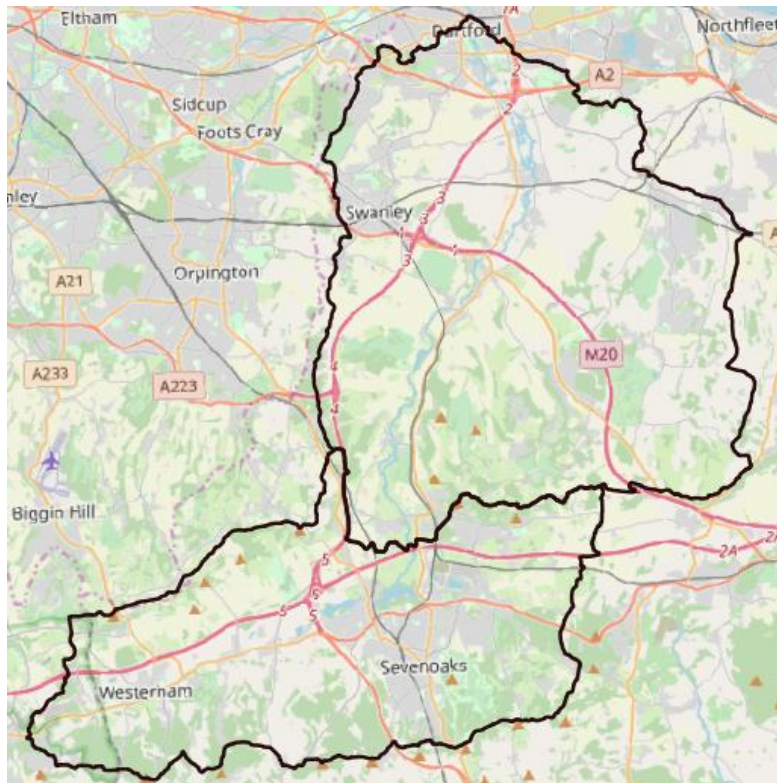


MODELLING NATURAL FLOOD MANAGEMENT AND CO-BENEFITS IN THE DARENT CATCHMENTS



For



Dated
Reviewed by
Lead author

31ST March 2020
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Contents

Introduction	2
Acknowledgements.....	3
Background to HydroloGIS Modelling	4
Strengths	5
Assumptions.....	5
Weaknesses.....	5
Data.....	5
Habitat Types	6
Methodology & Deliverables	7
Task 1: HydroloGIS.....	7
Task 2: Overland Flow Analysis.....	8
Task 3: Rivers and Floodplains.....	9
Task 4: Field and Boundary Actions	10
Instructions for use	12
Data Layers	12
Maps	13
Creating Solution Maps from Data Layers	14
Graded Solution Maps	14
Appendix A: Step-by-Step Instructions for Creating Maps in QGIS.....	15
Appendix B: The Viridian Team.....	16
Angus Middleton – Project Director	16
Leon Baruah – Technical Director	16

Introduction

Kent County Council AONB Unit (KCC) requested an assessment of natural flood management opportunities (NFM) within the Upper, Middle and Lower Darent river catchments. This assessment considered only water-related services, focusing mainly on flooding but also extending to erosion and diffuse pollution.

The scope of work included:

1. Running freely available data through our HydroloGIS models to identify the current degree of ecosystem service provision across the catchment. This was done individually for each of the four water services listed below, as well as for the combined delivery of all services.
2. Using HydroloGIS to identify where new habitats should be created to most improve delivery of the four services, both individually and combined.
3. Using HydroloGIS to calculate which interventions will deliver the greatest improvements to services delivery, again both individually and for combined service provision.
4. Extending HydroloGIS analysis to identify the greatest opportunities for creating leaky dams, floodplain storage and reservoirs. Understanding where solutions are likely to be restricted to field margins or not.
5. Delivery of data layers, maps and this report.

HydroloGIS was used to find which nature-based interventions should be undertaken to best deliver the following multiple benefits:

- Erosion
- reduction of soil adsorbing pollutants (e.g. phosphates)
- reduction of water soluble pollutants (e.g. nitrates)
- flood mitigation

The natural interventions identified in this report are the result of computer modelling and as such are imperfect representations of the real world. They are intended to be useful tools to inform the design and planning of catchment management, to aid with consultation and stakeholder engagement, and to form the basis of further works. They should not be considered the definitive, final answer to nature-based solutions, but rather an extremely good start.

