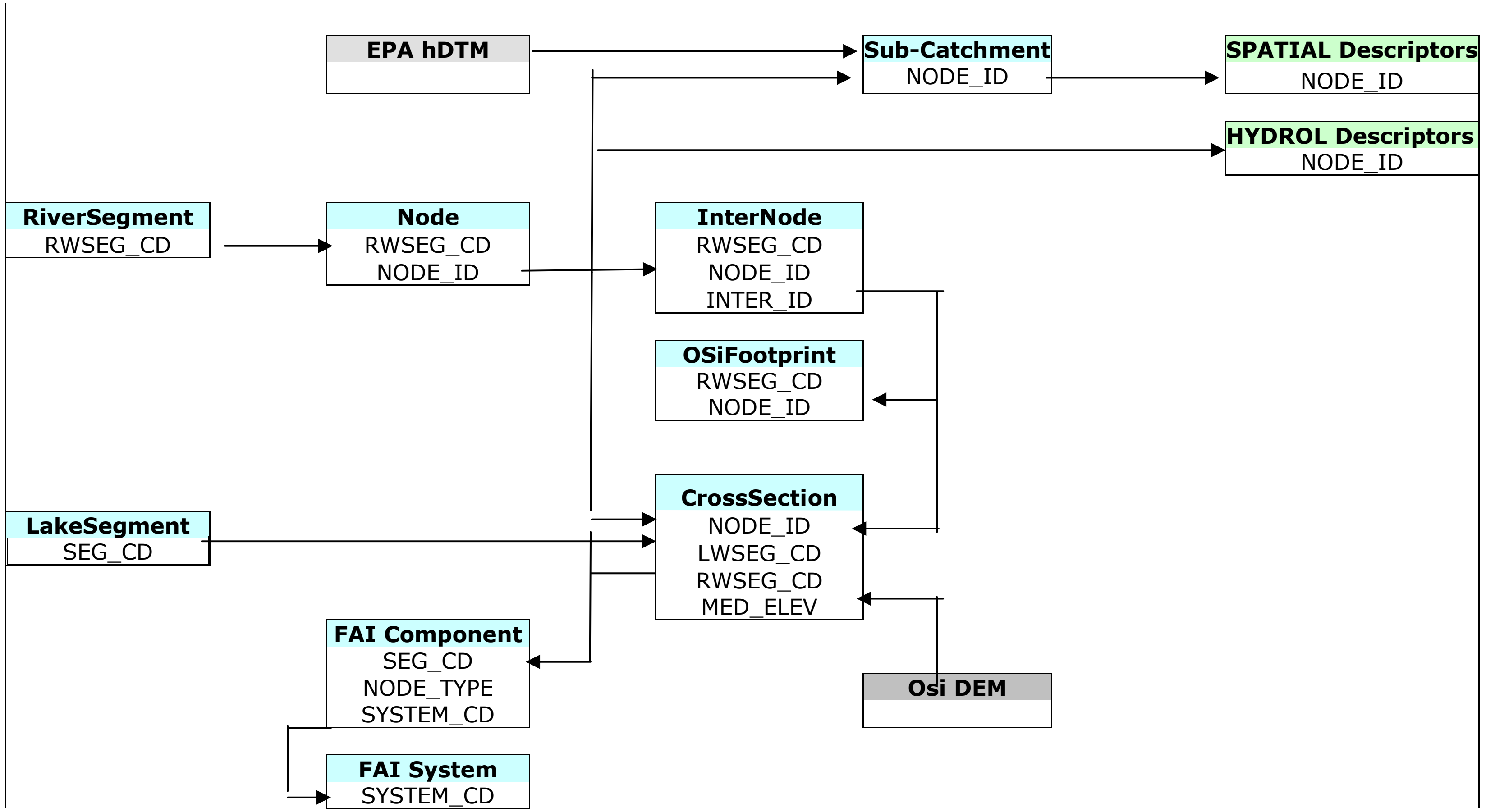
A1 Hydrometric Area – Accounting Statistics

