Appendix P

Shading Analysis Report

P.1 Shading Analysis Report

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Galway County Council

N6 Galway City Ring Road

Sunlight and daylight availability assessment

GCOB-4.04-21-005

Issue 2 | 28 September 2018

Job number 233985-04

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Contents

1 Executive Summary

This report summarises the outcome of a specialist study investigating the predicted effect of the N6 Galway City Ring Road (GCRR) on daylight and sunlight exposure for the surrounding site from Ch. 8+350 to 10+450 and Ch. 15+500 to 16+000, as shown on figure SK-D-909 in **Annex A**.

The metric used in the assessment comprises of:

- Shadow plots (qualitative assessment)
- Daylight factor (%)
- Daylight cumulative daily exposure for average month day (klx.hr/day)

These are technical indicators of the extent of shadows, the reduction of daylight and the reduction of daily exposure to daylight and sunlight.

In summary the results show that:

- The effects of the proposed N6 GCRR on daylight and sunlight exposure are localised where the proposed design has a higher profile from the existing ground level. This occurs at the bridge and viaduct locations where the differences in exposure between the baseline and proposed condition are noticeable
- Depending on the angle of the sun, the projected shadow of the proposed N6 GCRR reduces the daily exposure of the areas surrounding it. In general, during the summer months the area where the reduction is detectable extends about 20m from the edge of the proposed bridge and viaduct structures. During the winter months this area is extended up to 120m from the edge of these structures
- All remaining areas receive the same amount of daylight and sunlight exposure as the baseline condition

2 Introduction

As part of the environmental studies to inform the Environmental Impact Assessment Report for the N6 Galway City Ring Road, hereafter referred to as the proposed road development, Arup undertook a specialist lighting study to investigate the predicted effect of the proposed road development on vegetation in the areas surrounding the proposed road development from Ch. 8+350 to 10+450 (the N69 Moycullen Road to Sean Bóthar in Menlough which includes the River Corrib Bridge and the Menlough Viaduct) and Ch.15+500 to 16+000 (east of the Galway Racecourse Tunnel and the R339 Monivea Road).

To undertake this study, a series of simulations have been carried out comparing two scenarios: the existing environment without the proposed road development (baseline) and the operational phase of the proposed road development (proposed condition). The methodology used and the assumptions made in the simulations are described in the **Section 3** and **Section 4** of the report.

The results of the simulations are summarised **Section 5**.

Conclusions are summarised in **Section 6**.

3 Baseline

From a sunlight and daylight point of view, the areas surrounding the proposed road development are unobstructed. The presence of rivers and gentle slopes allows the landscape, which includes vegetation and trees, to receive most of the daylight and sunlight available at this latitude. For this reason, even the erection of a small structure will have a shadow effect on the surrounding landscape.

4 Methodology, Modelling and Assumptions

4.1 Methodology

The aim of the study was to assess the proposed road development against the existing baseline conditions to determine the potential impact on light levels experienced by vegetation in the shade of the structures.

The following metrics have been considered to evaluate the potential impact on sunlight and daylight for the site:

- Shadow plots (qualitative assessment)
- Daylight factor (%)
- Daylight cumulative daily exposure for average month day (klx.hr/day)

4.1.1 Shadow plots

Shadow plots were used to visually demonstrate the extent of the shadow area created by the proposed road development. This is not a numerical measure of exposure or illuminance in the shadow areas. These diagrams have a qualitative intent: they allow the viewer to see the movement of the shadow throughout the day and for different seasons.

4.1.2 Daylight factor

Daylight factor is expressed as a percentage ratio between the illuminance at a point and the simultaneous unobstructed illuminance under an overcast sky. Illuminance is the measure of the incident light at a given time.

Daylight factor is defined using the CIE Overcast Sky Model, thus it is invariant of orientation and time of the day/year. The sky model used approximates the typical overcast conditions, and therefore, the worst-case scenario for daylight conditions. For this reason, it is widely used in studies where the minimum daylight requirements are analysed. Values range from 0 – 100% for horizontal surfaces and 0 – 40% for vertical planes.

The results of the analysis provided an indication of the reduction of diffuse light available to a given point. Values are shown on a map and organised with a colour code. In human perception terms, a reduction of more than 20%[1] from baseline values is considered significant as it is visible. From this analysis, it is possible to read the extent and intensity of the impact of the proposed configurations on the surrounding area. What this parameter does not tell is the effect of the proposed road development on sunlight exposure.

Histograms are used to measure the extent of the areas which have a reduced daylight factor.

4.2 Daylight cumulative daily exposure for the average month day

Daylight cumulative daily exposure for the average month day is based on statistically probable weather conditions for each hour of the year.

Light exposure is a common metric that is used by agriculturists for plant growth. The quantities provide an indication of the total amount of light available on the plant for a given day.

The output of simulations is represented as site exposure maps, which show the value of exposure on the area included in the analysis. These maps allow a person to see where reduction occurs and how severe this is.

Histograms are used to measure the extent of the areas which have a reduced exposure. These charts show the percentage of data points which have an exposure

[1] BR 209, Site layout planning for Daylight and Sunlight, A guide to good practice: 2011

within a set value range. It is possible to measure the percentage of area where there is a reduction in exposure with the proposed condition.

4.3 Modelling

Sunlight and daylight availability for the site have been estimated by means of numerical simulations. The simulations have been carried out using the lighting software Radiance Ray Tracing System.

All calculations have been carried out on a series of grids located within the site computer 3D model. The location of grids and grid designations is illustrated in **Figure 1**. Analysis has been carried out on a baseline model of the existing environment, as shown on **Figure 2** for Grid 2 and for a model of the proposed road development as shown on **Figure 3** for Grid 2. The analysis grids correspond with the following sections of the proposed road development which were included in the study as outlined in **Section 2** above:

- Grid 1: Ch. 15+500 to 16+000 (east of Galway Racecourse Tunnel to R339)
- Grid 2: Ch. 8+350 to 10+450 (N69 Moycullen Road to Sean Bóthar, Menlough)
- Grid 3: Ch. 10+100 to 10+450 (Menlough Viaduct)
- Grid 4: Ch. 8+750 to 9+500 (River Corrib Bridge)
- Grid 5: Ch. 9+500 to 10+100 (Embankment between River Corrib Bridge and Menlough Viaduct)

