Firestone GCN Modelling:

Comparative impact modelling to inform planning.

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Executive summary

North Wales is a known hotspot for Great Crested Newts (GCNs). Previous ARC work (i.e. Arnell & Wilkinson, 2013) has trialled high resolution (25m) modelling to quantify a number of GCN attributes (e.g. distribution, habitat suitability, importance of metapopulations, etc.) in Anglesey, NE Wales and Powys.

Wrexham industrial estate is located within the boundaries of the aforementioned modelling work. The present work aims to use existing outputs from previous high resolution modelling (Anglesey and NE Wales), namely the resistance surface and the cleaned presence location data, in a comparative analysis. The overarching premise of the work is that a baseline, or current state, can be used as a reference, against which multiple theoretical development scenarios may be compared in order to assess their relative impacts.

The following work represents the development of an objective, data-driven, analysis method that can be used as a decision-making support tool, with regard to the consideration of GCN within the planning process. We utilise graph theory-based connectivity analysis techniques to quantify relative impacts of development options on GCN metapopulations in the localised area around Wrexham industrial estate, the site of a proposed development.

The development's main building footprint was supplied in the format of a shapefile. Locations of proposed mitigation ponds were also supplied in shapefile format. A total of three model scenarios were run: (i) Baseline model – the current state, with no development simulated. (ii) Post-development model – with the development of the area described by the building footprint simulated (i.e. made impermeable to GCN). (iii) Mitigation model – the same as the Post-development model, but with the proposed mitigation ponds added too.

We found that the modelled impacts of development of the Firestone site (building footprint) on the wider GCN population network appears to be minimal, with no loss of ponds/nodes and the loss of only one link that possesses a low importance value. Whilst the modelled impacts may represent a relatively conservative estimate, the addition of five ponds to the network, as a means of mitigation, appears to compensate more than adequately for the minor loss in connectivity.

Introduction

Great crested newts (GCN) are protected by both British and European law, which together make provision for the protection of the species and its associated habitats. In England and Wales it is illegal to (i) intentionally or deliberately capture, kill, or intentionally injure great crested newts. (ii) Deliberately disturb great crested newts or intentionally or recklessly disturb them in a place used for shelter or protection. (iii) Damage or destroy a breeding site or resting place. (iv) Intentionally or recklessly damage, destroy or obstruct access to a place used for shelter or protection. (v) Possess a great crested newt, or any part of it, unless acquired lawfully. (vi) Sell, barter, exchange, transport or offer for sale great crested newts or parts of them.

Any activity likely to contravene the legislation must be licensed by the appropriate party, whom issues licences for the purposes of "preserving public health or public safety or other imperative reasons of overriding public interest, including those of a social or economic nature and beneficial consequences of primary importance for the environment" [Regulation 44(2)(e)].

A licence will not be granted unless:

- "There is no satisfactory alternative" [Regulation 44(3)(a)], and
- "The action authorised will not be detrimental to the maintenance of the population of the species concerned at a favourable conservation status in their natural range" [Regulation 44(3)(b)].

Therefore, any proposed development must show that any damage to the status of GCN must be adequately compensated for. Compensation must amount to the maintenance of conservation status, taking into account population size, viability and connectivity.

Local planning authorities have the responsibility of ensuring that protected species issues are taken into account as a material consideration when determining planning applications. They must also ensure that protected species issues are taken into account in the preparation of Local Development Plans (LDPs). These responsibilities are underlined by Regulation 3(4) of the Conservation (Natural Habitats & c.) Regulations 1994, which require authorities to have regard for the conservation of European Protected Species, such as great crested newts.

When considering options for development plans, it can be costly and time-consuming to undertake detailed surveys at all ponds and GCN presence locations, for the purpose of quantifying impacts. Although it is usually a requirement that any submitted plans are accompanied by full surveys of the areas affected, this is not to say that **all** options considered prior to submission need to be subject to full surveys.