Hydro Area	Node Count	Sub-catchment & Spatial Descriptors	Hydrological Descriptors	FAI systems	Intermediate Nodes	FAI channel length(km)	FAI River Segments	FAI Lakes	FAI area rivers km^2	FAI Area Lakes km^2	FAI Area Estuary km^2
sum	**139488**	**134506**	**136870**	**1425**	**290790**	**46997**	**42283**	**2211**	**11901**	**1565**	**147**
01	2396	2212	2325	6	4113	709.48	852	24	147.58	15.12	18.97
03	1149	1010	1139	3	2722	444.24	300	44	49.72	2.87	0.00
06	2679	2500	2618	32	6435	1056.10	687	64	227.12	10.52	5.86
07	4913	4842	4849	8	11793	1903.06	1277	53	591.45	18.43	3.40
08	1505	1486	1493	17	3417	556.53	407	5	161.59	0.17	0.15
09	2858	2776	2832	11	6369	1016.57	799	17	372.24	21.97	1.50
10	2681	2583	2601	21	5509	909.14	845	13	179.49	7.36	18.58
11	871	869	867	20	1784	290.63	272	4	43.88	0.03	0.00
12	4483	4349	4349	16	9063	1482.08	1415	7	229.67	0.12	5.29
13	1252	1222	1223	28	2586	439.14	382	0	66.51	0.00	0.95
14	4725	4606	4630	11	11414	1787.49	1216	6	840.23	0.07	1.38
15	4691	4578	4605	1	10948	1741.34	1250	10	508.25	0.39	1.71
16	7212	6943	6955	10	15498	2419.49	2113	28	729.98	2.87	16.78
17	1277	1249	1246	46	2543	432.99	409	4	60.92	0.72	1.16
18	6605	6386	6378	8	15241	2427.94	1790	13	406.29	0.24	15.02
19	4002	3981	3985	44	9094	1481.71	1114	20	240.14	15.09	0.00
20	3578	3449	3435	88	7183	1175.63	1135	32	138.60	3.20	3.62
21	5094	4819	5051	126	6723	1205.98	2052	71	148.36	25.37	1.23
22	4525	4297	4400	63	8438	1411.90	1509	64	378.60	66.64	8.40
23	3844	3687	3724	68	7581	1245.80	1231	20	348.43	10.28	18.64

24	4161	4018	4041	39	9840	1641.82	1109	16	529.10	1.51	14.42

Hydro Area	Un—gauged Nodes	Sub-catchments & Spatial Descriptors	Hydrological Descriptors	FAI systems	Intermediate Nodes	FAI channel length km	FAI River Segments	FAI Lakes	FAI area rivers km^2	FAI Area Lakes km^2	FAI Area Estuary km^2
25	8747	8570	8680	6	20747	3341.42	2308	56	1232.36	166.94	1.07
26	10690	10305	10598	24	26244	4150.24	2694	236	1244.90	303.50	0.00
27	2731	2622	2632	55	6036	976.72	786	119	202.25	26.17	3.59
28	1772	1733	1737	25	3990	661.73	499	25	87.72	5.93	0.67
29	1525	1468	1517	12	3608	573.65	402	22	171.38	9.64	0.01
30	4782	4681	4752	8	9898	1574.60	1458	108	559.10	336.91	0.00
31	1985	1895	1953	65	2787	511.79	786	226	63.47	55.49	0.29
32	3515	3397	3501	90	5496	415.54	1314	112	184.02	41.80	0.01
33	3301	3139	3220	114	5650	983.81	1173	22	174.24	23.83	1.69
34	5948	5864	5917	23	12121	1992.53	1853	115	448.42	96.82	0.22
35	4502	4348	4477	52	8619	1430.85	1469	61	385.79	74.18	0.00
36	5558	5110	5319	42	12361	2039.46	1578	364	281.37	155.68	0.00
37	2670	2555	2651	42	3536	588.85	1084	49	91.29	12.38	0.27
38	3603	3416	3537	106	5361	946.64	1381	160	142.74	45.69	1.42
39	2463	2368	2440	46	3962	658.29	912	19	141.86	6.79	0.51
40	1195	1173	1193	49	2080	371.74	422	2	91.60	0.22	0.00