Figure 1: Positions and designation of analysis grids

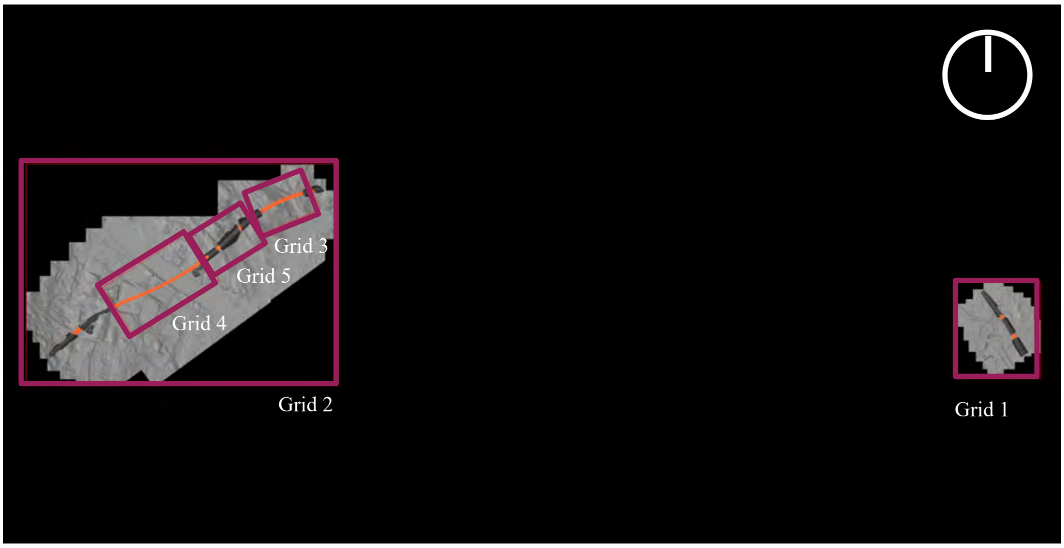


Figure 2: Model representation of baseline for Grid 2

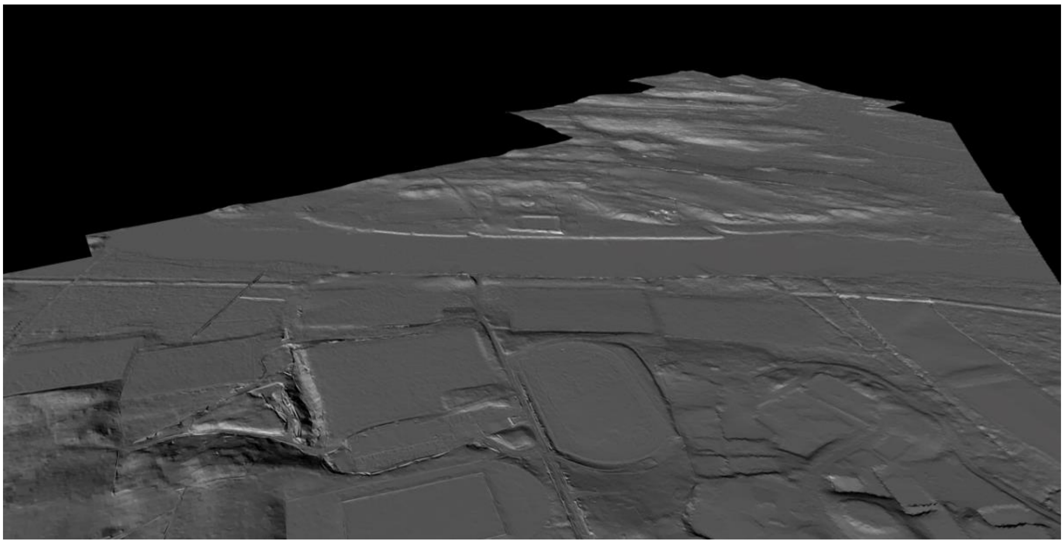
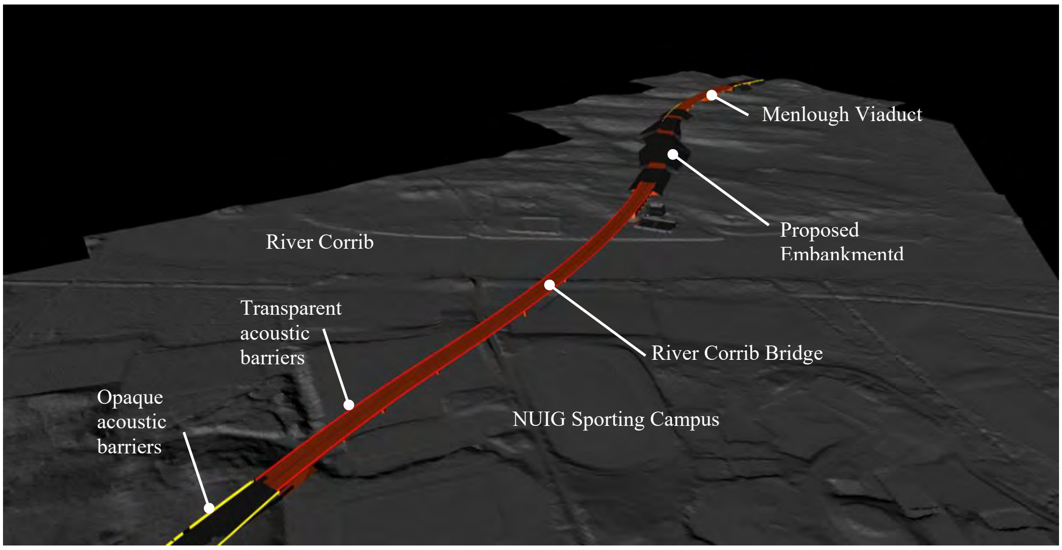


Figure 3: Model representation of the proposed road development for Grid 2



4.4 Assumptions

The following assumptions have been made:

- The weather condition and the diffuse / direct light components have been derived from the software Meteonorm 7. This software uses interpolation and statistics alongside the site location to generate a meteorological, site specific, dataset. The algorithms used are based on extensive research and contrasted with satellite data to improve accuracy.
- The weather data thus generated is based on relevant measured data, and adjusted to the characteristics of the site (altitude, distance to the sea, etc.) making it more reliable for locations away from urban centres.
- The dataset includes, for each hour of the year, values of irradiance (direct and diffuse), temperature, humidity, cloud cover, etc.

- This data has been used to generate a set of typical scenarios, one per month, and run the analyses to determine the typical daylight profile and the cumulative daily exposure
- The latitude of the site has been set to 529326.169E and 727156.65W (ITM co-ordinate system)
- The irradiance values have been converted into illuminance using a standard conversion factor of 100 lm/W
- The materials of the structure and the surrounding landscape have a limited influence on the exposure at ground level. Thus the calculation has been carried out without considering inter-reflected light. The calculation considers only direct sunlight and diffuse light from the sky. This is a worst case scenario approach
- For the transparent portion of the acoustic barriers (which is located along the River Corrib Bridge) a transmission factor of 50% has been used. All other elements of the proposed road development assessed have been considered opaque.

5 Results

The following sections provide a commentary on the results of the simulation for the various metrics used in the assessment.

5.1 Shadow Plots

Each image shows the situation of the site with respect to the sun at one particular moment.

Four sets of images are provided so that close up views of areas of the proposed road development are visible alongside the overview.

The images are composed of two parts: a view of the site from the direction of the sun, the perspective changes as the sun moves at different times of the day, any object that is visible would receive direct sunlight; and a fixed view of the site showing the location of the shadows relative to the suns position.

Each page presents the results for one of the areas modelled. Three days of the year were selected. Those times correspond to equinox and solstice days with hourly intervals.

By comparing the results for the proposed road development operational with the baseline of the existing environment, it can be observed that the effect is exacerbated in the winter months, when the sun angles are low and even, a low profile structure will result in long shadows.

Conversely during the summer, the effects of the proposed road development are more localised and less visible in the surrounding areas. Shadows in the summer are localised mostly below or close to the structure outline.

The following images show these two extreme scenarios for summer and winter and the proposed road orientations (northeast / north northwest). **Figures 4** and **5** represent grid 1 and **Figures 6** and **7** grid 2.