Acknowledgements

The data used during this project and in the production of the maps included in this report involve the following references and licenses:

- KCC for supplying the APBG 5m DTM data;
- OS data © Crown copyright and database right 2020;
- Copernicus EU-DEM v1.1 © Copernicus Land Monitoring Service 2020, European Environment Agency (EEA), European Union;
- Corine Land Cover 2018 © Copernicus Land Monitoring Service 2020, EEA, European Union;
- OpenStreetMap ©OpenStreetMap contributors [CC-by-SA](#);
- Bioclimatic Variables from WorldClim under [CC by-SA 4.0](#);
- MOD16 data retrieved from [NASA EOSDIS LP DAAC](#);
- Natural England and Defra for reference to Magic Map <https://magic.defra.gov.uk/MagicMap.aspx>;
- Forestry Commission information licensed under Open Government Licence v3.0 (OGL v3.0);
- British Geological Survey materials under OGL v3.0;
- Contains Environment Agency data licensed under OGL v3.0.

Background to HydroloGIS Modelling

The HydroloGIS modelling system is a novel GIS planning tool, developed to mitigate dangers to the water supply in river landscapes using nature-based solutions. The scientific research underpinning HydroloGIS has been collated from hundreds of papers by the Natural Capital Project and University of Leeds. The engine at the core of HydroloGIS is the 'Resource Investment Optimisation System' or RIOS. RIOS was created by the Natural Capital Project to account for biophysical, social and economic data when designing cost-effective investments in watershed services in Latin America. HydroloGIS transposes and extends the functionality of RIOS to UK river catchment/subcatchment regions, and is weighted towards using biophysical optimisation to improve ecosystem services provided by those regions.

Landscape issues are interpreted as a combination of up to four HydroloGIS objectives. It works by grid-based map analyses of the risk factors associated with each objective. These objectives are:

1. Erosion control: preventing soil particles from being washed into streams.
2. Reduction of soil adsorbing pollutants: preventing chemicals such as phosphates from being washed into streams. Soil adsorbing chemicals adhere to the surface of soil particles and so this objective is often linked to erosion control, although with important differences.
3. Reduction of water soluble pollutants: preventing chemicals such as nitrates from being washed into streams. Soluble chemicals dissolve in water and so can be highly mobile.
4. Flood mitigation: preventing excessive water entering streams and causing downstream flooding.
5. Overall provision: the most efficient ways to meet the above four objectives by creating single interventions. The results are a compromise to simultaneously reduce erosion, soil adsorbed pollution, soluble pollution and flooding.

The risk factors are calculated from a range of datasets, including landscape characteristics, weather and ecosystems. The risk factors are indexed and all locations within the catchment of interest are ranked by appropriately combining each indexed (and appropriately weighted) risk factor. Simultaneously, HydroloGIS models hydrological transport through the landscape, with all risk factors analysed along entire flow paths over the whole landscape.

The final calculation determines where habitat development would be best placed to intercept these flows and minimise risks, down to where placement is least favourable. A threshold is applied to select the highest ranked areas to achieve the relevant objective(s), to the extent required, so a map can be produced to show where the most effective interventions should be implemented. For example, the map can display only the highest ranked 0.2% of interventions, or the highest ranked 5% or even the highest 50%, depending on how extensive the user wishes the solutions to be.

Strengths

By adopting a ranking methodology, HydroloGIS is robust to systematic biases that may exist in any given data source. In this way, individual parameters and measurements minimally impact upon the output map of recommendations. In parallel, if a catchment manager is more risk averse, then the output map increases the area of habitat development by moving the ranking threshold further down the ranks. There are a multitude of ecosystem service developments employed by Defra's catchment treatments, with varying degrees of evidence supporting them. To reduce the risk of poor decision making, HydroloGIS only invokes interventions that have proven benefits. Viridian stands to improve greatly as the body of scientific knowledge increases.

Assumptions

Whilst data can be quickly evaluated for suitability within HydroloGIS, the data is assumed to be broadly correct. As such, fundamental flaws that may exist in alternative data sources will skew HydroloGIS' recommendations. To avoid such biases, data is evaluated in-house.