A2 Data Model Summary



A3 River Network

1x River Segment shapefile per hydrometric area. Rivers dataset geometry provided by EPA from WFD geo-database

e.g. RWSEG_06_NET.shp

Field	Example	Note
RWB_CD		EPA WFD River Waterbody Code (if applicable)
SEG_CD	GBNI9901843	EPA national River Segment Class code
NAME	Muff River	OSI River Name (if named)
LENGTH	1682.21	Length metres
ORDER	1	Strahler (1952) Stream Order value
LWSEG_CD		Lake Code - Lake Connector lines only (see field 'Feature' below)
LWLINK_CD		Lake Connector lines only (see field 'Feature' below)
FEATURE	river	Line Type Identifier 1) RIVER (standard river line) 2) LINK or TOP LINK to indicate if line is connector line through lake 3) BHWM line below mean high water in estuary 4) BIFF - to indicate a bifurcation or loop segment (NI cross border zone only)
NET_SHREVE	1	Shreve (1967) Stream Link Magnitude value
IS_ROI	01	(Cross Border Hydrometric Areas only) Flag to indicate if stream within or along RoI border
IS_NI	no	(Cross Border Hydrometric Areas only) Flag to indicate if stream within or along NI border
POUR_STAT	pourpt	(internal GIS flag to indicate if un-gauged nodes and catchments associated with this river segment
FLOOD_STAT	n.a.	(internal GIS flag to indicate if FAI Flood polygon developed for river segment (see STAGE I Report)
SYSTEM_CD	11_66	Code of river system outlet river segment. Used to integrate all u/s river segment FAI pieces to single river system FAI polygon (see STAGE I Report)
OPW_HYDROL	n.a.	(internal GIS processing flag)
OPW_OUTLET	Y	Flag to indicate if river segment is d/s (at sea) outlet of river catchment

A4 Lakes

1x Lake Segment shapefile per hydrometric area. Dataset geometry provided by EPA from WFD geo-database e.g.LWSEG_06_NET.shp

Field	Example	Note
MS_CD	EA_10_1	EPA WFD Lake Waterbody Code (if applicable)
SEG_CD	10_1	EPA national Lake Segment Class code
NAME		OSI Lake Name (if named)
COUNTY	Wicklow	County Name
HYDRO_AR	10	Hydrometric Area code
AREA_HA	1.1	Area hectares
IS_FARL	Y	Flag to indicate if lake included in FARL Descriptor for River Nodes (see STAGE II / IV Report)
FARL_NODE	river	Line Type Identifier 1) RIVER (standard river line) 2) LINK or TOP LINK to indicate if line is connector line through lake 3) BHWM line below mean high water in estuary 4) BIFF - to indicate a bifurcation or loop segment (NI cross border zone only)
FARL_STAT	1	Shreve (1967) Stream Link Magnitude value
FARL_AREA	01	Catchment Area associated with lake for FARL calculation (either true catchment area (if available) or assumed 1km2 for small headwater lakes on river network
FARL_NOTE	no	(internal GIS processing flag)
FARL_VAL	0.895188	(See STAGE II / IV Report)
FLOOD_STAT	na	*(internal GIS flag to indicate if FAI Flood polygon developed for Lake segment (see STAGE I Report)*
CAT_AREA	11_66	Lake catchment area (if available - only known for ~1830 of total of ~10,000 lake segments - residue being v small lakes)

A5 Ungauged Nodes

1x Node Shapefile per Hydrometric area

e.g. NODE_09.shp

Field	Example	Note
RWSEG_CD	08_206	River Segment Code
NODE_ID	08_206_1	Ungauged Node ID
NODE_EAST	314057	Node Easting
NODE_NORTH	274126	Node Northing
POUR_EAST	314063	Node Northing Point equivalent on EPA DTM
POUR_NORTH	274123	Node Easting Point equivalent on EPA DTM
MEAS_ALONG	1712.59	Node location - distance along river segment from u/s end
NODE_HYDRO	done	(GIS processing flag - Hydrological Descriptors analysis)
NODE_CATCH	poly	
POLY_AREA	1.008	Node catchment area km^2
IS_FARL	Y	Flag to indicate if Node also represents Lake outlet for FARL Descriptor (see STAGE II / IV Report)
COPY_STAT	*merged*	*(GIS processing flag -)*
XSECT	xsect	*(GIS processing flag -)*
OSI_ELEV	12.649	OSI DEM elevation at node (see STAGE I Report)
MED_ELEV	12.649	Median OSI DEM elevation adjacent to node (see STAGE I Report)
BACK_ELEV	12.649	Backwatering adjusted DEM elevation assigned to node (see STAGE I Report)
FEATURE	river	Line Type Identifier for parent River Segment of Node - 1) RIVER (standard river line) 2) BHWM line below mean high water in estuary 4) BIFF - to indicate a bifurcation or loop segment (NI cross border zone only)
WIDTH	200	FAI analysis width along Cross-Section line associated with Node (see STAGE I Report)
L_WIDTH	110	Left Hand Side - FAI analysis partial width along Cross-Section line associated with Node (see STAGE I Report)
R_WIDTH	90	Right Hand Side - FAI analysis partial width along Cross-Section line associated with Node (see STAGE I Report)