In the interest of optimising allocation of time and resources to full surveys, it would be immensely valuable to be able to assess relative impacts of options, without having to first undertake detailed surveys at all presence locations within the vicinity of candidate development sites. Desktop studies can be useful, in the interest of time and costs; however they still require data on GCN presence. These data are sometimes present, in the form of local/regional records centre data, but rarely provide much beyond the species' presence or absence.

The present study utilises Species Distribution Modelling (SDM) in order to quantify the potential value of populations at GCN presence locations and incorporates this data into a wider, landscape-level connectivity analysis. The connectivity analysis uses a resistance surface, which can be modified to reflect proposed developments, to model the likely movement of GCN through the landscape between locations of known presence. By using a metric that captures both the value of individual habitat patches (ponds/nodes) and the degree of connectivity at a landscape level, it is possible to compare the relative predicted impacts of multiple development scenarios without having to first carry out detailed GCN surveys at all sites. This approach allows many development options/scenarios to be compared with minimal outlay, both in terms of time and money.

Materials and Methods

Software & Data

The following software was used in this study:

- The majority of analysis was conducted in R (R Core Team, 2013), using the 'gdistance' (van Etten, 2012), 'rgdal' (Bivand et al., 2013) and 'raster' (Hijmans, 2013) packages.
- Network analysis was conducted using the Command Line version of Conefor software (Torné & Saura, 2013).
- Composition and creation of map outputs was carried out using ArcGIS 10.2 (ESRI, 2013).

All GCN presence location data used in this study was derived from the Cofnod dataset used in Arnell & Wilkinson (2013). MaxEnt model output and resistance surface GIS layers were all taken from Arnell & Wilkinson (2013). GIS shapefile data describing the proposed candidate development site and detailing the mitigation pond locations was provided by the client.

Study area

Figure 1 – Map showing location of study area.

The proposed development site is located in the Wrexham industrial estate, on the eastern outskirts of Wrexham town, north Wales (see Fig.1 above). The study area is essentially defined by a 2km buffer around the development site. However, after visual inspection we concluded that there were additional GCN records just outside the buffer (predominantly to the north-east), near enough to the study site as to be relevant. The study area was expanded to include these additional records.

Resistance Surface Scenarios

The resistance surface created for the Anglesey & NE Wales project was clipped to the extent of the study area. An unmodified version was used as the baseline "no

development" scenario. The remaining 2 scenarios were each represented by a modified resistance surface, where cells of the selected development site was assigned a high value (10000), rendering those cells impermeable to all intents and purposes.

Least Cost Pathways

Calculating Least Cost Pathways (LCPs) is a necessarily processor-intensive procedure, particularly when working at high resolutions. However these calculations can be minimised by limiting the number of pairs of points for which the LCPs are calculated. In this study, we filtered out any pair of points that possessed a Euclidean separation distance exceeding 2000m, a distance beyond which it is reasonable to assume that negligible dispersal occurs.

LCPs were calculated for the remaining pairwise combinations of points (1866 combinations/LCPs in total for the first two scenarios, 2130 for the mitigation scenario). LCPs were calculated for each the baseline, development and mitigation scenarios, which were represented by the resistance surfaces. Line shapefiles containing the LCPs, and their corresponding cost-distance values, as attributes, were generated for subsequent visualisation and map creation.

Graph construction and analysis

We used the graph theory software Conefor (see Software section) to highlight populations that are likely to be most important. Graph theory has been used for a variety of applications, including geography and computer science and recently has been employed to provide estimates of connectivity between habitat patches at landscape scale (Minor and Urban, 2007; Saura and Rubio, 2010; Urban and Keitt, 2001). This software is able to calculate a connectivity index (Probability of Connectivity, 'varPC') for each population, which is comprised of the habitat quality/patch size of each patch (varPC Intra), the patches' contribution to connecting between patches (varPC Con) and the position of the patch within the network (varPC Flux) (Saura and Rubio, 2010).

Nodes: The GCN presence points were used as nodes in graph construction. Each of the nodes was assigned a "patch" value, representing some surrogate for habitat value. These "patch" values were derived from the MaxEnt model output from the Anglesey & NE Wales project, on the basis that most suitable locations were of higher habitat value than less suitable locations.