Weaknesses

The HydroloGIS modelling employed in this assessment does not, per se, identify problems. That is, if a landscape is healthy then the HydroloGIS platform will still produce recommendations based on the determined rankings. Similarly, whilst the ranked recommendations are self-consistent (i.e., the best intervention for the landscape is truly the best interpretation of data), the impact of interventions is not well measured by HydroloGIS. Indeed, to date, systematic impact monitoring of ecosystem service projects worldwide is rare. Given the diversity of river catchments, accurate calibration of landscape interventions on sparse information demands more knowledge than is available, especially given climate change.

The assessment uses mainly open-source datasets that give uniform cover for the whole of England. This was done to make the system operable across the country, to reduce costs to clients wanting standard outputs and simplify licensing restrictions for future use of the modelled outputs. The exception in the UK is the OS Terrain 5 data, for which most clients already hold a license.

Data

The modelling relies on the accuracy and reliability of the data used in modelling, at least to the extent described above. The model uses a wide variety of datasets for a large scope of reasons, but those worth commenting on are as follows:

- Rainfall is derived predominantly from MODIS and historic monitoring data and has a 1km spatial resolution. Recent research on the InVEST model suggests that accurate rainfall data is important with quantified hydraulic modelling, but this requirement is ameliorated to some degree by the comparative nature of HydroloGIS modelling. Improved rainfall data may improve the accuracy of HydroloGIS modelling, but natural variation in rainfall events and the focus of HydroloGIS on reducing peak flood situations (rather than being a time-series model) means that the effect may not be great.

- Corine 2016 has a minimum mapping unit of 25 hectares. This is fairly coarse for land use and land cover data, since it would not identify useful features such as buffer strips and hedges. This could be greatly improved by using surveys with a 5m resolution, such that it would fit well with the terrain data, but any comprehensive land cover data with a better resolution would produce improved results. Corine is enhanced by addition of UK data such as Forestry Commission's National Forestry Inventory and various Ordnance Survey data.
- The Corine nomenclature such as 'non-irrigated arable land' might be considered blunt, since it gives no idea of crop types. However, creating habitats to deliver ecosystem services is a long-term undertaking. It is likely that there will be substantial change in the patterns and methods of agriculture during that time, so using more detailed data may be irrelevant or even counter-productive.
- BGS soil data is derived from a variety of sources and sampling densities, which in some areas will be moderately inaccurate. This will make a difference to the hydrology, universal soil loss and habitat interaction elements of the modelling. Detailed soil sampling could improve this, but it is far from certain that the degree of cost and effort would be justified: it is likely that the outputs of the modelling would change only marginally.

Habitat Types

The outputs from Viridian modelling suggest the creation of three broad habitat types: woodland (shown in green), wetland (shown in blue) and grassland (shown in orange). These habitat types have been chosen as there is reasonable evidence of their efficacy from international research and case studies. However, it is not sensibly useful from this scale and type of modelling to be more specific, since location-specific details will have to be decided from site visits; an example of this would be the tree species to plant at any given location.

The wetland creation thread refers to creation of water-retention features in the landscape. These are grouped together as 'wetland' rather than identified individually in the data, since they have comparable hydrological characteristics. It is usually fairly simple to identify which to apply from pre-existing local knowledge or local maps: re-wetting peat will be the sensible action in peatland areas, leaky dams where wetland is suggested in streams, and ponds or swales should be created in open land. A site visit or local knowledge will still be needed for the detailed design and construction of such features.

Grassland solutions refer to the creation or reversion to semi-natural grassland, or as low-input and under-cultivated, permanent grassland as can be achieved.

The model identifies the most efficient location to make intervention, as well as choosing the habitat type that will most effectively solve the problems in hand. there will be occasions when the suggested habitat type is not appropriate at that location for reasons external to the modelling. In this case, the location should be avoided and action taken in the next highest-priority area. Alternatively, Viridian can re-run the models with the new restrictions in place, so that the best solutions can be found for the revised circumstances.