A6 Intermediate Nodes

1x Intermediate Node Shapefile per Hydrometric area
e.g. NODE_INT_09.shp

Field	Example	Note
RWSEG_CD	08_206	River Segment Code
NODE_ID	08_206_1	Ungauged Node ID (parent of Intermediate Node)
INTER_ID	08_206_1_1	Intermediate Node ID
NODE_TYPE	Inter	Type Flag to indicate that 'node' is Intermediate Node
NODE_EAST	314057	Node Easting
NODE_NORTH	274126	Node Northing
MEAS_ALONG	1712.59	Node location - distance along river segment from u/s end
XSECT	xsect	*(GIS processing flag -)*
OSI_ELEV	12.649	OSI DEM elevation at node (see STAGE I Report)
MED_ELEV	0	Placeholder for copy of Median OSI DEM elevation adjacent to node, currently held in NODE Cross Section Class (see STAGE I Report)
BACK_ELEV	0	Placeholder for copy of Backwatering adjusted DEM elevation assigned to node, currently available in NODE Cross Section Class (see STAGE I Report)

A7 FAI Polygons (River System and River Segment levels)

Integrated River System Level
1x shapefile per Hydrometric Area
e.g. FAI_06.shp

Fields	sample	median elevation sampling
CATCH_CD	32_1052	Code of river system outlet river segment. Used to integrate all u/s river segment FAI pieces to single river system FAI polygon (see STAGE I Report)
COUNT	11	number of river segment FAI polygon elements comprising integrated river system FAI polygon
AREA_KM	0.551	area km^2 of integrated FAI polygon

River Segment and Lake components
1x shapefile per Hydrometric Area
e.g. XSECTPOLY_06.shp

Fields	sample	Note
SEG_CD	09_1	parent river RWSEG_CD code
FLOOD_Z	1	Flood Level above Bank. (Derived as 1m above the Node Backwatered Median OSI DEM Elevation (See STAGE I Report)
AREA_KM	0.016	Area of River Segment piece FAI polygon (have overlap with another segment FAI polygon piece)
NODE_TYPE	river	River or Lake
SYSTEM_CD	09_631	Code of river system outlet river segment. Used to integrate all u/s river segment FAI pieces to single river system FAI polygon (see STAGE I Report and FAI polygon class)

A8 Node Footprints and Cross Sections

OSI DEM sampling Node Footprint polygons associated with each Node and Intermediate Node

1x shapefile per Hydrometric Area

e.g. OSI_FOOT_06.SHP

Fields	sample	Issued Fields
NODE_ID	26_1_1	NODE_ID / INTERMEDIATE NODE ID
RWSEG_CD	26_1	parent RWSEG_CD Code
WIDTH	50	WIDTH of OSI DEM sampling Footprint (width is multiple of 10m cells)
HEIGHT	50	HEIGHT of OSI DEM sampling Footprint (height is multiple of 10m cells)

Cross Section lines associated with each Node and Intermediate Node

1x shapefile per Hydrometric Area

e.g. XSECT_06.shp

Fields	sample	Note
NODE_ID	09_1_1	NODE_ID / INTERMEDIATE NODE ID
NODE_TYPE	river	River or Lake
SIDE	right	Left or Right side from Node (d/s direction)
COUNTER	1	Counter
RWSEG_CD	09_1	parent river RWSEG_CD Code (river cross sections only)
MED_ELEV		Median OSI DEM elevation adjacent to node (see STAGE I Report)
BACK_ELEV		Backwatering adjusted DEM elevation assigned to node (see STAGE I Report)
LWSEG_CD		parent lake LWSEG_CD Code (lake shore radial 'sections lines' only)