Figure 4: Winter low angle sunlight at 21 December 12:00, note long shadows

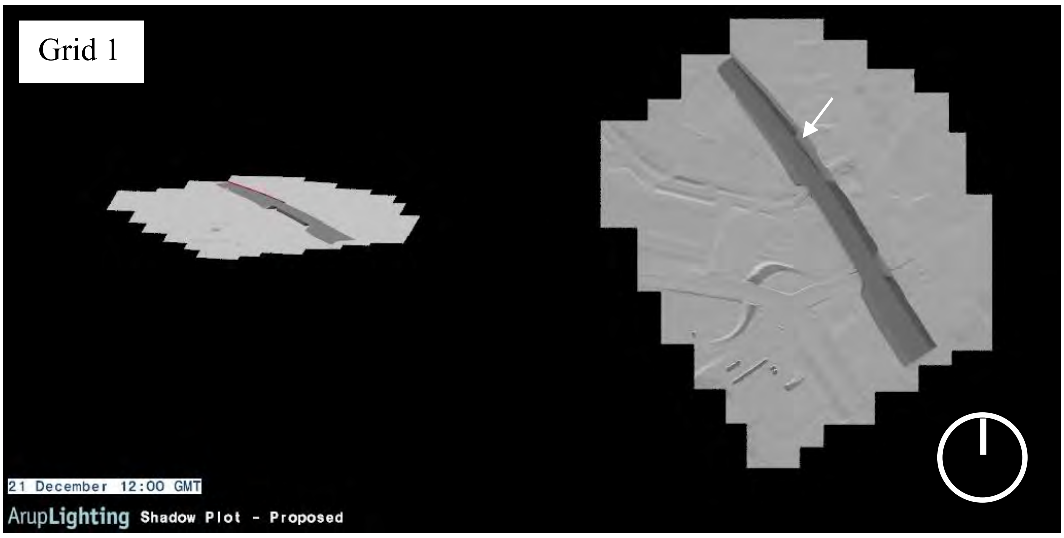


Figure 5: Summer sunlight at 21 June 12:00, showing very short shadows

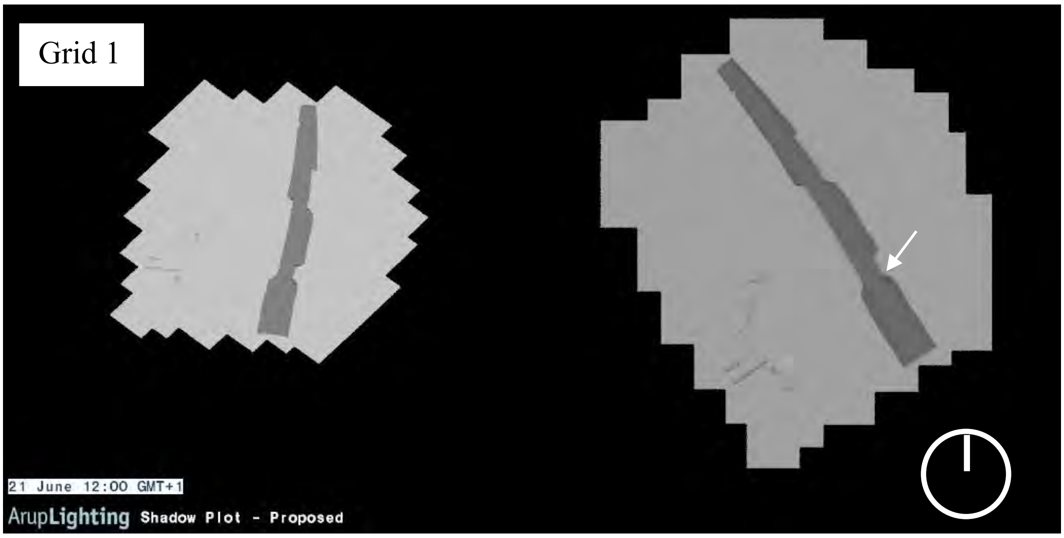


Figure 6: Winter low angle sunlight at 21 December 12:00, showing long shadows

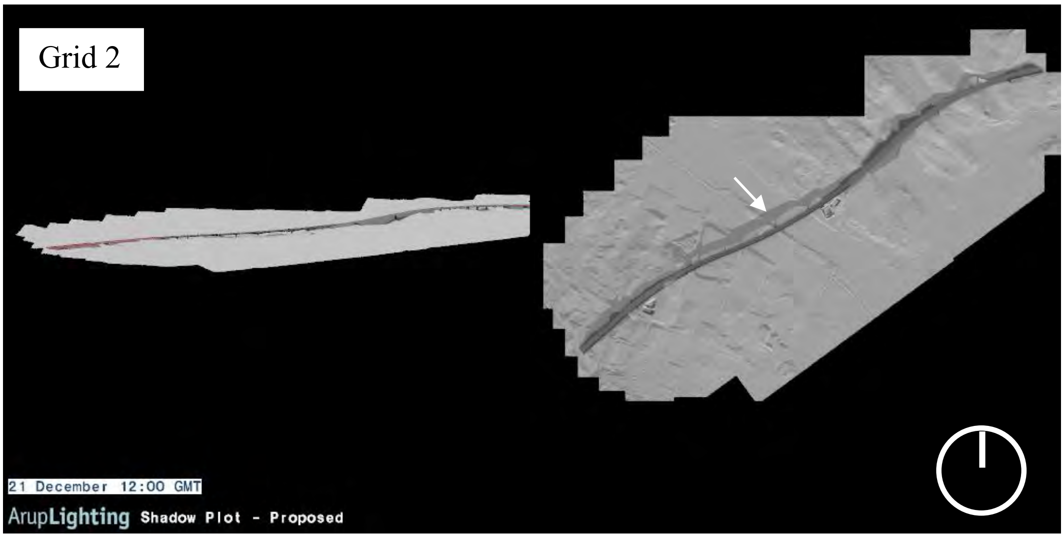
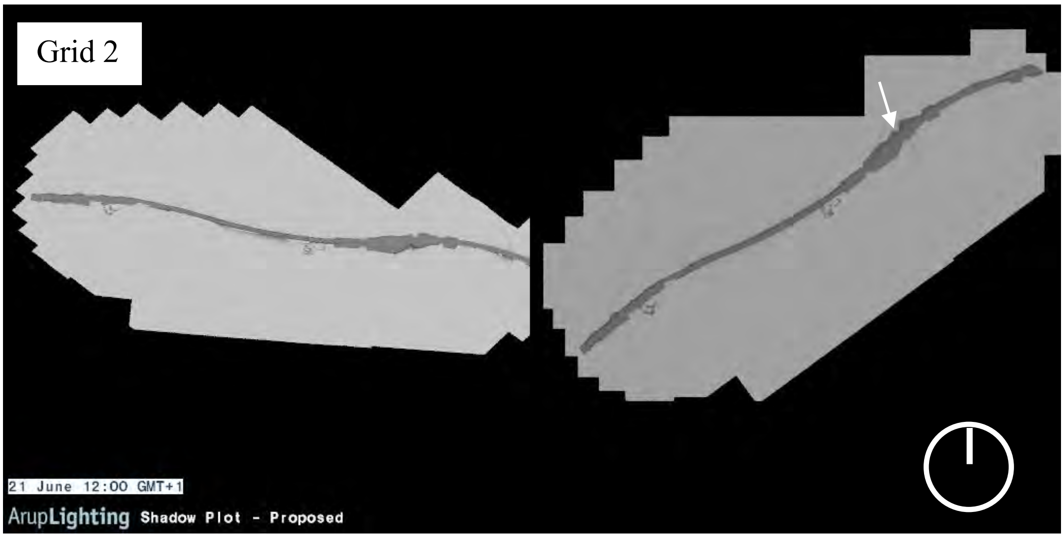


Figure 7: Summer sunlight at 21 June 12:00, showing very short shadows



5.2 Daylight Factor

This section shows in more detail the effect of the proposed road development on the available daylight. As the baseline corresponds to a completely unobstructed portion of land, the values of daylight factor are essentially 100%.

However, given that the alignment of the proposed road development does not create a significantly larger obstruction to daylight than the surrounding ground level, the effect on the daylight factor is limited to the areas surrounding the bridges and viaduct.

There are however some localised effects. These are:

- Along the Menlough Viaduct and River Corrib Bridge (grid 3 and 4 respectively) and within 10m from the bridge and viaduct edge, at the widest point, values are in the range of 60 – 100%.

- Areas below the bridge and viaduct see a larger reduction in daylight factor. The recorded values are in the range of 10 - 30%.
- All other surrounding areas, including grids 5 and 1, are unaffected and retain the same level of daylight factor than in the baseline condition.

It is noted that 99% of baseline area receives 100% daylight factor (see the yellow bar which is reading a value of 99% on 100% daylight factor range, Figure 8).

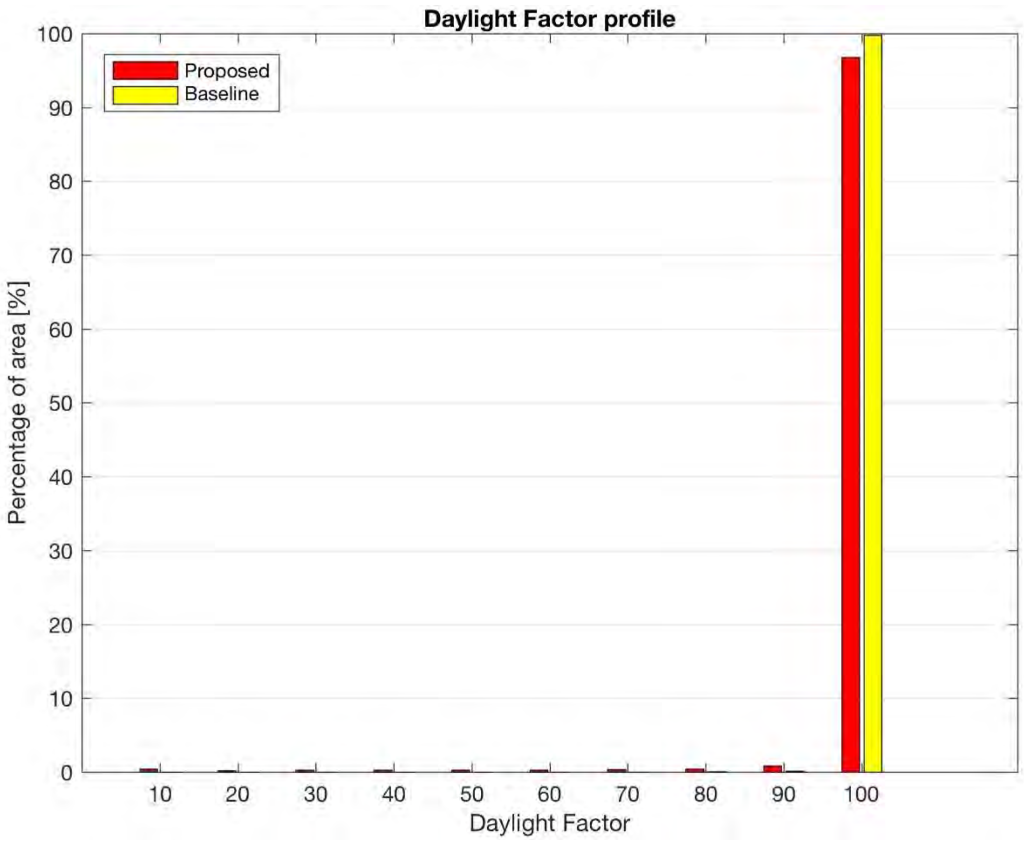
By looking at the histograms of data, the areas that are more affected by the proposed road development are represented by grid 3 and 4, along the Menlough Viaduct and River Corrib Bridge sections.

The embankment in grid 5 does not have the same effect as the bridge and viaduct and any reductions are localised to the area at the short underpasses and to the south of the embankment, and are therefore limited.

Considering grids 3 and 4 the reduction in area receiving 100% daylight factor with the proposed bridge is approximately 10%. If we consider this in perspective and look at the full extent of grid 2, which is the actual area considered in the assessment and includes grids 3, 4 and 5, this difference becomes much smaller: around 3% of the total (this is because grid 2 includes a very large area which is not affected by the bridge).

The diagram for grid 2 is shown below in **Figure 8**.