Edges/Links: The LCP cost-distance values were used as edge/link distance values in the graph construction – the higher the LCP cost-distance value, the further apart the two corresponding nodes are.

Conefor Parameterisation: In order to calculate varPC values for the graph objects, thresholds must first be defined. In the context of this study, the threshold relates to dispersal distances. Although the median dispersal distance used in previous studies was 250m, a recent further literature review led us to revise this up to 400m. Research carried out by Jehle *et al*. (2005) suggests that a median dispersal distance of 250m may be somewhat conservative. Furthermore, Joly *et al*. (2001) suggest that a median dispersal distance of 400m is appropriate.

As all of our edge/link values are in cost-distance, rather than Euclidean distance, the threshold had to be converted into corresponding units of cost-distance. In order to do this, we calculated an average cost per metre of the LCPs (0.924), which characterises the wider landscape, then multiplied this landscape value by 400 to give a cost-distance of 369.6 for median (0.5 probability) dispersal.

For each node, the varPC index and its components were recorded. For each edge/link, the change in overall, landscape PC number associated with its removal from the graph (representing link importance) was recorded. The overall PC number, a measure of combined graph object coherence, was also recorded for each of the scenarios.

Results

Initial, baseline analysis (no sites developed)

Those edges/links with cost-distance values above a cost-distance threshold equivalent to a Euclidean distance of 2000m (2000 x 0.924 = 1848) were removed from the final maps, as dispersal beyond this cost-distance is deemed to be negligible, leaving a total of 1444, 1443 and 1559 remaining links for the Baseline, Post-development and Mitigation scenarios respectively.

In the initial baseline model (see Appendix 1) the bulk of pond/nodes are down the eastern side of the study area in a slight crescent shape, wrapping around the industrial estate. They are most densely distributed in the middle, thinning out to the north and to the south. There are a few sparsely distributed nodes to the west of the development site, which are relatively poorly connected to the main part of the network. More important ponds/nodes generally represent those that are better connected, and less important ones generally represent those that are more isolated. Overall pond/node importance (sum of PC components – Intra, Flux and Con) is reflected in the diameter of the corresponding pie-chart.

Due to the relatively dense configuration of the main body of the network of nodes, the links between them are good and numerous. There are some more tenuous links, separating a small sub-cluster in the south of the study area from the main body of the network, but not so much as to be significant. There appears to only be one, relatively low importance link crossing the proposed development site.

Regarding composition of importance/PC metric for each node, 'varPC Con' is very low, almost non-existent, due to the spatial configuration of individual nodes within network components (removal does not increase fragmentation of components significantly). For the main part, the only visible components of PC are 'Intra' (red) and 'Flux' (green). The variations in relative proportions of these components is broadly explained by isolation of the pond/node in question – 'Intra', representing the actual habitat patch value, increases as a function of isolation, thus those ponds/nodes that are more isolated tend to display a higher proportion of red.

Development Scenario

As mentioned above, there is only one link that crosses the development site (see Baseline model, Appendix 1). There are no nodes lost as a result of the development. Beyond the loss of the individual link, there are no significantly discernable impacts on the network through the development of the site (see Post-development model, Appendix2). The loss of the link, which is of relatively low importance, results in a decrease in overall landscape value (PCnum) of just 0.01%, from 390.645 to 390.602 (See Fig. 2).

Mitigation Scenario

Five ponds/nodes were added to land adjacent to the building in the mitigation scenario (see Mitigation model, Appendix 3). They border the development to the south and east and connect well with the two existing nodes in the immediate vicinity, as well as the main body of the network, via numerous new links. The new nodes also improve the connectivity of the southern part of the overall network to the sparse western nodes. The addition of 5 nodes (i.e. habitat patches) to the network in conjunction with the increase in cohesiveness of the network through improved connectivity results in a healthy increase in overall landscape value (PCnum) of 3.2%, from post-development value of 390.602 to 403.178 (see Fig.1).