Methodology & Deliverables

Viridian collated all the necessary data for the WHERE catchment, using the Water Framework Directive Cycle 2 catchment boundary as the template for the study area. HydroloGIS uses entirely open-source data as standard, apart from the APGB 5m DTM data. Very kindly, KCC supplied this data for Viridian to model on their behalf as part of the contract.

The data modelled includes a wide variety of climatic, topographic, land use, land cover, geological and geographical datasets. The Viridian ran this through their various hydrological, soil- and vegetation-interaction algorithms at a 5m pixel scale to produce normalised, comparative rankings of ecosystem service provision across the catchment. This produced the following deliverables:

1. Run HydroloGIS to understand current landscape function and prioritise future interventions;
2. Produce flow accumulation networks and identify area of natural ponding;
3. Specify outline designs for leaky dams, offline storage and reconnection of flood plains; and
4. Identify areas where mid-field and field boundary actions will be most appropriate.

The tasks have been described individually below.

Task 1: HydroloGIS

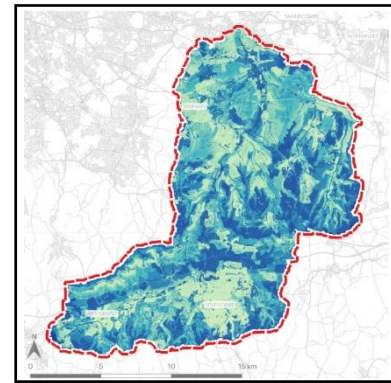
Water-flow ecosystem services need to be understood in the context of the entire landscape, the flows of water across that landscape and the distance between solutions and beneficiaries. We therefore used our HydroloGIS system to characterise the landscape in terms of flooding, erosion/siltation and diffuse pollution.

The outputs are data layers and maps showing current, relative landscape function across the catchments, and prioritised solutions that most improve the provision of water-flow service. There are four objectives considered in the modelling: flood mitigation, reducing soluble pollutant runoff (e.g. diffuse nitrates), reducing soil adsorbed pollutant runoff (e.g. diffuse phosphates), reducing erosion/siltation; and the greatest compromise solutions to delivering all these benefits simultaneously. In the process of creating these outputs, HydroloGIS also creates flow accumulation networks and identifies area prone to rainfall ponding. These are all described in more detail below.

Understand Landscape function

This is the current, relative function of the catchments. Each 5m pixel was ranked for how well it is currently functioning to keep flood waters out of the streams, reduce diffuse pollution and reduce erosion/siltation. This assesses

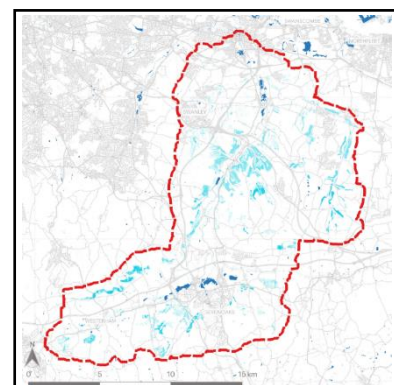
entire flow paths and connectivity, as well as the individual characteristics of each pixel across the catchment. An example of the mapped output for flooding is shown to the right, but similar outputs were created for soil-adsorbed pollutants (such as phosphates), soluble pollutants (such as nitrates), erosion/siltation, and all services combined. The dark areas on the map show a high degree of current service provision, the pale areas show a relatively low provision (those areas most likely to be causing problems in the rivers).



Relative landscape function for flooding

Identify prioritised catchment solutions

These are the prioritised solutions for the catchments, looking at planting trees, reversion to semi-natural grassland and water retention features. Each 5m pixel is ranked for how much impact it will have on local problems, if the use on that pixel is optimised. An example of the mapped output for flood reduction is presented on the right, showing the best 2%, 5%, 10% and 20% of solutions (dark to light blue, as solutions are predominantly water retention features). Similar outputs were created for soil-adsorbed pollutants (such as phosphates), soluble pollutants (such as nitrates), erosion/siltation, and flooding.