A9 Spatial Catchment Descriptors

Gauged Locations Gauged_Spatial_issue_2102.dbf

Field	Sample Value	description
STATION_NU	01041	Station code
WATERBODY	DEELE	Station waterbody
LOCATION	SANDY MILLS	Station location
CENTE	217110	Catchment centroid easting
CENTN	401430	Catchment centroid northing
ALTBAR	139.4	Mean Elevation (catchment)
ALT_MIN	7.0	Min Elevation (catchment)
ALT_MAX	366.6	Max Elevation (catchment)
ALT_RANGE	359.6	Elevation Range (catchment)
ALT_STD	83.6	Standard Deviation Elevation (catchment)
SAAR	1329.37	SAAR rainfall (catchment) (1961-1990 period) mm/year
URBEXT	0.86	proportion of urban extent (corine), as %
FOREST	15.49	proportion of forest extent (corine, FIPS, Coillte), as %
PEAT	26.04	proportion of peat extent (corine), as %
PASTURE	63.37	proportion of pasture extent (corine), as %
ALLUV	3.42	proportion of alluvium extent (EPA/TEAGASC subsoils), as %
FORMWET	0.69	Mean FLATWET index
SAAPE	498.46	SAAPE(1961-1990 period) mm/year
POLY_AREA	116.1800	Catchment area (km2) (GIS Polygon)
URB_AREA	1001236	urban extent (m2)
PEAT_AREA	30255478	peat extent (m2)
ALLUV_AR	3971307	alluvium extent (m2)
PAST_AR	73625859	pasture extent (m2)

FOREST_AR	17995071	forest extent (m2)
FAI_PROP	0.123	Proportion of catchment occupied by FAI polygon
IS_STAGE2	y	*Station in FSU Project Analysis*
		[1] 'Pasture' comprises 4 Corine Landcover 2000 classes:- 211(non-irrigated arable land), 231(pasture), 242 (Complex Cultivation patterns) 243 (Land principally occupied by agriculture with significant areas of natural vegetation).

Ungauged Nodes

1 Shapefile per Hydrometric Area e.g. UN-GAUGED_06.dbf

This shapefile combines the ungauged catchment polygon (STAGE III) and Spatial Catchment Descriptors (STAGE IV)

Field	Example	Note
SHAPE		Un-Gauged Node sub-catchment polygon
NODE_ID	03_410_1	Node Identification code
DTM_AREA	1.097	Catchment Area (km^2) - see Stage III Report
POLY_PARTS	*1*	*(internal check sum)*
POLY_AREA	*1.097*	*(internal check sum)*
STA_STATUS	*pasture*	*(internal GIS process status flag)*
CENTE	264940	Catchment Centroid - ING Northing
CENTN	349260	Catchment Centroid - ING Easting
ALTBAR	71.9	Catchment Mean Altitude (m)
ALT_MIN	50.7	Catchment Minimum Altitude (m)
ALT_MAX	104.8	Catchment Maximum Altitude (m)
ALT_RANGE	54	Catchment Altitude Range (m)
ALT_STD	11.5	Catchment Altitude Standard Deviation (m)
SAAR	977	Standard Average Annual Rainfall (mm) (Met Eireann)
SAAPE	468.24	Standard Average Annual Potential Evapotranspiration (mm) (Met Eireann)
FORMWET	0.68	Mean Flatwet value
URBEXT	0	proportion of urban extent (Corine Landcover 2000), as %

URB_AREA	0	area m^{-2} of catchment Urban
PEAT	0	proportion of Peat extent (Corine Landcover 2000), as %
PEAT_AREA	0	area m^{-2} of catchment Peat
ALLUV	6.68	proportion of Alluvium extent (Teagasc/EPA Subsoils), as %
ALLUV_AR	73215	area m^{-2} of catchment Alluvium
FOREST	6.35	proportion of Forest extent (Corine Landcover 2000 & Coillte Teo & Forest Service (FIPS 1998) databases), as%
FOREST_AR	69636	area m-^{2} of catchment Forest
ARTDRAIN	7.23	proportion of Benefitting Lands (OPW), as%
ARTDR_AREA	79286	area m^{-2} of catchment Benefitting Lands
PASTURE	100	proportion of 'Pasture' [1] extent (Corine Landcover 2000), as%
PASTURE_AR	1096800	area m^{-2} of catchment Pasture
FAI_CLP_AR	123	area km^{-2} of catchment occupied by FAI polygon
FAI_PROP	0.025	proportion of catchment occupied by FAI polygon
		[1] 'Pasture' comprises 4 Corine Landcover 2000 classes:- 211(non-irrigated arable land), 231(pasture), 242 (Complex Cultivation patterns) 243 (Land principally occupied by agriculture with significant areas of natural vegetation).