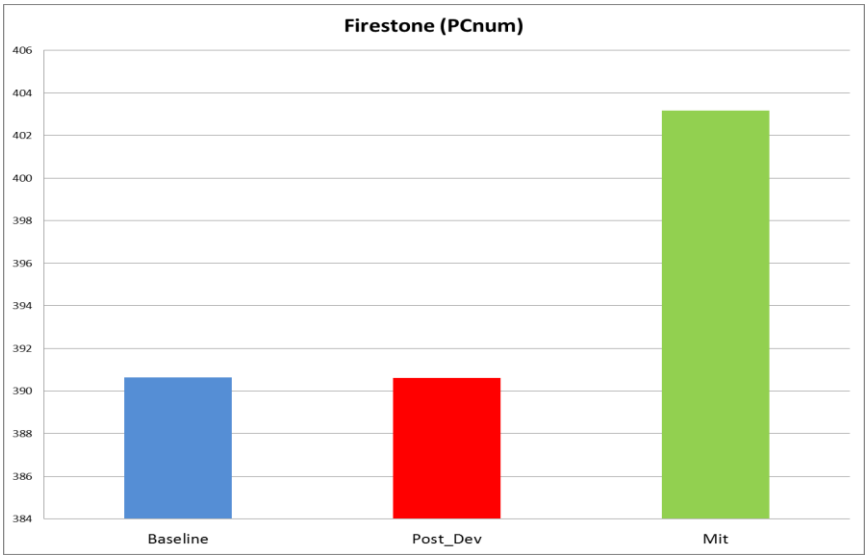

Figure 2 – Graph displaying the overall landscape metric, PCnum (sum of all nodes' components) associated with each scenario. The baseline model, 'no development', is coloured blue, post-development model is coloured red and the mitigation model is green. *Note that Y-axis does not start at zero*

Discussion

Methods

We used MaxEnt output as a surrogate for habitat patch value. The approach could be augmented by the addition of HSI data and ground-truthing. Nevertheless, this approach follows a clear and logical theoretical grounding and in the absence of HSI, or other survey data, may provide a more realistic representation of potential patch habitat value than a simple binary present/absent approach.

Generally, the methods used in this study offer useful insights into the way that the target taxa may use and move through the landscape, although data-imposed limitations must be recognised and considered when interpreting the outputs. For instance, the resistance layers, the basis for LCP creation, are far from a perfect representation of the real world. It is highly probable that barriers exist that are not captured by the data sources used to derive the resistance surfaces (i.e. fences, walls, etc). Furthermore, there is a paucity of research relating to the relative resistance of landcover types to GCN movement – this research would be invaluable in calibrating more accurate resistance surfaces.

Nonetheless, providing the limitations are kept in mind when interpreting outputs, the methods outline in this study can highlight key areas for potential corridors of dispersal, which can be verified through short-term, focussed surveys (i.e. drift netting). They can also provide a consistent, objective, transparent means of comparing various development scenarios, without the cost of detailed surveys. This could potentially allow planners to consider a greater number of options, refining them through the methods used here, before carrying out more detailed analysis on only the best two or three.

Model Outputs

It is important to note that the comparative analyses carried out in this study, were done so on the strict basis that specific combinations of development sites and nodes (those stipulated by the client) comprised the development scenarios. The authors would recommend the use of extreme caution when trying to extrapolate beyond the remit of the specified combinations of developed sites set out herein. Furthermore, the modelled impact of the development does not necessarily capture the full range of possible negative effects associated with such a development. For instance, the footprint of the building will

not be the spatial limit of influences during construction (i.e. people and vehicles moving around site). However, the identification of important dispersal pathways and ponds should allow planners and developers to minimise impacts through avoiding them where possible.

These analyses elucidate the current structure of the GCN population network in the localised area around the proposed, Firestone, development site and highlight the links most important to the taxa's dispersal capabilities. The 'post-development' model shows that there is relatively little impact to the GCN population network through the development of the proposed site; specifically the loss of a single, relatively low importance, link. The 'mitigation' model suggests that the impact of the development is more than compensated for by the addition of five new ponds (under the assumption that these ponds are made suitable for GCNs).