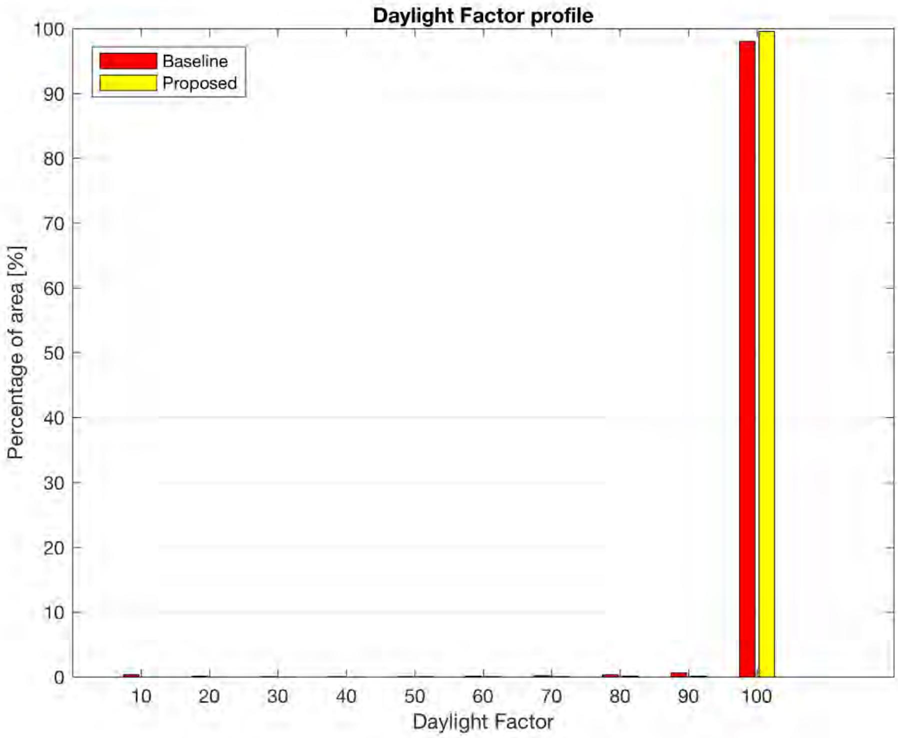
Figure 8: Daylight factor profile chart in Grid 2



The area receiving a certain daylight factor value is represented by the length of the corresponding bar. The baseline is receiving 100% daylight factor for almost all its extent (99% percentage of area at 100% daylight factor). The proposed road development has a limited effect, reducing this area by approximately 3% (97% of the total area achieves a daylight factor of 100%).

The same situation is observed for grid 1.

Figure 9: Daylight factor profile chart in Grid 1



Figures 10 to 14 illustrate the daylight factor distribution with the proposed road development operational for each of the grids. Note the localised effects below the bridge and viaduct and along the embankments.