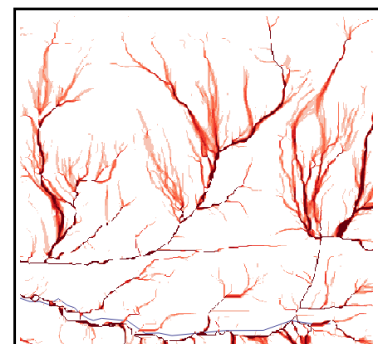


Ranked interventions for flooding

Task 2: Overland Flow Analysis

Create flow accumulation network

The hydrological aspect of HydroloGIS identifies where water flows over the surface of the landscape. The magnitude of water flowing across each pixel is calculated and concatenated to form the flow accumulation network. This is useful for identifying where most water naturally crosses the landscape and so where features such as ponds will intercept most water. This will help ensure they provide benefits from disrupting flows such as flood mitigation. The image to the right shows a flow accumulation extract, with the darker red denoting higher degrees of flow.

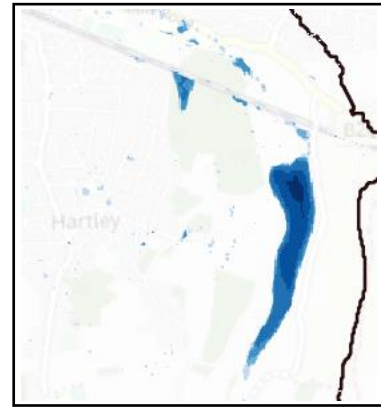


Flow accumulation network extract

Combining the flow accumulation network with areas of natural ponding (overleaf) can be powerful for placing ponds to capture water for irrigation at least effort.

Identify area of natural ponding

The landscape contains depressions and areas of flat ground, which can confuse hydrological algorithms as they assume water always flows downhill. This can be overcome by 'filling' the DTM: the depressions and flat areas are altered so that they have a very shallow gradient in the direction of the neighbouring flows. The filling method captures the depth of each depression, so understands just how much water could accumulate there during heavy rains before being able to flow out again. This gives an idea of the depth of rainfall flooding that could be experienced in that location, or how much water could be captured in a pond. Depressions close to streams can be well deployed for leaky dam and flood plain works.



Areas of natural rainfall ponding

Outputs are supplied as a series of GIS data layers (with accompanying QGIS style-files, where appropriate); as well as a variety of pdf maps of current landscape function and prioritised solutions. The latter make accessing the results more convenient for users with limited GIS ability.

Task 3: Rivers and Floodplains

HydroloGIS specifies three broad intervention types: water retention, reversion to semi-natural grassland and woodland creation. The latter two require little additional comment at this stage, other than showing where features could be placed across entire fields (grassland) or restricted to field boundaries (arable).

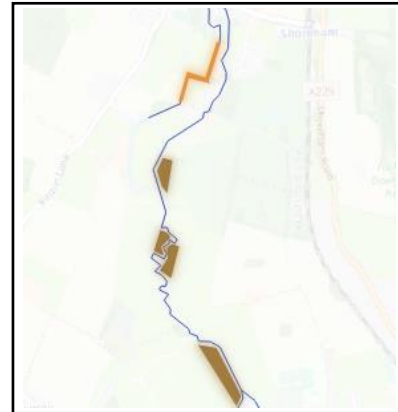
The water retention features along water courses were upgraded into more detailed measures, comprising either leaky dams or flood plain actions (reconnection and offline storage).

This was achieved by considering only those HydroloGIS flood solutions within 30m of watercourses. This was followed by detailed visual inspection of modelled areas using general mapping (such as OS Explorer), aerial photography and ground-level images.

Leaky dams and floodplain activities

Greatest opportunities for leaky dams and reconnecting the flood plain were identified by removing all parts of the HydroloGIS outputs that are more than 30m from a watercourse. The remaining areas show where water retention in or next to streams will be effective.

These areas were then reviewed manually with other map and imagery data, and specific reaches of the watercourses were identified as being especially appropriate for either installing leaky dams or reconnecting the flood plain. Leaky dams have been suggested only in rivers less than 5m wide, although our assessment of width is based on available evidence and may not be accurate in all cases. They have been placed in areas that seem likely to store water well, but without impacting on buildings, infrastructure or arable land. An example of this is shown by the image to the right, where the watercourses are blue, leaky dam are orange and floodplain activities brown.