Conclusions

The modelled impacts of development of the Firestone site (building footprint) on the wider GCN population network appears to be minimal, with no loss of ponds/nodes and the loss of only one link that possesses a low importance value. Whilst the modelled impacts may represent a relatively conservative estimate, the addition of five ponds to the network, as a means of mitigation, appears to compensate more than adequately for the minor loss in connectivity.

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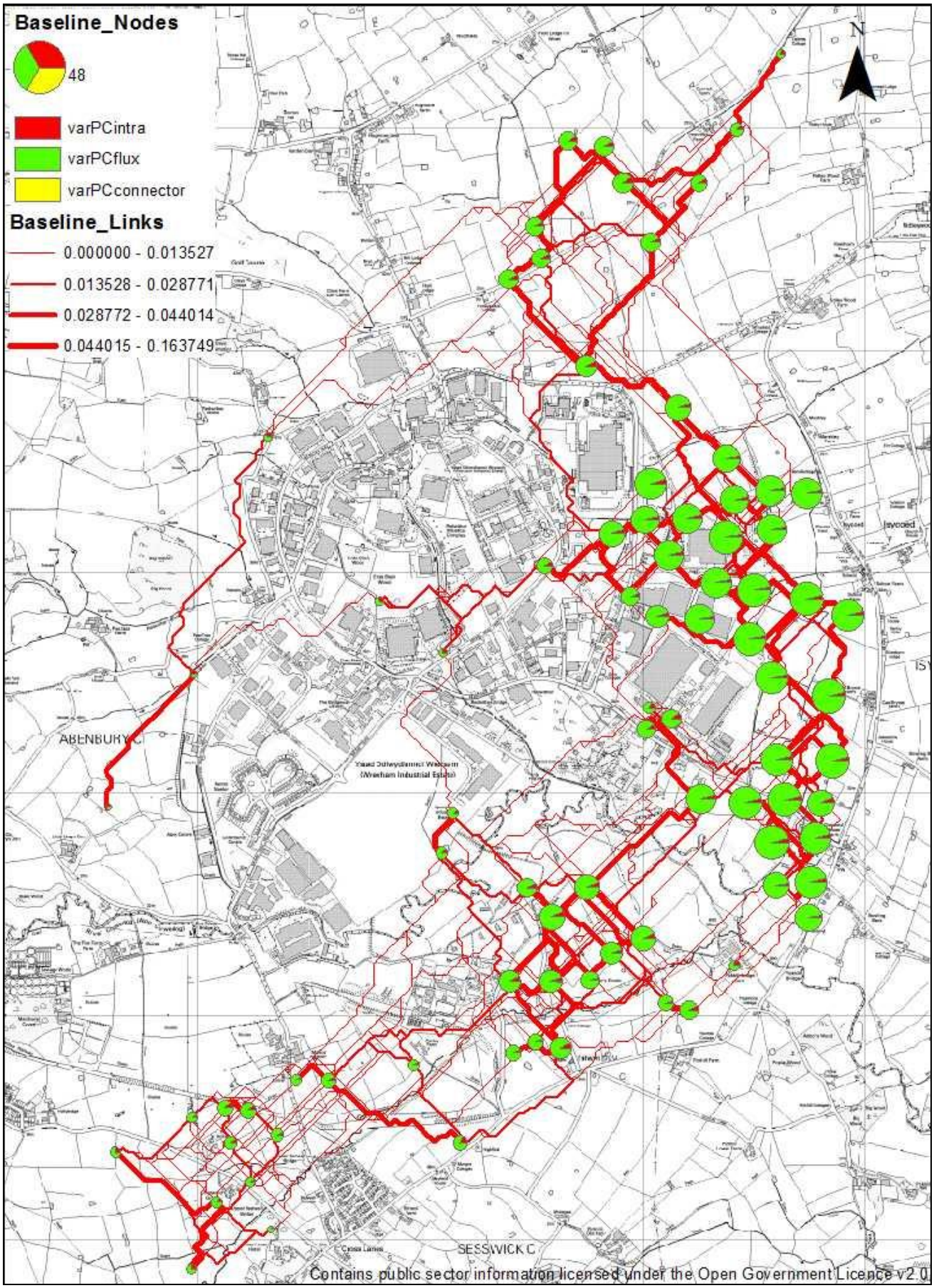