Figure 10: Grid 1 daylight factor distribution, proposed road development

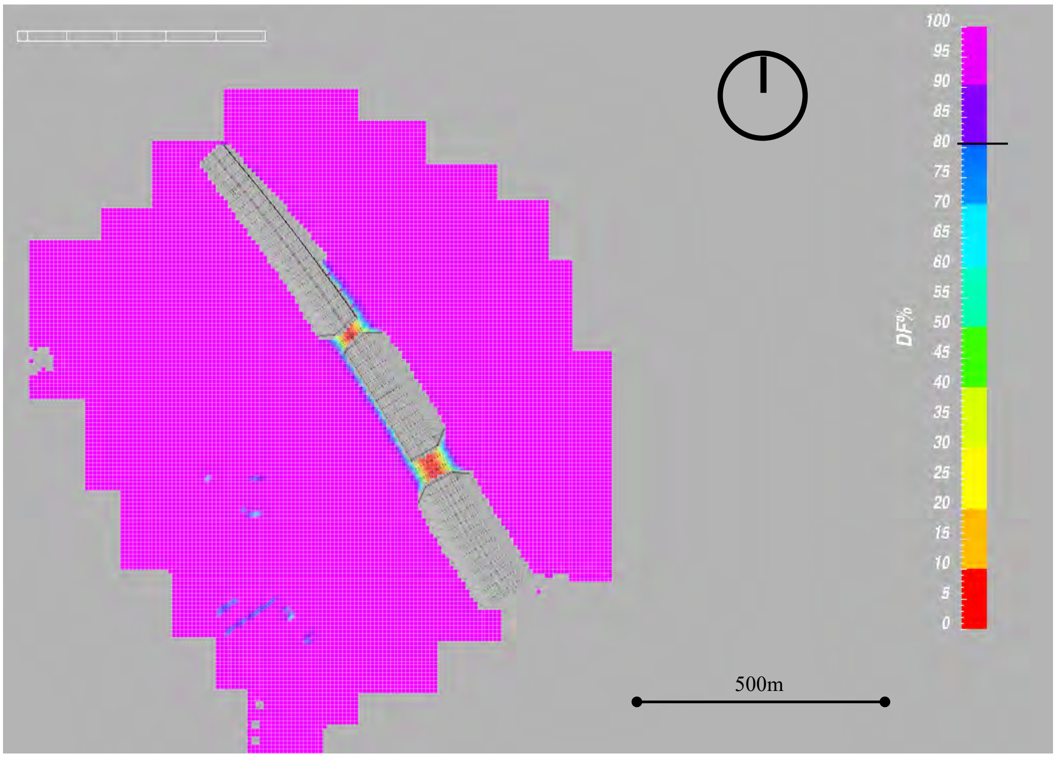


Figure 11: Grid 3 daylight factor distribution, proposed road development

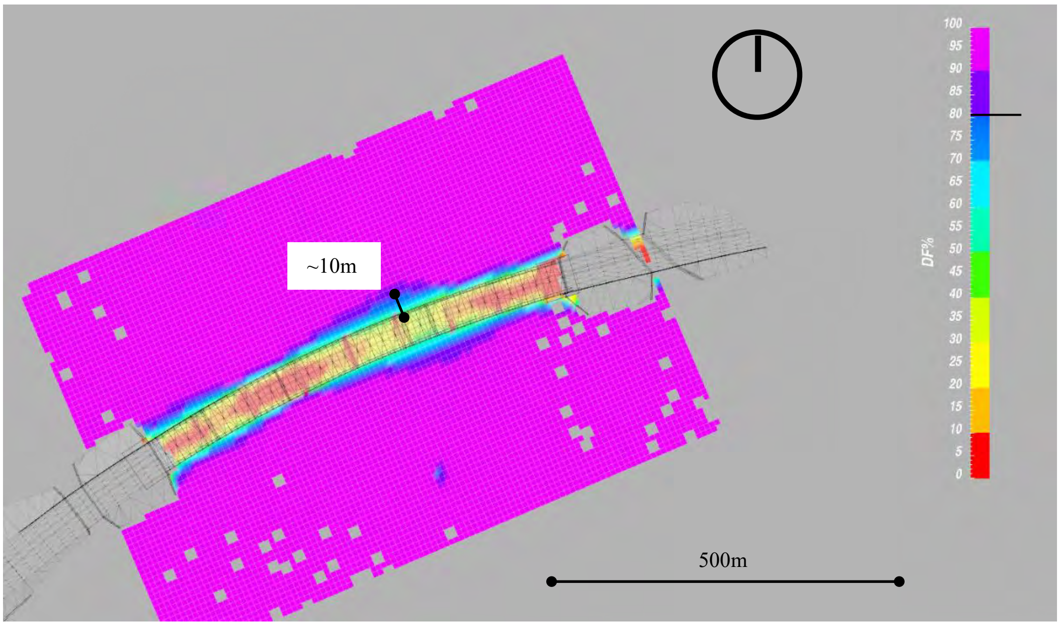


Figure 12: Grid 4 daylight factor distribution, proposed road development

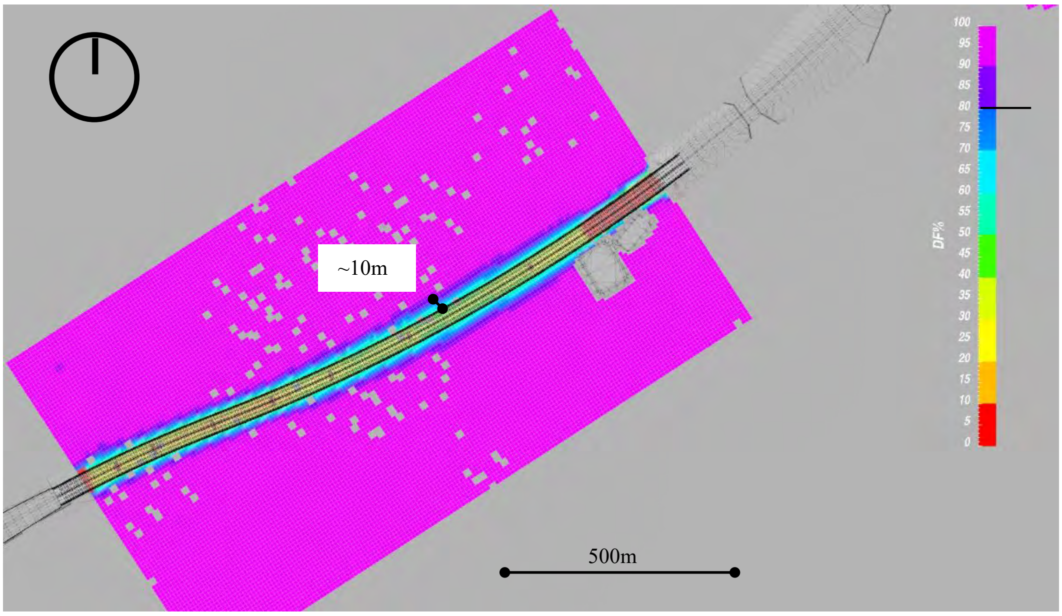


Figure 13: Grid 5 daylight factor distribution, proposed road development

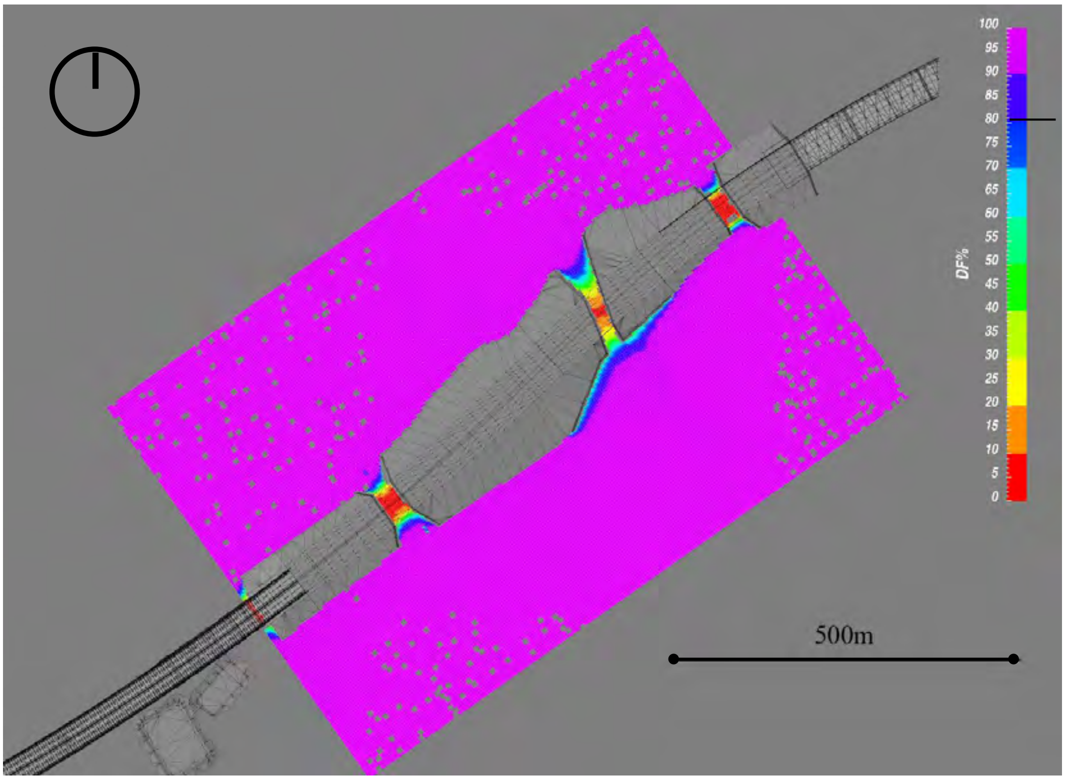
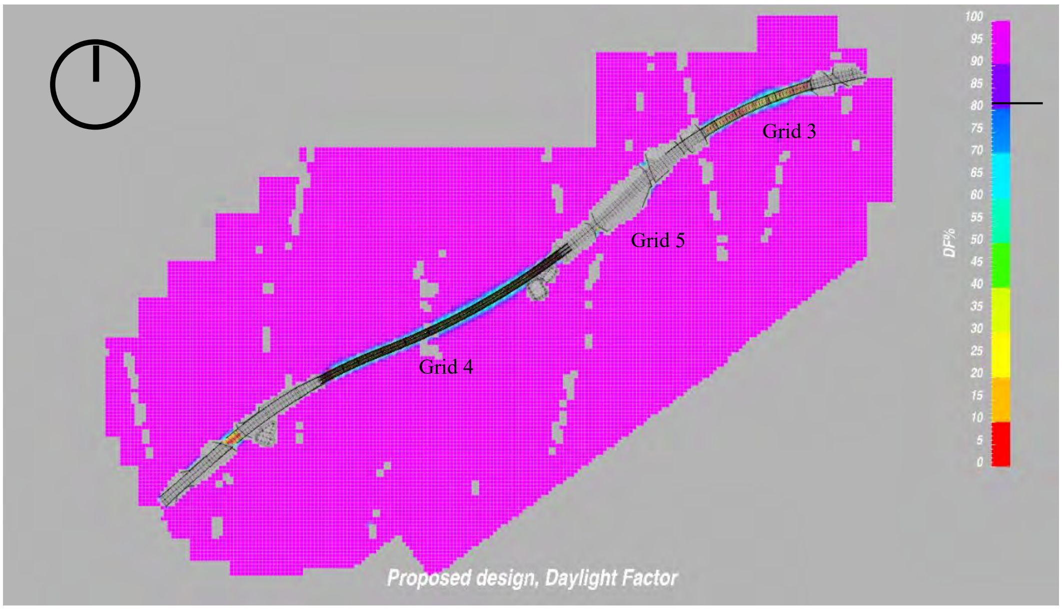


Figure 14: Grid 2 daylight factor distribution, proposed road development. Note that grid 2 encompasses grid 3, 4 and 5



5.3 Daylight cumulative daily exposure

As it can be expected the baseline, largely unobstructed, is quite uniform in exposure levels and around 99% of the landscape receives the same value in baseline condition and proposed condition.

Looking at the data, during the summer, the effects of the proposed road development are localised around the Menlough Viaduct. Results confirm the effects that were described by the daylight factor analysis: there is a portion of landscape, close to the elevated sections of the proposed road development which receives less exposure. The surrounding areas, beyond 20m from the edge of the proposed road development, are unaffected by the proposed construction.

It is during the winter months that the difference becomes larger, with areas of landscape showing a reduction in exposure than in baseline for distances of up to 120m from the edge of the proposed road development. This is caused by the low sun angles. This reduction is cumulative, as exposure is a daily total value. The results for grid 3, in December and June, are compared to illustrate this effect.

Figure 15 shows the daylight average daily exposure for December at grid 3. Landscape up to 120m from the north side (upstream) of the River Corrib bridge will experience a reduction in daylight exposure. The maximum exposure in winter is about 50 klx.h/day and the reduced exposure is approximately 30 klx.h/day. This reduction is approximately 1/15th of the exposure available at the same location during summery time in June.

Figure 16 shows the daylight average daily exposure for June at grid 3. Landscape up to 20m from the north side (upstream) of the River Corrib bridge will experience a reduction in daylight in the range 0 – 50 from baseline%. The most affected locations are below the bridge where the reduction is higher than 50%.

As it has been done for daylight factor analysis, the data has been further analysed with histograms. This has allowed to estimate the extent of area receiving a given average daily exposure, for equinoxes and solstices.