Leaky dam priorities

Within floodplain activities, offline storage ponds (which are connected to the watercourses and fill mainly during high river levels) have been suggested where this appears to be the best storage solution for flood waters. However, in some instance floodplain reconnection may be more appropriate than offline storage. The available data was generally not sufficient to identify which would be more effective, so the 'LeakyDams_Floodplain_Opportunities_Inspected' layer identifies potential locations for flood plain reconnection or offline ponds, but does not distinguish between the two options.

Task 4: Field and Boundary Actions

Interventions on arable land are likely to be restricted to field boundaries, comprising features such as hedges and buffer strips. On the other hand, interventions on grassland will have more scope for interventions across entire fields, such as constructing leaky bunds or planting woodland blocks. New data layers were therefore created that distinguish between interventions located on grassland and arable land.

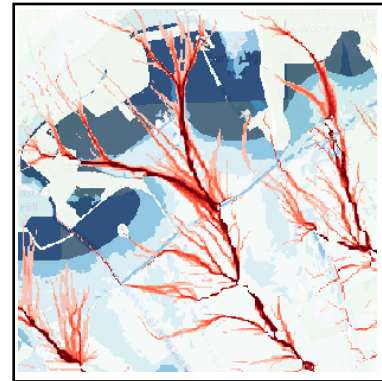
Identify whole-field NbS opportunities

Flows crossing the landscape can effectively be interrupted by creating various interventions across entire fields, such as planting woodland, creating wetlands or raising a series of leaky bunds. This should be done only in those locations where water retention will lead to significant reduction in local problems, as identified by HydroloGIS. The habitats will capture water and slow its flow across the landscape, whereas bunds will act as dams, causing water to accumulate behind them instead of continuing to flow downhill. This water can percolate into the ground, or on impermeable soils can slowly escape downhill, for bunds, this can be achieved through apertures or drainage layers in the bunds. It is these features that can make them 'leaky'. Bunds can be created using imported materials or by reprofiling the field.

Landowners will probably be unwilling to create such features on arable land, as they would prevent cultivation and/or waterlog plants during periods of rain. Such constraints are less germane in pasture, especially for bunds, since grazing can continue unabated once the bunds have been constructed, and flood impacts

will be modest and short-lived. Landowners may be willing to change entirely the use of low-value land such as rough pasture, so creating woodland or wetlands could be possible in these locations.

The highest opportunities to create such features are shown on the data layers of water retention features restricted purely to grasslands (Darent_objective_solution_grassland_only). These can be blended with the flow accumulation network to identify, for instance, both where to create bunds and their direction (at right angles to the flow paths). The example to the right shows the priority interventions on grassland (dark blue is higher priority, pale blue lower priority) and the flow accumulation network (darker red is greater flow and pale red lesser flow). The bunds should be created in the blue areas and cutting across the red lines.



Priority areas for creating grassland bunds

The exact location and number of bunds will depend on local conditions, such as angle of slope or presence of farm tracks. For instance, a steeper field will require more bunds to retain the same volume of water as a shallow field, since each bund will hold water within a smaller up-slope area.

Identify field boundary opportunities

HydroloGIS does not implicitly consider hedgerow creation for reducing water flows and their associated problems. However, the numerical characteristic for established, woody hedges and woodland are similar, due to the undergrowth element of woodland. Planting hedges will offer a good chance of reducing flows in areas suggested for tree planting, especially in arable areas where mid-field or total field cover will not be attractive. The example to the right shows priority phosphate reduction areas on arable land, where hedges should be planted roughly at right angles to the flow lines.



Priority areas for phosphate reduction and flow accumulation

It is also possible to create water-retention features along field boundaries, such as swales or ditches connecting to storage ponds.

Planting hedges or other field-margin activities could be considered on pasture as well as arable land, but the `_arable_only` layers show where activity on field margins is likely to be the only option.

The hedges should be planted across the gradient as much as possible (at right angles to the flow accumulation lines). Raising the hedges on earth mounds would improve water retention characteristics, especially for young hedgerows, but this may not fit the vernacular in all locations.

Instructions for use

The following guides will enable an able user of GIS systems and those familiar with maps to gain the most from the products we have created.

All files have been sub-divided into 'Data' or 'Maps'. The former contains the GIS layers; the latter contains the maps created by Viridian for ease of reference by non-GIS audiences.