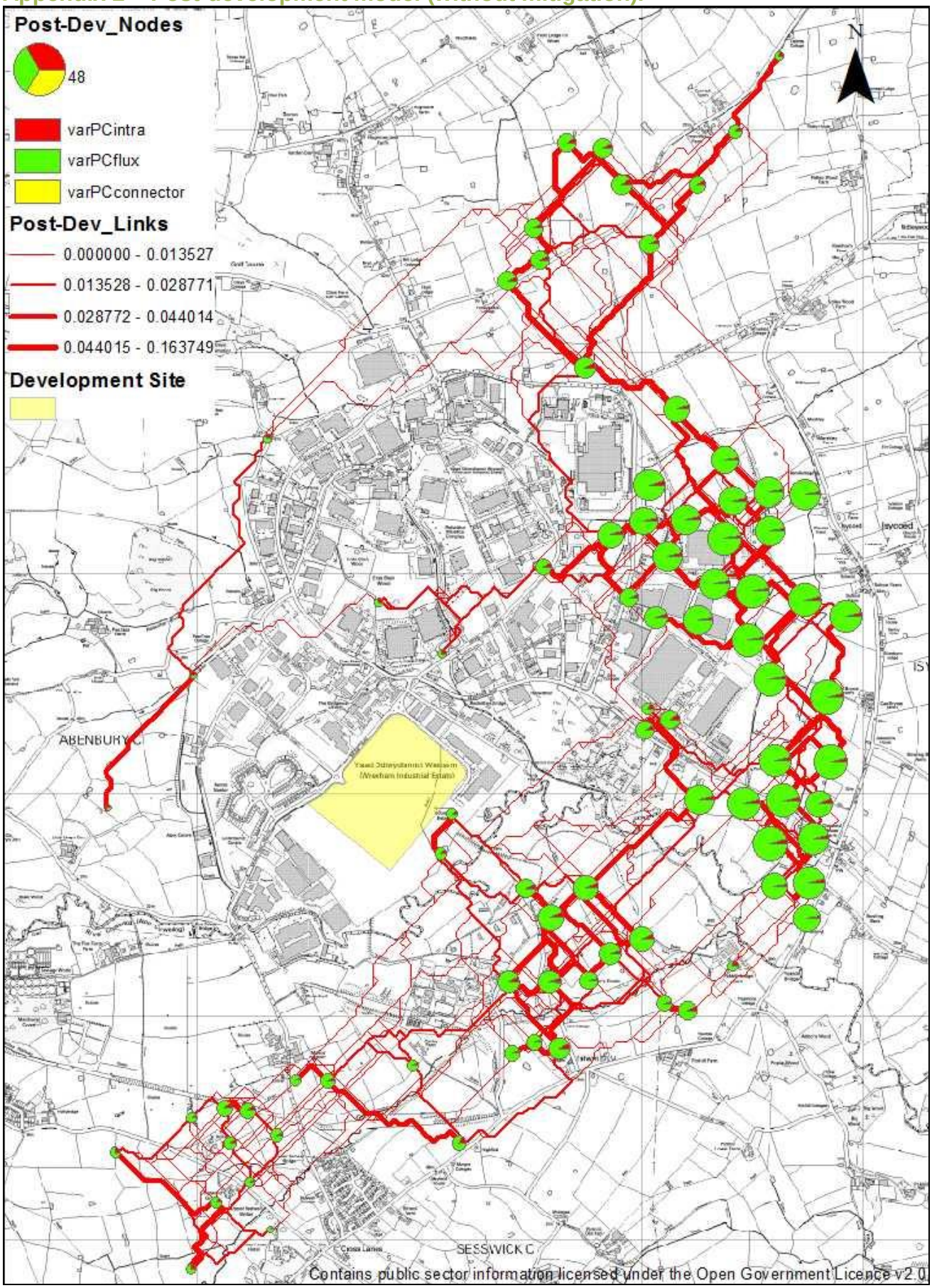
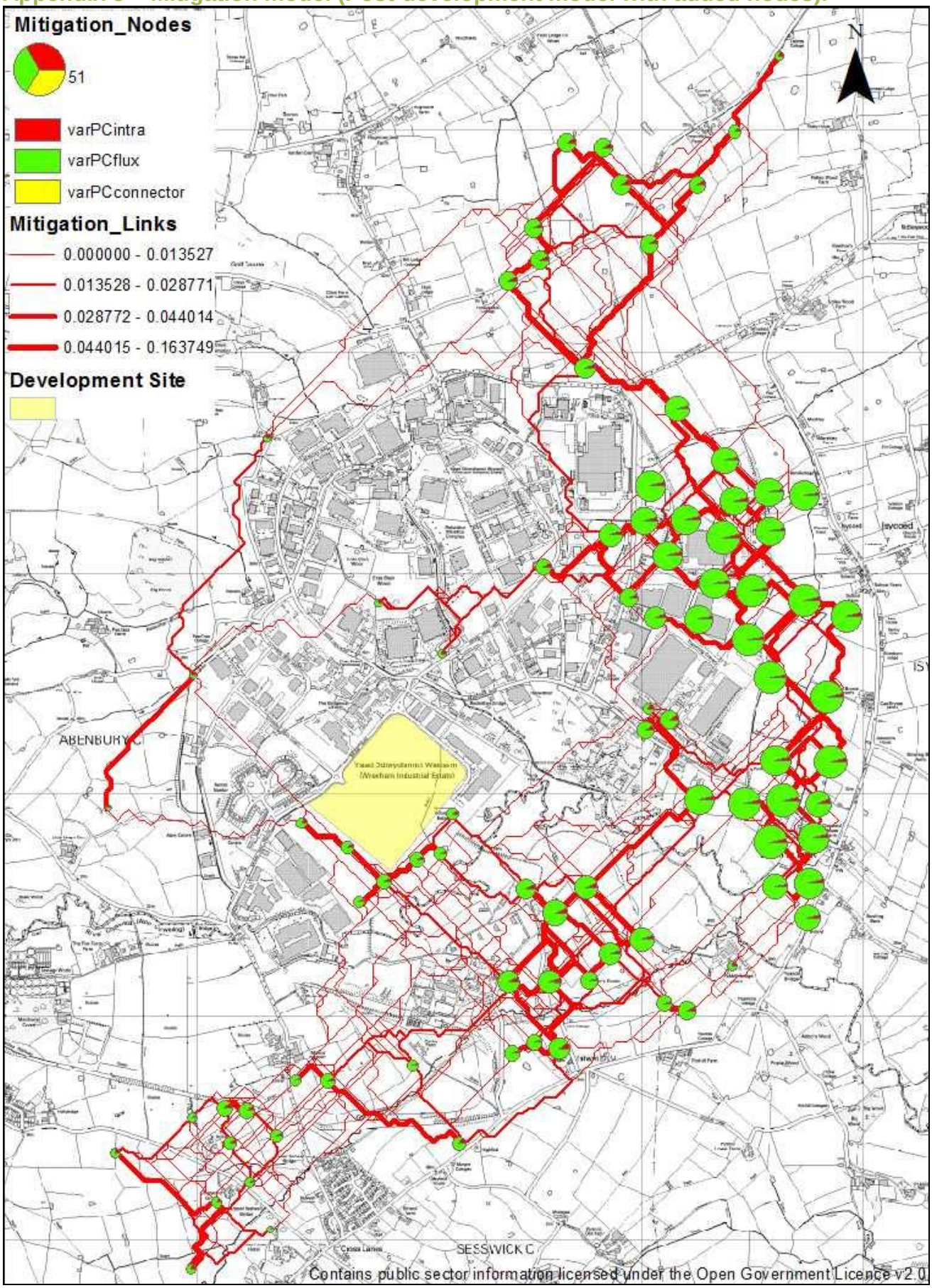
Appendix 1 – Baseline model (no development).



Appendix 2 – Post-development model (without mitigation).



Appendix 3 – Mitigation model (Post-development model with added nodes).