Figure 15: Daylight average daily exposure for December at grid 3

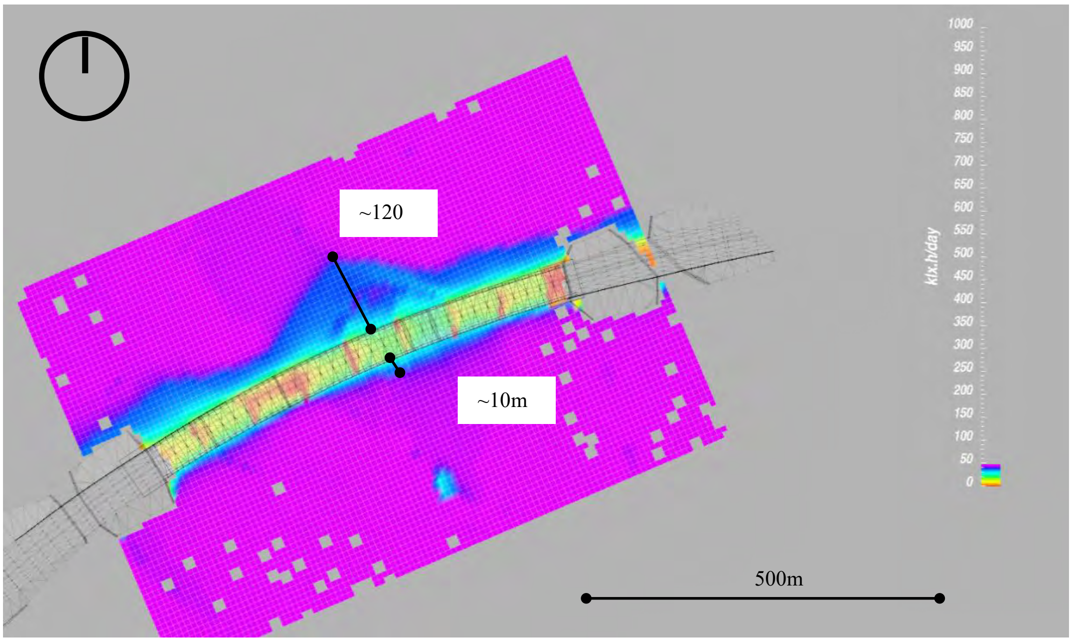


Figure 16: Daylight average daily exposure for June at grid 3

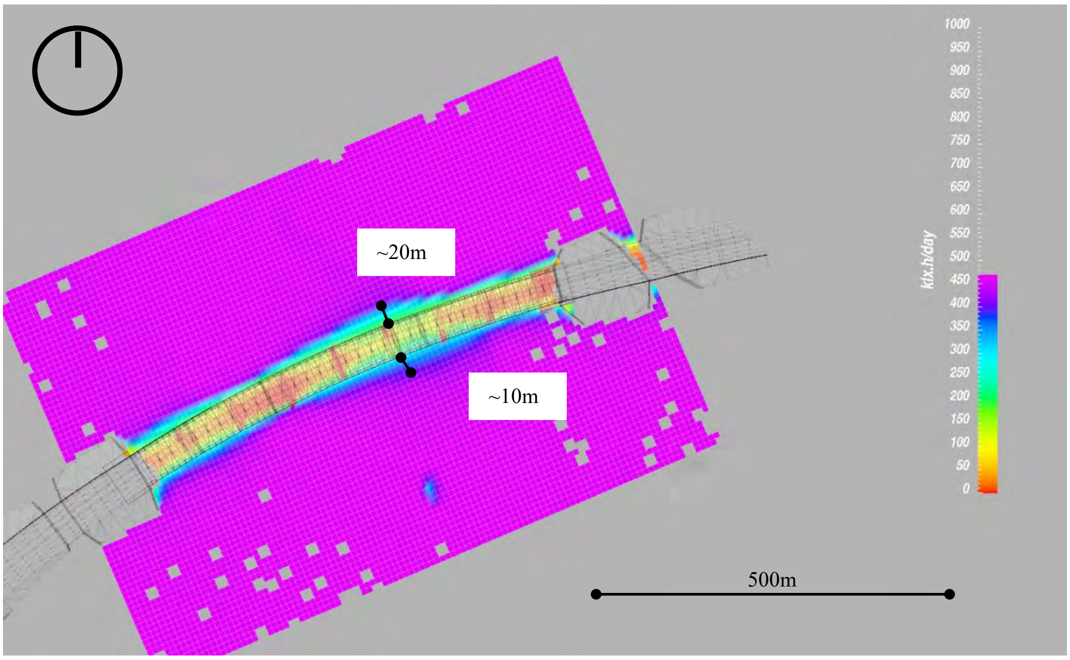


Figure 17: Daylight average daily exposure for December at grid 2

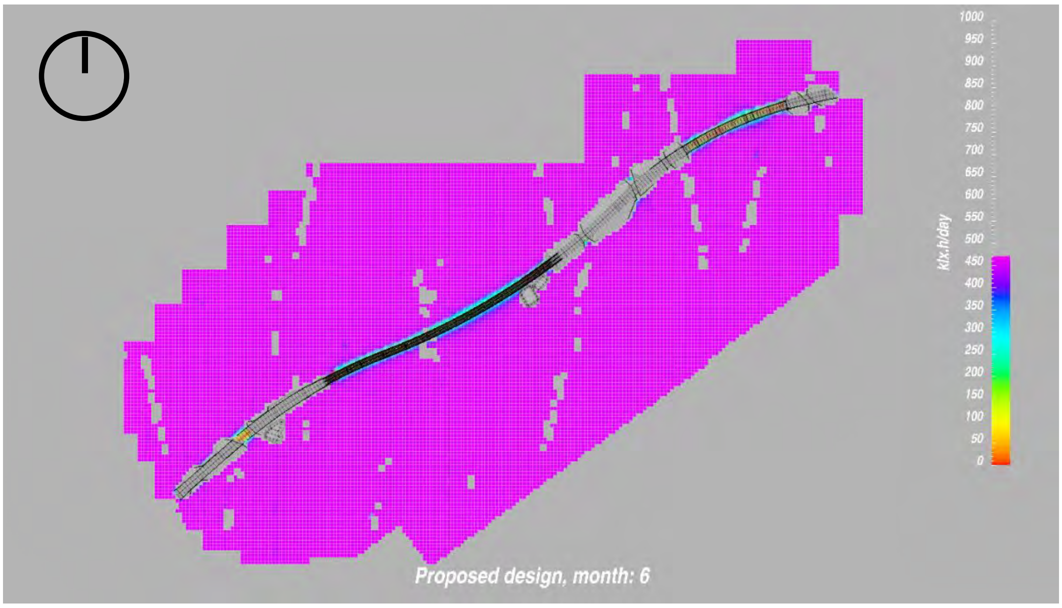


Figure 18: Daylight average daily exposure for December at grid 2

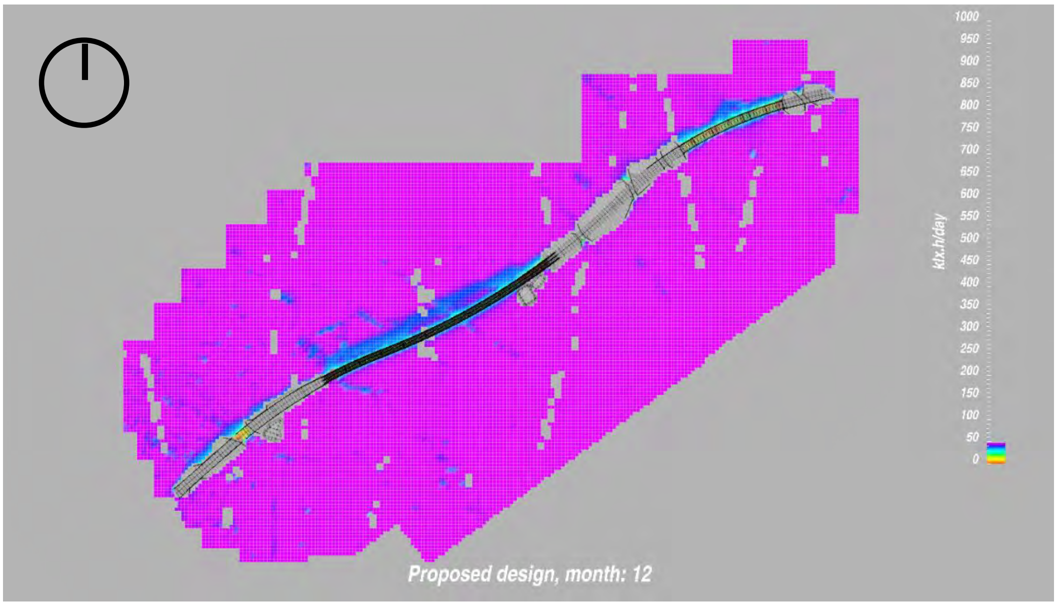


Figure 19: Daylight average daily exposure for December at grid 1

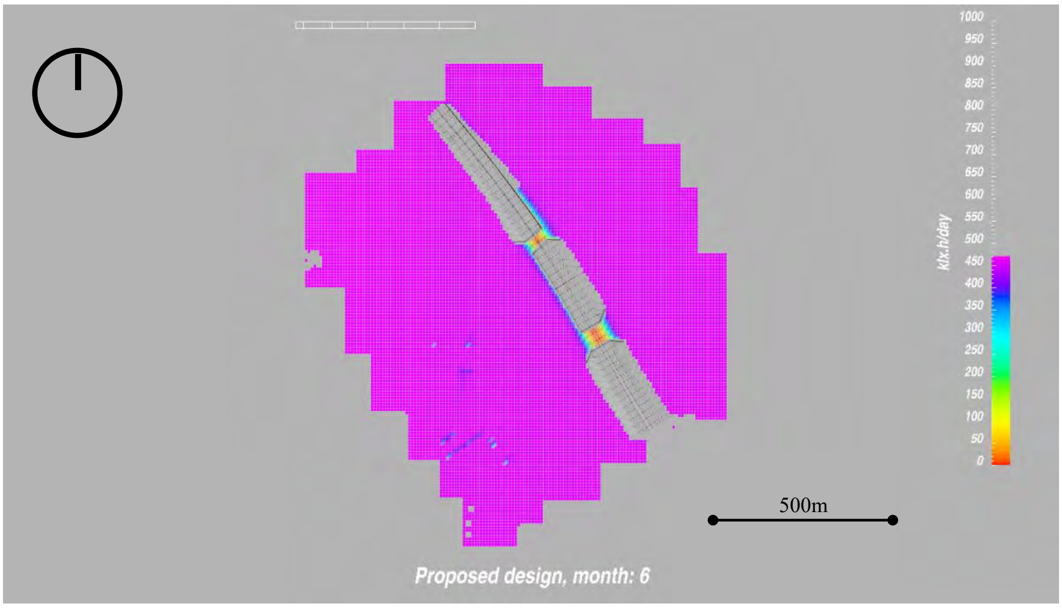


Figure 20: Daylight average daily exposure for June at grid 1

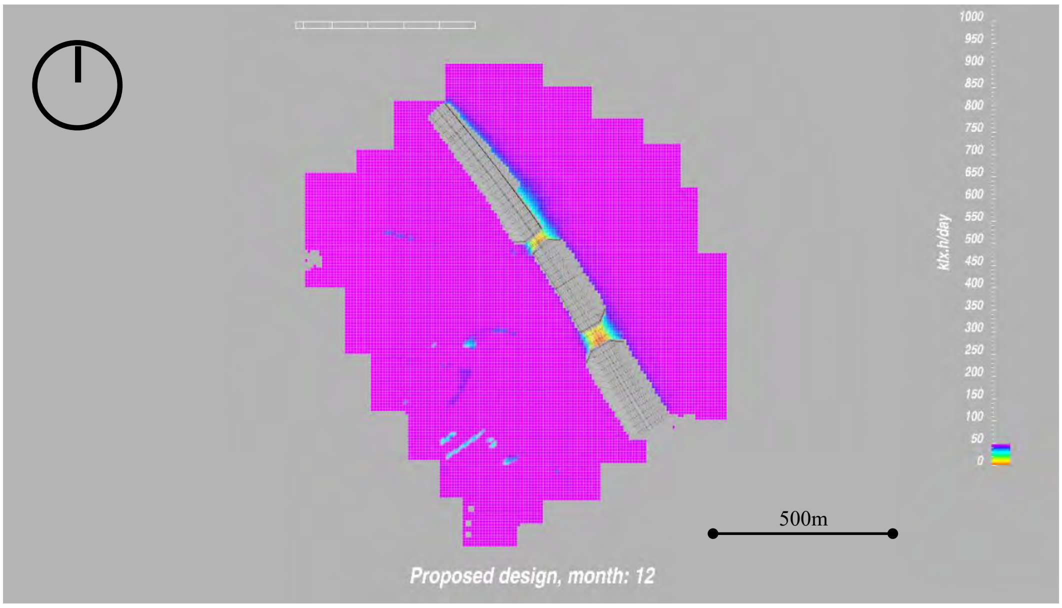
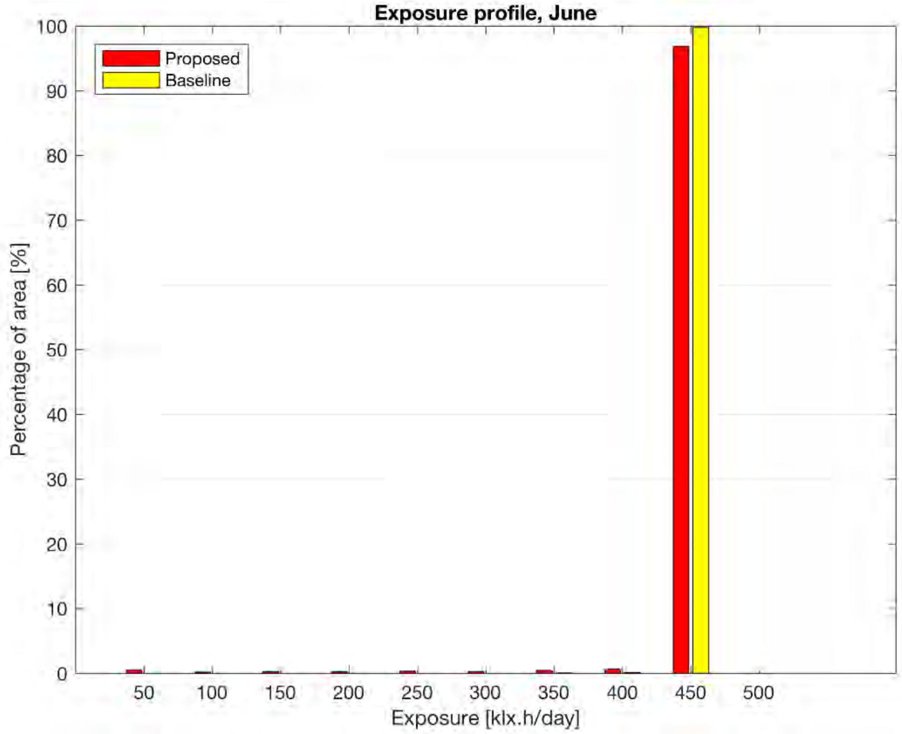
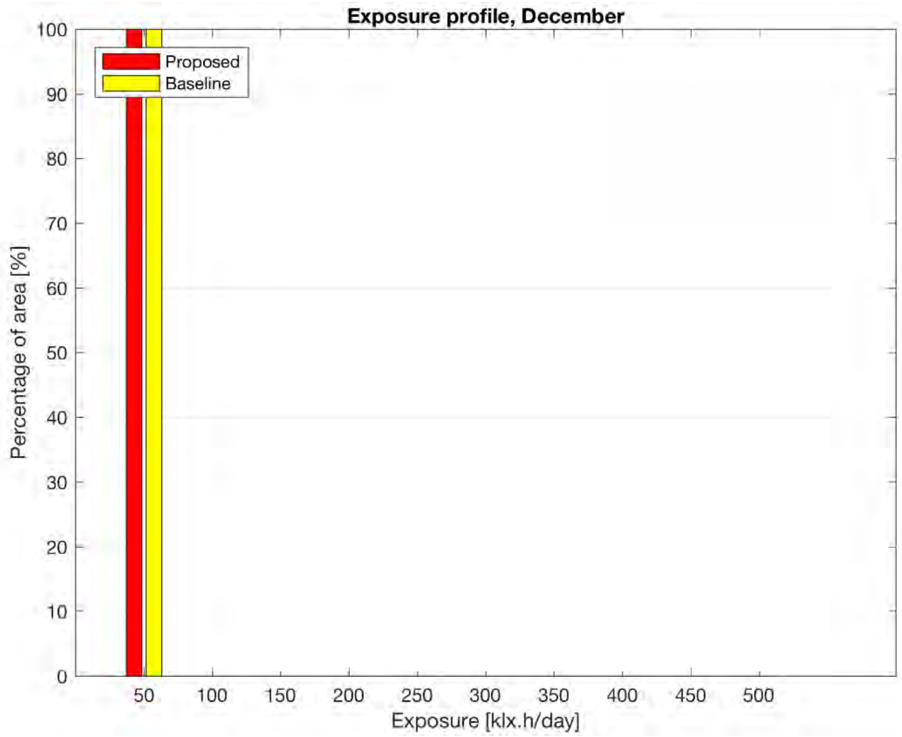


Figure 21: Exposure profile chart



The chart shows the percentage of area within a certain exposure value. As it can be seen, for grid 2, the proposed condition has a reduction of area exposed to the maximum sunlight and daylight available of around 3%.