A10 Hydrological Catchment Descriptors

Gauged Locations Gauged_Hydrol_090109.dbf

Field	Sample Value	description	Note
Gauged			
STATION_NU	01041	Station code	
WATERBODY	DEELE	Station waterbody	
LOCATION	SANDY MILLS	Station location	
ORG	EPA	Organisation Responsible	
AREA	116.18	Catchment Area km^2	
MSL	32.632	Mainstream length (km)	Based on longest path distance to source
NETLEN	171.012	Length of upstream hydrological network (km)	
STMFRQ	251	Number of stream segment elements in upstream river network	
DRAIND	1.472	NETLEN (km) / POLY_AREA (km^2)	
S1085	7.065	Slope of MSL (excluding top 10% and bottom 15% portions). rise (m) / run (km)	
ARTDRAIN	0	Index of Arterial Drainage extent (area of Benefiting Lands as %)	source dataset "benefit_scheme_v1"
ARTDR_AREA	0	Arterial Drainage extent (area m^2 of catchment with Benefiting Lands)	
ARTDRAIN2	4.47	Percentage of river network included in OPW Scheme Channels	source dataset "channels_scheme_v1"
ARTDR_LEN	7.65	Length of upstream river network (km) included in OPW Scheme Channels	
TAYSLO	3.027	Slope as per Taylor and Schwarz (1952).	based on slope (m/km) of series of 500m long sub-elements of MSL

FARL	0.798	FARL Index value	Flood Attenuation by Reservoirs and Lakes. Flood Estimation Handbook (vol 5, chapter 4),
POLY_AREA	116.18	Catchment area (km2)	area of GIS catchment polygon
GAUGE_X	227307	Gauge location easting (ING)	
GAUGE_Y	399030	Gauge location northing (ING)	
RWSEG_CD	01_1540	EPA River Network code of segment at gauge site	
TOP_RWSEG	01_307	EPA network code of headwater source segment	(see MSL)
IS_STAGE2	Y	*Station in FSU Project Analysis*	
TAY_STAT	done	*GIS processing flag*	
HA	01	*Hydrometric area*	

Ungauged Nodes 1 file per Hydrometric Area e.g. HYDROL_06.dbf

Field	Sample Value	description	Note
Ungauged			
NODE_CD	01_4315_1	Ungauged Node Indentifier	
MSL	32.632	Mainstream length (km)	Based on longest path distance to source
NETLEN	171.012	Length of upstream hydrological network (km)	
STMFRQ	251	Number of stream segment elements in upstream river network	
DRAIND	1.472	NETLEN (km) / POLY_AREA (km^2)	
S1085	7.065	Slope of MSL (excluding top 10% and bottom 15% portions). rise (m) / run (km)	
ARTDRAIN2	4.47	Percentage of river network included in OPW Scheme Channels	source dataset "channels_scheme_v1"
ARTDR_LEN	7.65	Length of upstream river network (km) included in OPW Scheme Channels	

TAYSLO	3.027	Slope as per Taylor and Schwarz (1952).	based on slope (m/km) of series of 500m long sub-elements of MSL
FARL	0.798	FARL Index value	Flood Attenuation by Reservoirs and Lakes. Flood Estimation Handbook (vol 5, chapter 4),
POLY_AREA	116.18	Catchment area (km2)	area of GIS catchment polygon
RWSEG_CD	01_1540	EPA River Network code of segment at un-gauged site	
TOP_RWSEG	01_307	EPA network code of headwater source segment	(see MSL)
IS_STAGE2	Y	*Station in FSU Project Analysis*	
TAY_STAT	done	*GIS processing flag*	

A11 Hydrological Descriptor GIS Polyline files

MSL

Mainstream Length
MSL Based on longest path distance to source

Gauged Locations

GIS Polyline file	Field	description	Note
MSL_GAUGED.shp	Station_nu	OPW Station Code	
	Length	metres	
	MSL	length in km	
	IS_STAGE2	Y	(Flag - subset of Hydrometric stations included in FSU)

Ungauged Nodes

GIS Polyline files	Field	description	Note
(1 per Hydrometric Area)	Node_cd	Ungauged Node Identifier	
e.g. MSL_03.shp	Length	metres	
	MSL	length in km	

S1085 Slope

Slope of MSL (excluding top 10% and bottom 15% portions)