An example of a map location is:

`/Maps/DarentAdsorbedPollutantProvision.pdf`

Data Layers

Data layers files are in GeoTIFF (*.tif) raster format, which can be read by available GIS software.

The data files are prefixed by the objective, or ecosystem service, they are intended to describe or improve. Files for the individual objectives are prefixed by:

- flood_mitigation_
- erosion_control_
- pollutant_retention_soil_adsorbed_
- pollutant_retention_water_soluble_

Files describing the combined case, overall objectives, are prefixed by:

- overall_ or overall_provision_

The files themselves are divided into two folders: CurrentProvision and PrioritizedIntervention, respectively.

Within the CurrentProvision folder, each file contains HydroloGIS scores describing the potential for ecosystem service improvement. High scores represent high potential for improvement (i.e., low current ecosystem service provision from the landscape) whilst low scores represent low potential for improvement (high ecosystem service provision).

Within the PrioritizedIntervention folder, filenames appended by 100pct_solution describe the optimal land-use for each pixel to achieve the prefixed objective. These are indexed raster files where the values 1, 2, and 3 are assigned as:

1. Wetland
2. Woodland
3. Grassland

Files appended by percent_thresholds describe the priority percentiles used to describe the optimal x% intervention scenarios. These are in rank order, and normalised between zero and one, with null pixels assigned -1.

To create maps combining these data layers, please see the section “*Creating Solution Maps from Data Layers*” below.

Example locations for these files are:

```
/Data/PrioritizedIntervention/Darent_erosion_control_100.00pct_solution.tif  
/Data/PrioritizedIntervention/Darent_erosion_control_percent_thresholds.tif
```

Maps

Maps are in .pdf format and are found in the ‘Maps’ folder of the respective catchment. An example is:

```
/Maps/DarentAdsorbedPollutantProvision.pdf
```

All map files follow the naming convention:

```
<Catchment name><Ecosystem problem><Data description>.pdf
```

The ‘Ecosystem problem’ (or *objective*) elements are:

- Flood
- Erosion
- AdsorbedPollutant
- SolublePollutant

corresponding to the objective data layers (including an Overall combination of these elements) described above. The ‘Data description’ elements are:

- Provision
- Solution
- Solution_2pct
- Solution_10pct.

Maps suffixed with Provision correspond to the data in the CurrentProvision folder within the Data folder of the relevant catchment folder. For example, the following two locations correspond to each other:

```
/Maps/DarentAdsorbedPollutantProvision.pdf  
/Data/CurrentProvision/Darent_pollutant_retention_soil_adsorbed_provision.tif
```

Maps suffixed with Solution correspond to the data in the PrioritizedIntervention Data folder. The maps are produced as is described above, showing a gradient of different intervention levels. For example, the following three locations correspond to each other (with the data threshold set at 20%):

```
/Maps/DarentAdsorbedPollutantSolution.pdf  
/Data/PrioritizedIntervention/Darent_pollutant_retention_soil_adsorbed_100.00pct_solution.tif
```


/Data/PrioritizedIntervention/Darent_erosion_control_percent_thresholds.tif

Maps suffixed with `Solution_2pct` or `Solution_10pct` have specific thresholds applied to the data (2% and 10%, respectively).

Creating Solution Maps from Data Layers

For this example, we will show how to combine two `PrioritizedIntervention` rasters to produce a map of the most effective 10% of solutions across the catchment for reducing erosion.

To construct an optimal intervention scenario for a given objective, in a GIS system, select the pixels from the raster with the appropriate objective (e.g. `erosion_control_100pct_solution.tif`) that lie below a threshold percentage (e.g. 10%) in the corresponding thresholds raster (e.g. `erosion_control_percent_thresholds.tif`).

On the Viridian solution maps, the data indexed as 1. Wetland, 2. Woodland, and 3. Grassland in the `100pct_solution` raster are coloured 1. Blue, 2. Green, and 3. Orange, respectively.

The `percent_thresholds` geoTIFF raster files in the *CurrentProvision* folder are the prioritization rasters. These are used in conjunction with the `100pct_solution` objective raster, using the prioritization raster to select some threshold value to select areas within the indexed objective raster to identify what to plant where.