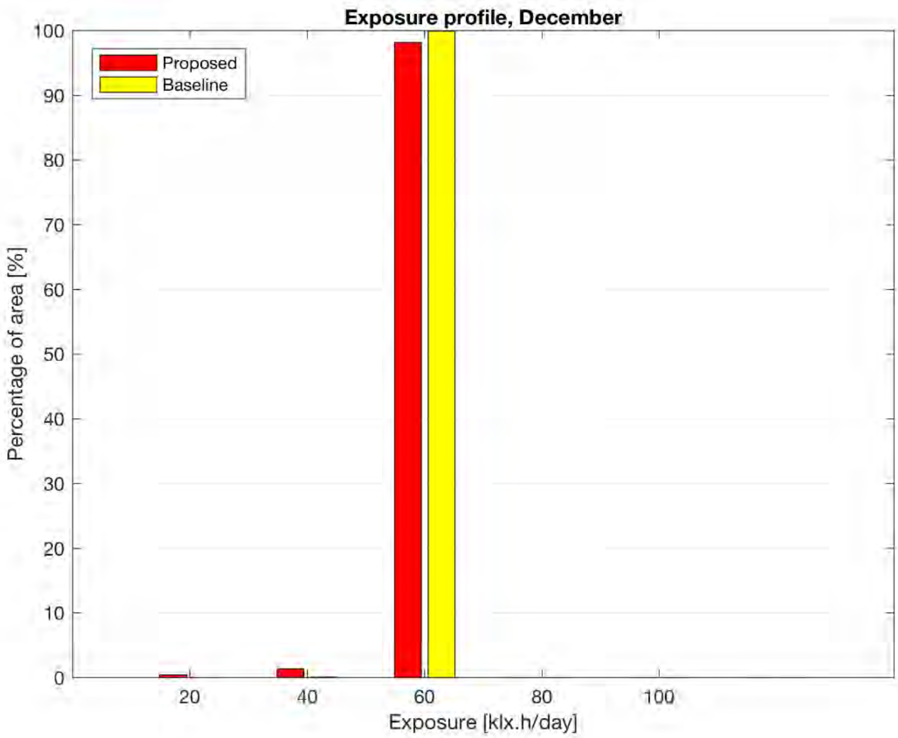
Figure 22: Exposure profile for December at grid 2



As the histograms analysis is based on a set interval, all the values for December falls in the first set of values. Thus, there is no detectable difference in exposure area between proposed road development being operational and the baseline condition, in winter. This is confirmed by the low exposure to light, typical of winter months.

For maximum clarity, an alternative histogram has been determined, with a finer value interval. This is shown in **Figure 23**.

Figure 23: Exposure profile for December at grid 2, with alternative value ranges to highlight difference of exposure from baseline to proposed design.



It can be observed that the difference is extremely small, even with the more detailed value ranges and most of the data shows unaltered exposure from baseline to proposed condition.

The same conclusions are demonstrated by the histograms of grid 1.