Gauged Locations MSL_S1085_GAUGED.shp
Ungauged Nodes 1 file per Hydrometric Area e.g. MSL_S1085_06.shp

GIS Polyline files	Field	description	Note
Gauged	Station_nu	OPW Station Code	
	IS_STAGE2	(Flag - subset of Hydrometric stations included in FSU)	
Ungauged	NODE_CD	Ungauged Node Identifier	
Common fields	Length	metres	
	OSI_STATUS	GIS- data processing flag	
	OSI_TOP_Z	Elevation at upstream start (OSI 10m DTM)	
	OSI_END_Z	Elevation adjacent Gauge (OSI 10m DTM)	
	OSI_GRADE	Slope (OSI 10m DTM)	(OSI_Top_z - OSI_End_z) / Length * 1000
	MOD_TOP_Z	if required, modified values of OSI_TOP_Z	
	MOD_END_Z	if required, modified value of OSI_END_Z	
	MOD_LEN	if required, modified S1085 section length	
	MOD_GRADE	if required, modified values of Slope	(MOD_Top_z - MOD_End_z) / Mod Len * 1000
	S1085_GRAD	Final S1085 Slope	
	HA	Hydrometric Area	

TAYSLO **Slope based on method of Taylor and Schwarz (1952)**

Gauged Locations MSL_TAYSLO_GAUGED.shp
Ungauged Nodes 1 file per Hydrometric Area e.g. MSL_TAYSLO_06.shp

GIS Polyline files	Field	description	Note
Gauged	Station_nu	OPW Station Code	
	IS_STAGE2	(Flag - subset of Hydrometric stations included in FSU)	
Ungauged	NODE_CD	Ungauged Node Identifier	
Common fields	Seg_number	500m element counter from source to Gauge	
	OSI_STATUS	GIS- data processing flag	
	OSI_TOP_Z	Elevation at upstream source (OSI 10m DTM)	
	OSI_END_Z	Elevation adjacent Gauge (OSI 10m DTM)	
	OSI_GRADE	500m section element Slope (OSI 10m DTM)	(OSI_Top_z - OSI_End_z) / Length * 1000
	MOD_TOP_Z	if required, modified values of OSI_TOP_Z	
	MOD_END_Z	if required, modified value of OSI_END_Z	
	LIFT_END	if required, modified value of MOD_END_Z	
	MOD_GRADE	500m section element Slope (OSI 10m DTM) inc modifications	(MOD_Top_z - MOD_End_z) / Length * 1000
	MOD_STATUS	if required, Flag to indicate type of modification	
	TAYSLO	TAYSLO value for each gauged and ungauged node – see Hydrological Descriptor files	

A12 Aquifer, Soil & Subsoil Permeability Class Statistics

Aquifer **Geological Survey of Ireland**

Field	Example	Note
ungauged_aquifer.dbf		
RWSEG_CD	01_1190	EPA river segment code
NODE_ID	01_1190_1	Node Code
gauged_aquifer.dbf		
STATION_NU	01041	Gauged Station Code
WATERBODY	DEELE	Waterbody
LOCATION	SANDY MILLS	Location
Common Fields		
CHECK_SUM	100.000	sum of LG_RG_PC, LL_PC, LM_RF_PC, PU_PL_PC, RKC_RK_PC, RKD_LK_PC
POLY_AREA	1.041	Area of gauged/ungauged node catchment polygon
DATA_AREA	1.041	Sum area of Aquifer data classes in catchment
LG_RG_AR	0	Area (m^{-2}) of Locally & Regionally Important Gravel Aquifers
LG_RG_PC	0.000	LG_RG proportion, as %
LL_AR	0	Area (m^{-2}) of Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
LL_PC	0.000	LL proportion, as %
LM_RF_AR	0	Area (m^{-2}) of Locally Important Aquifer - Bedrock which is Generally Moderately Productive & Regionally Important Aquifer - Fissured bedrock
LM_RF_PC	0.000	LM_RF proportion, as %
PU_PL_AR	1041200	Area (m^{-2}) of Poor Aquifer - Bedrock which is Generally Unproductive & Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones
PU_PL_PC	100.000	PU_PL proportion, as %

RKC_RK_AR	0	Area (m^{-2}) of Regionally Important Aquifer - Karstified (conduit) & Regionally Important Aquifer - Karstified
RKC_RK_PC	0.000	RKC_RK proportion, as %
RKD_LK_AR	0	Area (m^{-2}) of Regionally Important Aquifer - Karstified (diffuse) & Locally Important Aquifer - Karstified
RKD_LK_PC	0.000	RKD_LK proportion, as %