To show where the best 10% habitats should be planted, set a threshold of <0.1 on the `percent_thresholds` raster to select the areas that would offer the most benefit for erosion (or whichever ecosystem service is of interest). The corresponding area in the `100pct_solution` raster will then identify what habitats offer the greatest improvement in erosion control (or other chosen ecosystem service) for those areas.

Graded Solution Maps

To plot the data as presented in the `...Provision.pdf` maps, the above process is replicated for thresholds between 0 and 0.2, with transparency levels applied for each threshold boundary:

1. $0.00 \leq \text{threshold} < 0.02 \Rightarrow \text{transparency} = 0\%$
2. $0.02 \leq \text{threshold} < 0.05 \Rightarrow \text{transparency} = 40\%$
3. $0.05 \leq \text{threshold} < 0.10 \Rightarrow \text{transparency} = 60\%$
4. $0.10 \leq \text{threshold} < 0.20 \Rightarrow \text{transparency} = 80\%$

This visually grades which habitat to place where by transparency, the more transparent layers corresponding to lower priorities.

Appendix A: Step-by-Step Instructions for Creating Maps in QGIS

The following steps will enable you to create a map showing the highest 20% of prioritised solutions for Marrs Holbeck.

In QGIS 3, open the "Raster Calculator" in the "Raster" drop-down on the top menu bar.

In the Output Layer dialog box, enter a name of your choice '`<something>.geotiff`'. This will be the name of the top 20% priority map you will create.

Use "Selected Layer Extent" to trim the output geotiff to the same dimensions as any of the data files in the *Data* folder supplied by Viridian.

Enter the following expression in the "Raster Calculator Expression" dialogue box:

```
(0.0 < "Darent_flood_mitigation_percent_thresholds@1") * (0.2 > "Darent_flood_mitigation_percent_thresholds@1") * "Darent_flood_mitigation_100.00pct_solution@1"
```

The logic behind this expression is:

(Select percentage thresholds above 0, i.e., exclude null data) AND (Select percentage thresholds below 0.2, i.e. the top 20% solutions) IN (solutions raster, i.e., the "what to do" raster)

One final nuance is that QGIS will set no-data values to some highly negative number, and any other values that do not pass the above filtering conditions are set to zero. To properly display the output selection, you have to also set an additional transparency filter on the layer to excise the zeros. This can be done using the "Layer Properties" tool and selecting the "Transparency" window. In the "No data value" area, type '0' in the "Additional no data value" dialogue box.

Styling for the map should be as described in the report: 1 = Wetland (blue), 2 = Woodland (green), and 3 = Grassland (orange).

Appendix B: The Viridian Team

The key members of staff involved in this project were:

Angus Middleton – Project Director

Angus has a background in earth sciences and environmental engineering, and has been a director of environmental consultancies for over a decade. Since 2013 he has strived to improve our understanding of natural capital and make the commercial delivery of ecosystem services a reality. He has created partnerships between business, universities and NGOs to develop new tools, blending commercial pragmatism with scientific rigour and stakeholder concerns. Angus formerly ran an environmental consultancy that specialised in the environmental risk analysis of agricultural land. His development of the tools and methods employed by this company were so successful that it was acquired by a division of the Daily Mail group in 2013.

Angus was recently a member of the Innovation Advisory Board for NERC. He excels at delivering simple solutions to complex environmental problems.

Leon Baruah – Technical Director

Leon has a professional background in GIS and data analysis in environmental risk. Leon's expertise lies in problem solving; in devising and developing meaningful solutions to interesting and complex problems. He is a motivated and scientifically minded programmer/developer, with a keen interest in enhancing nature to benefit both people and nature itself. In his spare time, he volunteers for MapAction (mapaction.org), a disaster relief geodata/mapping charity. He was an Enterprise Fellow of the Royal Society of Edinburgh, sponsored by the Natural Environment Research Council to develop eco-hydrology research he previously undertook in commercial and academic spheres into Viridian.

Leon was awarded a Ph.D. in observational cosmology in 2015 from the University of Sussex; his thesis was on non-parametric searching of galaxy clusters in the Dark Energy Survey, using statistical and machine learning techniques. He is adept at communicating technical concepts and detailed data to a variety of audiences, from school children to international scientists. Leon has a strong affinity for architecting solutions and having to think about/identify problems to produce concise & engaging solutions.