Figure 24: Exposure profile for June at grid 1

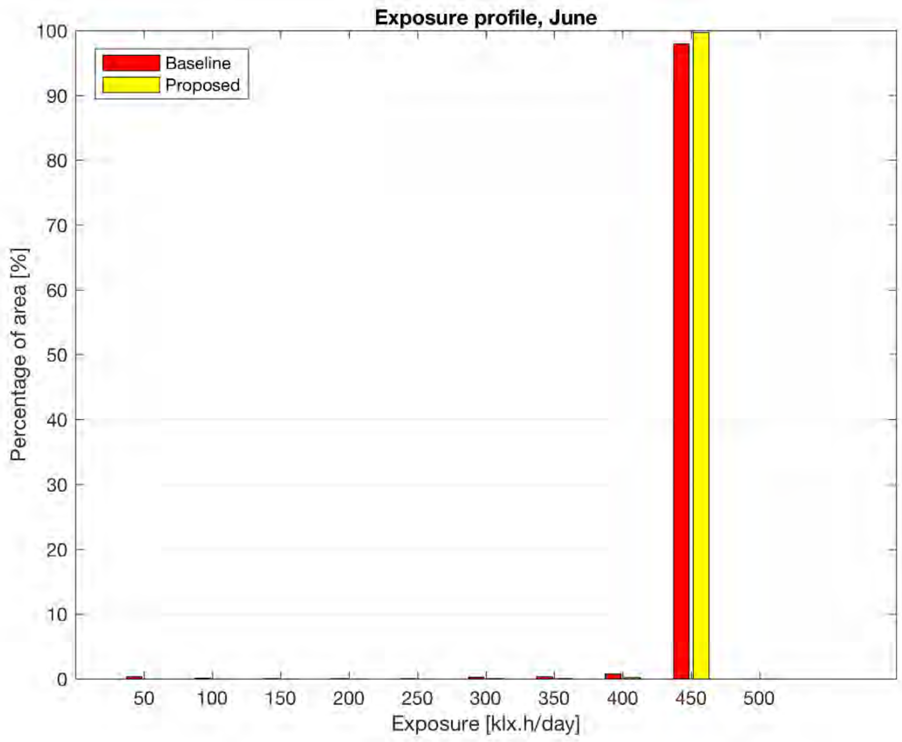
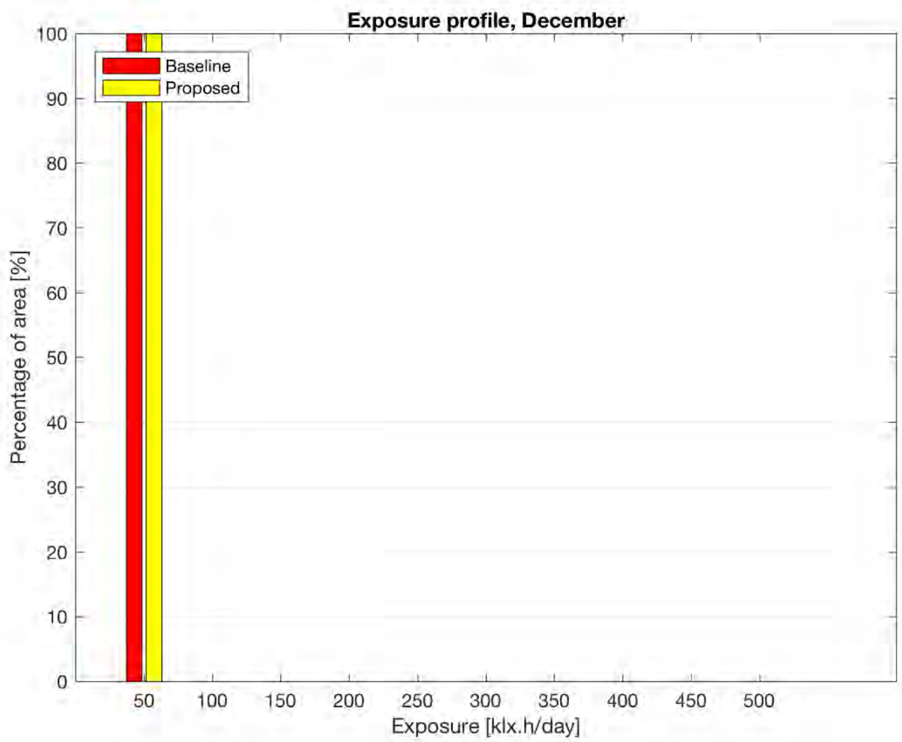


Figure 25: Exposure profile for December at grid 1



6 Conclusions

From the analyses carried out the following conclusions can be made:

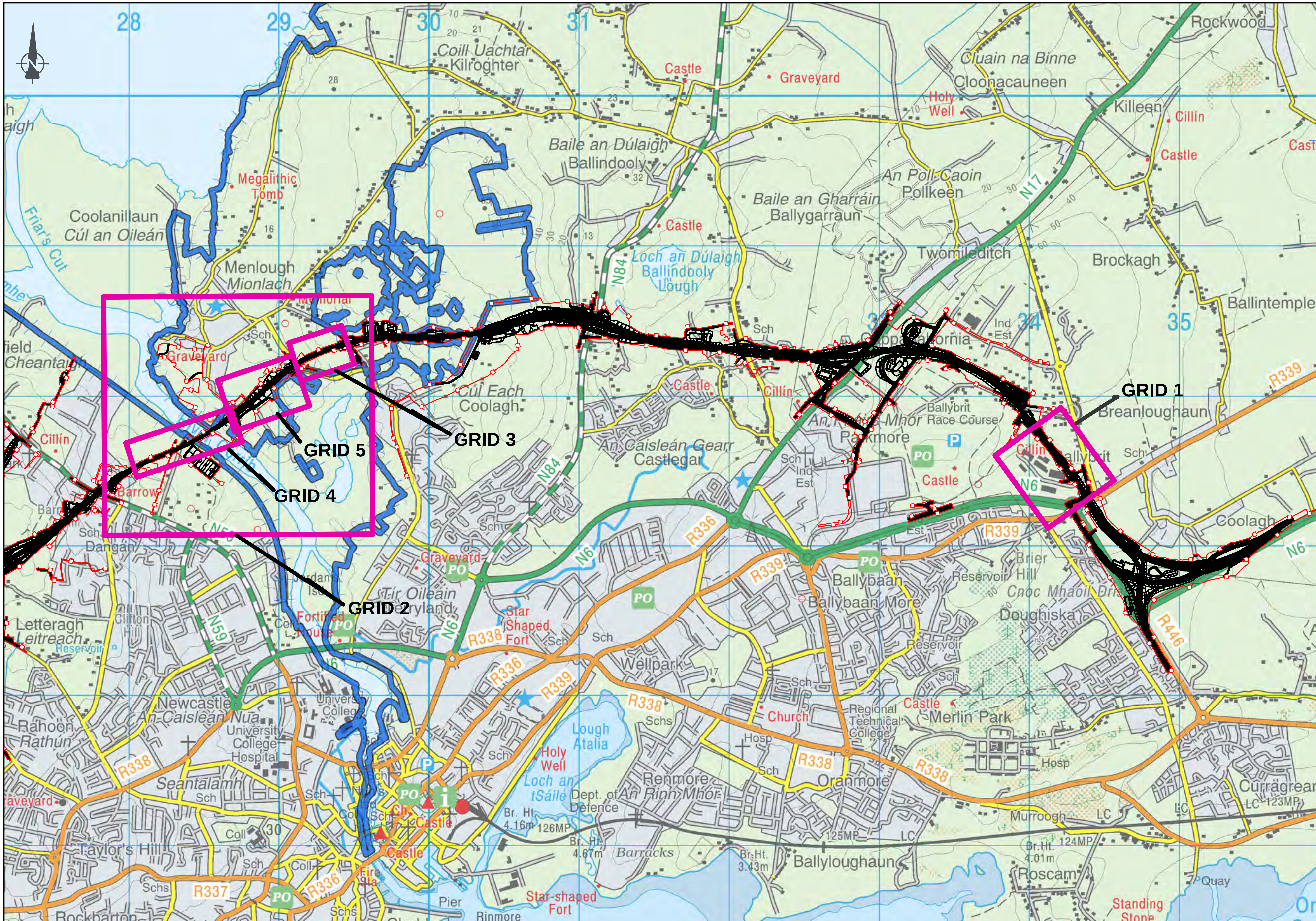
- Results show that the greatest shadow effects of the proposed road development are localised close to the bridge and viaduct locations
- Areas directly below the River Corrib Bridge and Menlough Viaduct and at less than 10m from its projected edge, see a *visually* noticeable reduction in daylight; these are localised areas
- For all other areas daylight availability is retained
- Depending on the angle of the sun, the projected shadow of the proposed road development reduces the daily exposure of the areas surrounding it.
- In general, during the summer months the area where the exposure reduction is detectable extends about 20m from the edge of the proposed River Corrib Bridge and Menlough Viaduct. During the winter months, this area extends up to 120m from the edge of these structures
- The absolute exposure in winter is much less than in summer for both baseline and proposed condition, hence when the effects of the proposed bridge are maximum (area of reduced exposure up to 120m in the winter) the exposure difference is extremely small, in absolute terms, as it is winter (the difference in winter is about 1/15th of the exposure available in summer).
- For all other areas, given the transient effects of the shadow of the proposed road development, the exposure available with the baseline is retained.
- With the exception of localised effects under the bridge or in close proximity to it, the daylight and sunlight availability are largely unaltered with the proposed condition

Annex A

Shading Analysis Locations

A1

A3



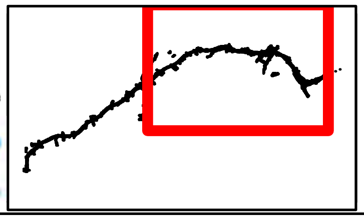
FOR INFORMATION

Legend

- Proposed Road Development
- Proposed Development Boundary
- Lough Corrib cSAC
- Grid Locations

Clients

Comhairle Chontae na Gaillimhe
Galway County Council



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Job Title
N6 Galway City Ring Road

Scale: **1:25,000**
Date: **September 2018**

Issue	Date	By	Chkd	Appd
I1	28/09/2018	MH	MH	EMC

Drawing Title
Location of Shading Analysis Grids

Drawing Status
FOR INFORMATION

Job No	Drawing No	Issue
233985-00	GCOB-SK-D-909	I1