Soil **Teagasc**

Field	Example	Note
ungauged_soil.dbf		
RWSEG_CD	01_1190	EPA river segment code
NODE_ID	01_1190_1	Node Code
gauged_soil.dbf		
STATION_NU	01041	Gauged Station Code
WATERBODY	DEELE	Waterbody
LOCATION	SANDY MILLS	Location
Common fields		
CHECK_SUM	100.000	sum of PD_PC, WD_PC, AlluvMin_PC, Peat_PC, Made_PC, WATER_PC
POLY_AREA	1.041	Area of gauged/ungauged node catchment polygon
DATA_AREA	1.041	Sum area of Soil data categories in catchment
PD_AR	633586	Area (m^{-2}) of Soil category PD (Poorly Drained)
PD_PC	60.851	PD proportion, as %
WD_AR	346682	Area (m^{-2}) of Soil category WD (Well Drained)
WD_PC	33.296	WD proportion, as %
ALUVMIN_AR	55424	Area (m^{-2}) of Soil category AlluvMin
ALUVMIN_PC	5.323	AlluvMin proportion, as %
PEAT_AR	5509	Area (m^{-2}) of Soil category Peat
PEAT_PC	0.529	Peat proportion, as %
WATER_AR	0	Area (m^{-2}) of Soil category Water
WATER_PC	0.000	Water proportion, as %
MADE_AR	0	Area (m^{-2}) of Soil category Made (Made Ground)
MADE_PC	0.000	Made Ground proportion, as%
		Analysis Categories agreed between EPA and ESBI for hydrometric analysis

Subsoil Permeability **Geological Survey of Ireland**

Field	Example	Note
ungauged_subsoil.dbf		
RWSEG_CD	01_1190	EPA river segment code
NODE_ID	01_1190_1	Node Code
gauged_subsoil.dbf		
STATION_NU	01041	Gauged Station Code
WATERBODY	DEELE	Waterbody
LOCATION	SANDY MILLS	Location
Common Fields		
CHECK_SUM	100.000	sum of H_PC, M_PC, L_PC, ML_PC, NA_PC, WATER_PC
POLY_AREA	1.041	Area of gauged/ungauged node catchment polygon
DATA_AREA	1.041	Sum area of Subsoil data classes in catchment
H_AR	0	Area (m^{-2}) of Subsoil Permeability Class H (High)
H_PC	0.000	High proportion, as %
M_AR	1035691	Area (m^{-2}) of Subsoil Permeability Class M (Moderate)
M_PC	99.471	Moderate proportion, as %
L_AR	5509	Area (m^{-2}) of Subsoil Permeability Class L (Low)
L_PC	0.529	Low proportion, as %
ML_AR	0	Area (m^{-2}) of Subsoil Permeability Class M/L (Moderate/Low)
ML_PC	0.000	Moderate/Low proportion, as%
NA_AR	0	Area (m^{-2}) of Subsoil Permeability Class N/A
NA_PC	0.000	Not Applicable proportion, as%
WATER_AR	0	Area (m^{-2}) of Subsoil Permeability Class Water
WATER_PC	0.000	Water proportion, as%
		Analysis Categories agreed between EPA and ESBI for hydrometric analysis

A12 Lake descriptors used in FARL index

A file that lists the individual lakes and calculation components included in the FARL index calculation is provided as "**Farl_lake_list.dbf**". The identification code for each lake (field 'lwseg_cd') conforms to the national lakes GIS dataset (EPA).

Field	**Sample Value**	**Note**
STATION_NU	26001	Hydrometric Gauge - Station Code
LWSEG_CD	26_156	Identification Code, as per national Lake GIS dataset (EPA)
LAKE_AREA	0.001615	Surface Area of Lake (km^2)
LCAT_AREA	7.637	Catchment Area of Lake (km^2)
LAREA_LCAT	0.9855	($1 - \sqrt{r}$) - where r = LAKE_AREA / LCAT_AREA
CAT_AREA	240.280	Catchment Area of Station
W	0.0318	LCAT_AREA / CAT_AREA
FARL	0.9995	FARL Index value for **individual** lake in gauge catchment context (as per FEH vol5, chapter 4)